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MULES, FUELS, AND FUSION: ENERGY, ENTROPY, AND THE CROSSING OF THE PANAMANIAN TRANSIT ZONE, 1848-1990

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MULES, FUELS, AND FUSION: ENERGY, ENTROPY, AND THE CROSSING OF THE PANAMANIAN TRANSIT ZONE, 1848-1990

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On April 3, 2019

Approval signatures are on file with the University of New Hampshire Graduate School.

To Mom, Dad, and Lydia:

You've been with me on this journey the longest, and throughout it all you've provided constant love, insight, and support. Thanks for keeping my entropy at bay.

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Writing a dissertation isn't about being smart, it's about being persistent. Or at least that's what some very smart people have told me. I've only been able to be persistent thanks to the remarkable levels of support that I've received from countless people. I firmly believe that any endeavor worth pursuing takes a village to realize, and I've been fortunate to say that the village behind this project consists of some truly exceptional people that I consider myself blessed to know and to have worked with.

The history department at UNH is a special place. In addition to being remarkably talented scholars, our faculty consists of skilled teachers who genuinely care about the wellbeing of their students. This is a rare quality and one which has made my journey considerably easier. We are also fortunate to have two amazing administrators, Lara and Laura. I'm 90% certain that without them Horton Hall would simply collapse. Of all the people I've had the chance to work with at UNH however, no one has had as substantial an impact on my intellectual and personal growth as Kurk Dorsey. Kurk's humor, encouragement, and intellect have shaped the way I think and the way I write, and it's with the utmost sincerity that I say I hope that I can be half the scholar, mentor, and person that he is, although perhaps with a slightly higher free throw percentage.

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History Fellowship allowed me to conduct research in Panama which was a tremendous experience and greatly augmented my understanding of the Canal. Trips to the National Archives were conducted thanks to the support of the Angelo Kontarinis History Fund, the Chesley Family Fund, and the Nguyen Family Fund. The financial support that this project received is exceptional, and without the ability to conduct research trips and focus exclusively on writing this project would not encompass the scope, nor the depth that it currently does.

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ABSTRACT

MULES, FUELS, AND FUSION: ENERGY, ENTROPY, AND THE CROSSING OF THE PANAMANIAN TRANSIT ZONE, 1848-1990

By

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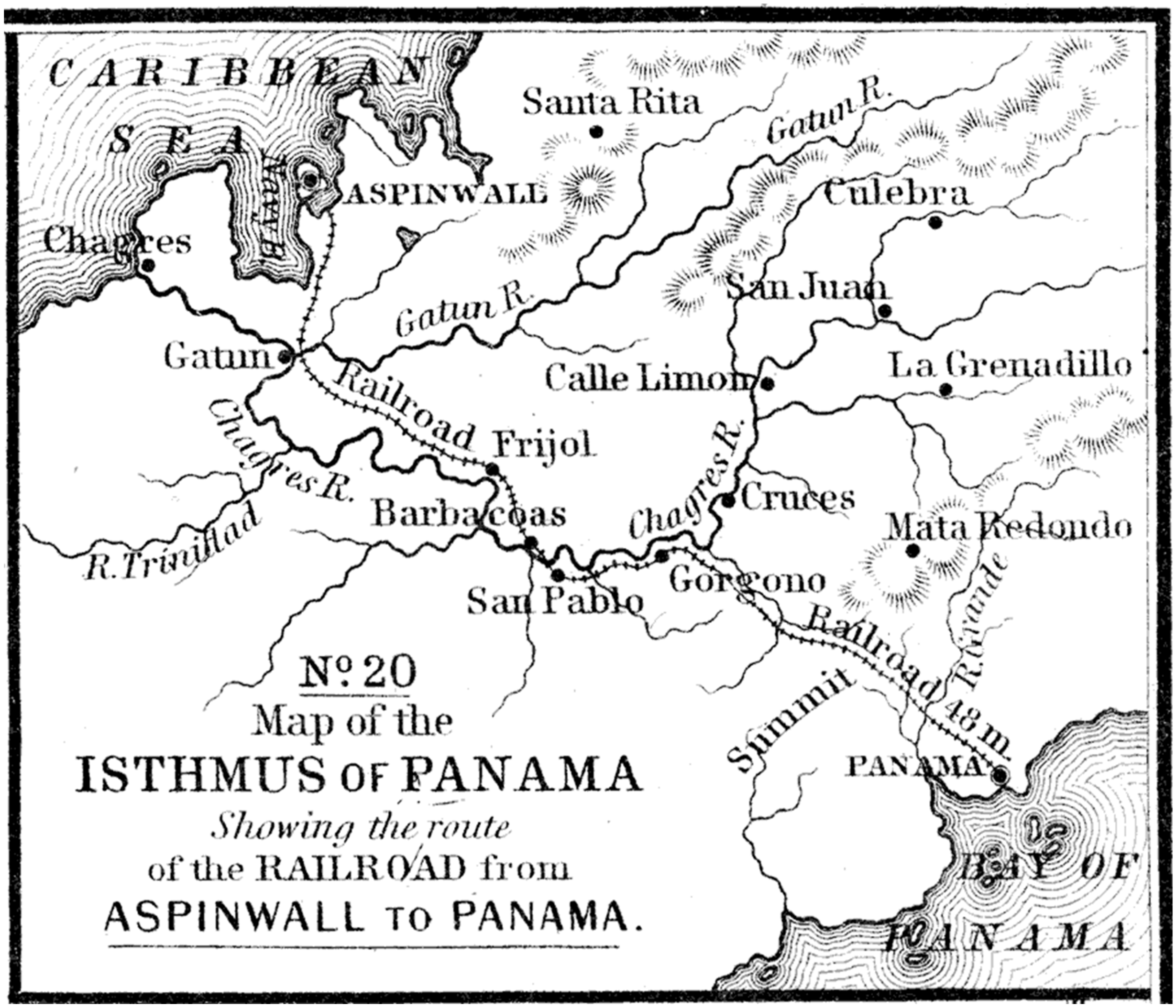
University of New Hampshire

Between 1848 and 1990 Americans attempted to construct numerous infrastructural projects in Panama in hopes of bridging the Isthmus and connecting the seas. These schemes ran the gamut from the creation of the Panama railroad in the early 1850s through attempts to detonate nuclear explosives to create a sea-level canal in the 1960s. While these projects seem quite alien to one another, these two plans, and other attempts to cross the Isthmus, were unified by their shared reliance on energy's capacity to overcome the entropy of the Panamanian environment. In order to reshape Isthmian landscapes, American engineers, scientists, and policymakers had to first harness and unleash a variety of energy sources that could do the work of moving earth, constructing structures, and imposing order on the Panamanian landscape. Their efficacy was always mediated by entropy, the environment's tendency to trend towards disorder. Without constant injections of energy, the fluid Panamanian landscape would shift and move, destabilizing the landscape and wrecking human altered landscapes. This contentious relationship between energy and entropy catalyzed an energetic arms race in which Americans looked towards increasingly powerful sources of energy to hold entropy at bay. Ultimately this proved a double-edged sword. By altering the environment in increasingly complex ways, they simultaneously created the potential for increasing volumes of entropy. This positive feedback

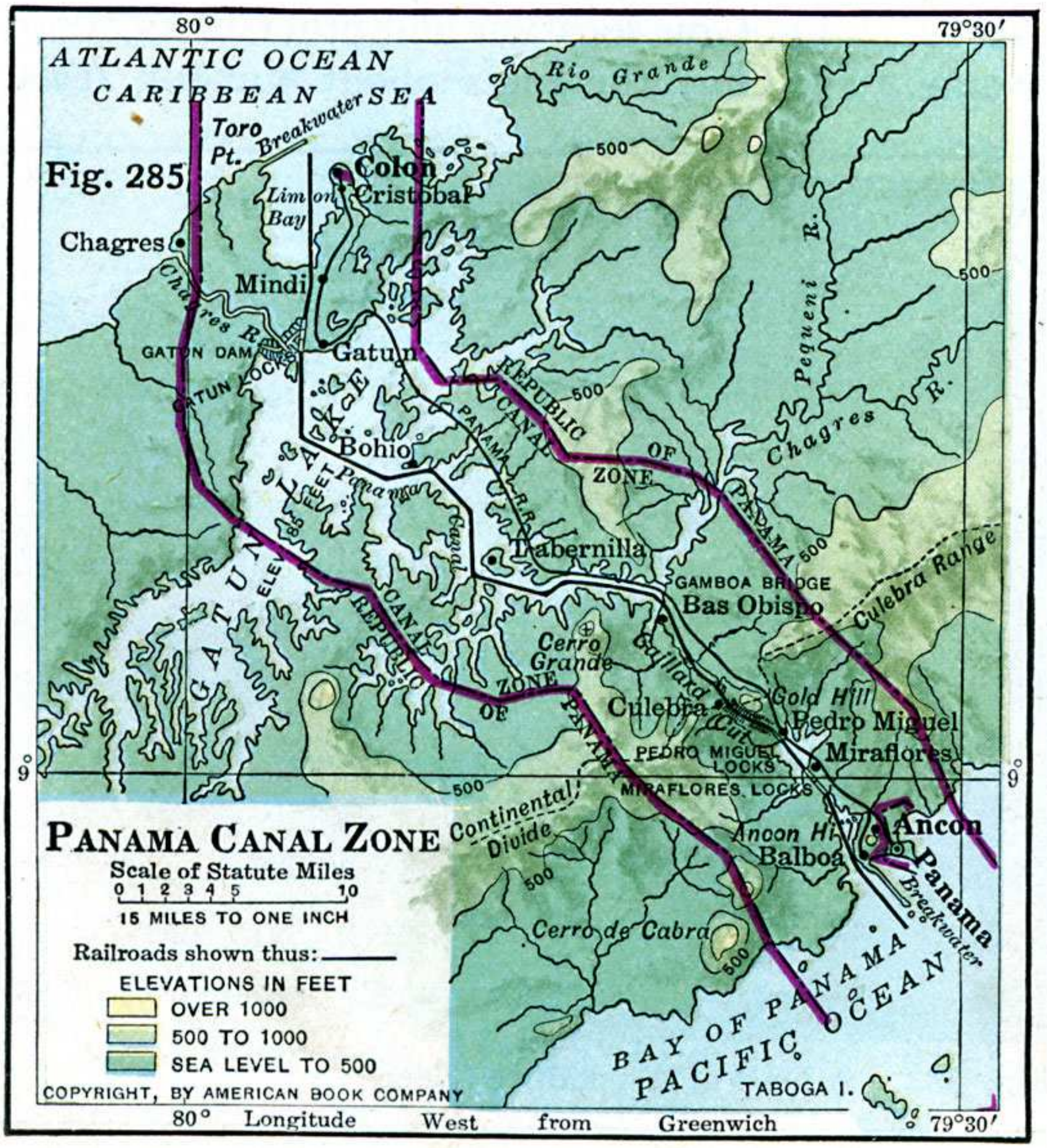
loop forced humans to consume more energy to contain entropy, thus restarting the cycle of energetic and entropic growth.

This project tracks this process starting with the creation of the railroad and follows it through the creation of the Panama Canal in the first two decades of the 1900s, initial attempts to restructure the Canal during the interwar years, the attempt to build a new canal through the use of nuclear excavation, and finally attempts to use the Isthmus to facilitate the transportation of Alaska North Slope oil during the 1970s and 1980s. Along the way, the project tracks how new energy sources provided new opportunities to reshape Panama, and the unforeseen consequences that accompanied these processes. Ultimately, the unrelenting presence of entropy suggests that while energy granted Americans the illusion of control over the natural landscape, their authority was never as absolute as they hoped.

Maps of Panama



"Map of the Isthmus of Panama, Showing the Route of the Railroad from Aspinwall to Panama," ca. 1858, located in *Mitchell's School Atlas*, (Philadelphia: E.H. Bunker & Co., 1863), retrieved from Florida Center for Instructional Technology, "Maps ETC." located at https://etc.usf.edu/maps



“The Panama Canal Zone” from Albert Perry Brigham and Charles MacFarlane, *Essentials of Geography* (New York: American Book Company, 1916) retrieved from Florida Center for Instructional Technology, “Maps ETC.” located at https://etc.usf.edu/maps

INTRODUCTION: Energy and Entropy: An Environmental Arms Race

In a speech before the American Legion in August of 1977, Ambassador Sol Linowitz attempted to sum up the deep cultural attachment Americans felt for the Panama Canal: "It was in a very real sense our moonshot of the early 1900s."[1] Linowitz's comment reflected both the ingenuity and persistence required to gouge the Canal out of the Panamanian landscape, as well as the technological leaps that made such an ambitious project possible. Perhaps more than anything else it reflected the civic pride Americans felt for the monumental accomplishment. And while Linowitz might not have intended it, it also reflected the energetic demands of both projects. The Apollo project required the generation of unprecedented amounts of force to tear asunder the shackles of gravity and escape from the terrestrial prison that had confined humanity for hundreds of thousands of years. The Canal required a comparable, if more diffused, application of energy to realize the centuries-long quest to divide the Isthmus and unite the world.

My dissertation, "Mules, Fuels, and Fusion: Energy, Entropy and the Crossing of the Panamanian Transit Zone, 1848-1990," expands on Linowitz's observation by arguing that historians cannot understand attempts to traverse the Isthmus without emphasizing the importance of energy, a concept that historian Richard White has defined simply as "the capacity to do work."[2] The history of American infrastructural construction in Panama has been defined by the dynamic relationships between muscles, motors, and movers, and the environmental

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[1] Linowitz, Sol Address in Favor of Treaties speech before the American Legion Convention, Denver Colorado. August 19, 1977, located in "The Meaning of the Panama Canal Treaties." US Department of State, September 1977, US National Archives at College Park (hereafter USNA), Record Group 185 (hereafter RG 185), Collection: UD UP 30: Treaty Implementation Records, Box 4: Folder: State Department Texts of Treaties Relating to the Panama Canal No. 6, 6A, 6B, 6C, pg. 11.

[2] Richard White, *The Organic Machine* (New York: Hill and Wang, 1995), pg. 6.

alteration they enabled in the Panamanian Transit Zone over a one hundred and fifty year period.[3] Ultimately, energy provides environmental historians with the capacity to view connections between seemingly disparate developments. Traditional histories of Americans in Panama silo their stories into discrete events such as the creation of the railroad, the creation of the canal, or the proposal for a nuclear canal. A focus on energy provides continuity by suggesting that the differences between these developments was quantitative rather than qualitative. The creation of the Panama Railroad in the 1850s may seem alien to the proposed nuclear canal of the 1960s, but both projects were predicated on the need to control and deploy remarkable volumes of energy, as well as tap new sources of energy. Thus, energy allows historians to cut through narrow perspectives of the Panamanian past and recognize the energy proliferation that defined all American attempts to create transportation networks in Panama.

While Linowitz's comment reflects a single moment, the human desire to harness energy to transport materials across Panama spans centuries. From the mules that helped laborers build the Panama railroad in the 1840s and 1850s to the proposed detonation of nuclear explosives to create a new sea level canal in the 1960s, animals, chemicals, and atoms provided the energy to convey people and goods across the Isthmus. Ultimately, the efficacy of these energy sources proved a double-edged sword. Because energy allowed humans to dig up, dredge out, and detonate Isthmian landscapes, it generated an unfounded sense of control over the Panamanian environment. Consequently, for much of the 20th century, the story of the Panama Canal was a triumphantalist narrative in which shrewd American engineers relied on technical prowess, a

[3] The idea of thinking of Panama as a "Transit Zone" is a particularly useful concept as it implies that the Panama Canal is not the only significant route through Panama, but rather one of several infrastructures created to cross the Isthmus. This allows historians to establish more continuity between events both before and after the construction of an American canal. Aims McGuiness's study of the Panama Railroad uses this concept to great effect in, Aims McGuinness, *Path of Empire: Panama and the California Gold Rush, The United States in the World* (Ithaca: Cornell University Press, 2008).

can-do attitude, and American ingenuity to conquer a hostile environment and create one of the largest manmade structures in history.[4] A British Ambassador to the United States, James Bryce, went as far as to call the Panama Canal, "the greatest liberty that man has ever taken with nature."[5] Environmental and energy histories, however, suggest that this sentiment belies a simple truth; energy's capacity to alter landscapes in the Transit Zone often was accompanied by unforeseen consequences.

At the root of the tension between environmental alteration and control is the intimate relationship between energy and entropy. While the concept of energy is familiar enough to historians at this point in time, entropy may be less so. First coined in an 1865 paper by the German theoretical physicist Rudolf Clausius, entropy measures the degree of disorder in a closed system and is closely tied to the concept of energy—in short, entropy can undo the work done by energy. Clausius also defined the second law of thermodynamics, stating that entropy in the universe constantly expands. By extension, this principle means that available energy in a closed system can only ever decline.[6] Although they probably never used the word "entropy," its existence created an obstacle for the human actors attempting to create transportation networks on the Isthmus. Energy consumption flowed in one direction. After initial large-scale investments of energy, the capacity to do work became scarce. To counter this development Americans had to acquire and deploy constantly increasing amounts of energy to keep Isthmian transportation networks functioning.

[4] This school of thought began even as the canal was being completed with Frederic J Haskin, *The Panama Canal* (Garden City, N.Y.: Doubleday, Page & Co., 1913), and continues into the 21st century with Matthew Parker, *Panama Fever: The Epic Story of One of the Greatest Human Achievements of All Time--the Building of the Panama Canal*. (New York: Doubleday, 2007.).
[5] David G. McCullough*, The Path between the Seas: The Creation of the Panama Canal, 1870-1914* (New York: Simon and Schuster, 1977), pg. 543.
[6] Vaclav Smil, *Energy: a Beginners Guide,* (Oxford: One world publications, 2006), pg. 5.

Fortunately for them, Panama was by no means a closed system. Americans imported energies in the form of human bodies, animals, coal, oil, and even radionuclides in hopes of providing enough energy to alter and stabilize the environment. While people could use these energies to alter the environment radically over the short-term, they struggled to counter the entropy that threatened to undermine what they had wrought. It was here that entropy became most problematic. If energy in a closed system is in a constant state of decline, the natural question would be: how do humans do the work of maintaining environments after they alter them? Theoretically, this was merely a matter of obtaining more energy. In practice, maintenance proved far more vexing. Financially, short term acquisitions of energy, while extensive, were justified on the grounds that they were one-time investments. The long-term impetus needed to overcome entropy was much less alluring. As a result, the demands of maintaining transportation networks in Panama always existed in tension with Americans' desires to expand and adapt the waterway to meet the needs of new technologies and energies.

More importantly, as humans used energy to alter the environment in increasingly dramatic ways, they also required increasing volumes of energy to maintain permanence in a dynamic environment. Landslides are a natural occurrence in Panama. And yet, as Americans dug the Canal and steepened the slopes of the Cut, slides grew both more frequent and more pronounced. Human energy consumption and landscape alteration exacerbated the potential for landslides to disrupt the Canal, and entropy mandated that the only way to maintain the canal in the face of such instability was to apply more energy from external sources.

The rub is that as time goes on, and as human attempts to alter landscapes grow increasingly more complex, the potential for entropy to prevent these landscapes from operating properly also grows, and in turn requires an injection of more energy to maintain the status quo.

The result is a sort of an entropic arms race in which humans, gaining access to new and more powerful sources of energy, alter their environment in more complex and, consequently, unstable ways, increasing the energetic cost of maintenance. In order to overcome entropy and add energy to the system, they consume even more energy, thus creating a positive feedback loop in which energy consumption grows rapidly. I believe that this trend is true of almost any environment. Be it urban or rural, large or small, the mandates of energy, landscape alteration, and entropy dictate an ever-increasing reliance on energy in order to maintain human altered landscapes.

Climactic and geographic forces directly impact this relationship easily, particularly when environmental realities combine with culturally generated assumptions about how landscapes should operate. Panama exemplifies this phenomenon. The tiny land bridge that splits the Atlantic and Pacific Oceans is just about 50 miles wide at its narrowest point. Those 50 miles vary wildly from the lowland swamps that dot the coast to the thousand-foot mountains of the Continental Divide that run through the heart of the Isthmus. These environmental realities generate a unique climate defined more than anything else by the presence of water. Panama has two seasons, a wet season running from May to December and a dry season running from January to April. During the wet season, massive deluges wash away soil, cause landslides, and often wreak havoc with manmade infrastructural networks.[7] Towards the coasts it was the highly viscous muds that complicated manmade infrastructural networks. While not as dramatic as landslides, shifting silts could prove just as problematic and required considerable volumes of energy to counter. American engineers, often unfamiliar with the Panamanian environment,

[7] The challenges faced by American infrastructure and state planning in fluid environments has been well established by David Biggs in *Quagmire: Nation Building and Nature in the Mekong Delta*, (Seattle, University of Washington Press, 2012) in which Biggs describes how the canals, and swamps of the Mekong Delta wreaked havoc with first French and later American attempts to impose order over the region.

struggled to deal with these realities. In this sense, entropy combined energetic realities with environmental conditions and cultural assumptions about landscape stability to define American attempts to reshape Panama by their incessant demand for access to energy.

This dissertation uses the thermodynamic definition of entropy in a literal sense to describe the central tension between the need for increasing volumes of energy and the consequences that stem from that process. As an exercise it also deploys “entropy” as a metaphor by using the more popular definition of the concept: the tendency of the natural world to trend towards disorder. This more liberal interpretation uses the effective operation of the Canal itself as a measure of “order,” suggesting that from the perspective of American administrators, this objective was paramount. Entropy then encapsulates those actors, be they human or natural, that prevent the Canal from working as intended. It’s worth noting that, despite the negative connotations entropy is associated with in contemporary society, this dissertation does not assume that entropy is a negative force. Instead the term is only used to describe a shift from one state of being to another. While the metaphorical use of “entropy” does have shortcomings, I am intrigued by the concept’s ability to reflect similarities between seemingly divergent forces, be they diplomatic, environmental, financial, or anthropogenic in nature.

At its most fundamental level, entropy provides a means of differentiating between short-term and long-term uses of energy. Substantive landscape engineering- like the construction of an interoceanic canal for instance- tends to rely on short, intensive injections of energy. Maintenance of landscapes, on the other hand, relies on more diffused applications of energy. Entropy allows historians to cut through the distinction between alteration and maintenance by identifying the ways in which energy, or a lack thereof, dictated both processes. In this dissertation, I will use “energy” broadly to describe the forces that Americans used to build a stable transportation network, and I will use “entropy” to denote forces that tended to undermine the functioning of the transit networks in the zone.

Environmental and energy history are well suited to deal with the questions raised by efforts to transit Panama. Because the story of Americans in Panama is the story of humans attempting to harness and unleash energy to overcome entropy and restructure the environment of Panama, insights from environmental and energy histories are essential to understanding the history of the Isthmus. Yet this is not a story of energy determinism. While the human capacity to control and deploy energy developed rapidly over the 19th and 20th centuries, this in and of itself did not yield infrastructural networks. Decisions about when and where to deploy energy were just as important as energy sources themselves. The decision to adopt electrical energy in the later years of Panama Canal construction and the decision not to use nuclear energy to construct a new canal in the 1960s both were accompanied by significant repercussions. To fully understand the way energy impacted the Isthmian Transit Zone we need to think of energy not as a monolithic wellspring for progress, but rather as a purveyor of possibilities. The chemical processes that generated energy presented humans with countless opportunities, yet it was human decision and technology, cultural forces, that actualized this potential.

The story of American energy in Panama then is a complex one which combines human actors, natural forces, and the energy that mediated their interactions. My dissertation will examine the promise of energy as a tool to mitigate entropy and shape landscapes to human ends, and the challenges that resulted from its application. Ultimately, I argue that Panama offers historians a wonderful chance to see that energy catalyzed the creation of altered landscapes by keeping the entropy that vexed the maintenance of permanent structures at bay. [8] And yet, this process was never absolute. As humans adopted new, more powerful energy sources they often unleashed as much entropy as they contained, ushering in an incessant clash between energy and entropy that defined American attempts to cross the Isthmus for nearly 150 years.

Remembering Panama

Literature on Americans in Panama is nearly as voluminous as the spoil removed from the Culebra Cut. The herculean efforts to cross and later divide Panama have attracted the attention of numerous historians, resulting in economic, racial, political, intellectual, and labor histories of the Isthmus.[9] Despite this attention, historians have only begun to use environmental history (and have yet to use the growing scholarship on energy) to better understand Panama.[10]

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[8] The term "hybrid landscapes" sums up the ideas of a variety of scholars who by the early 1990's were trying to emphasize the interconnections between natural and cultural forces. William Cronon's article "The Trouble with Wilderness" in William Cronon, ed., *Uncommon Ground: Rethinking the Human Place in Nature*, (New York: W. W. Norton & Co., 1995), 69-90, controversially pointed out that our idea of wilderness was itself a cultural construct. Similarly Richard White's *Organic Machine* emphasizes the Columbia River as a manifestation of the combination of human actions and natural forces. The term also bears distinct similarities to "Second Nature" or human constructed nature an idea that Cronon introduced in, *Nature's Metropolis: Chicago and the Great West* (New York: W.W. Norton, 1991).

[9] While Frederic Haskin, *The Panama Canal*, was among the first to give Americans insight into the Canal he was by no means the last. Soon personal memoirs such as Mrs. Ernest von Muenchow, ed., *The American Woman on the Panama Canal* (Balboa Heights, Panama: Star and Herald, 1916), http://ufdc.ufl.edu/AA00013480/00001; and Harry Franck, *Zone Policeman 88* (New York: The Century Company, 1920), made their way north from the Isthmus. Interest in the Canal was renewed in the late 1970s thanks in large part to the Carter-Torrijos treaties. Books such as McCullough's *The Path between the Seas,* and Walter LaFeber, *The Panama Canal: A Crisis in Historical Perspective* (New York: Oxford Univ. Press, 1977), soon came to provide Americans with an updated account of the Isthmus. The 1980's saw increased attention paid to the experiences of silver laborers with works such as Michael L. Conniff*, Black Labor on a White Canal: Panama, 1904-1981*, (Pittsburgh, Pa: University of Pittsburgh Press, 1985); and Bonham C. Richardson, *Panama Money in Barbados, 1900-1920* (Knoxville: University of Tennessee Press, 1985). In more recent years studies have become even more divergent with Panamanian perspectives, Ovidio Diaz Espino, *How Wall Street Created a Nation: J.P. Morgan, Teddy Roosevelt, and the Panama Canal* (New York: Four Walls Eight Windows, 2001), labor histories, Julie Greene*, The Canal Builders: Making America's Empire at the Panama Canal*, (New York: Penguin Press, 2009); and economic studies, Noel Maurer and Carlos Yu*, The Big Ditch: How America Took, Built, Ran, and Ultimately Gave Away the Panama Canal* (Princeton, N.J: Princeton University Press, 2011).

[10] As of this moment the only monographic environmental history of the Panama is Ashley Carse, *Beyond the Big Ditch: Politics, Ecology and Infrastructure and the Panama Canal* (Cambridge, MA: The MIT Press, 2014). Despite this, interest in the environmental history of Panama seems to be growing. A recent issue of *Environmental History* had a round table on the potential of an environmental history of Panama which included Carse, Paul Sutter,

This project combines several recent trends in these fields to better understand the creation and maintenance of Isthmian landscapes and the energy regimes that made them possible.

My focus on energy marks a departure from existing literature on Panama in several ways. First, energy challenges the triumphantilist narrative exemplified by David McCullough's *The Path Between the Seas*. Despite the lasting value of this monograph, McCullough's celebration of American ingenuity lends itself to a story arc that begins with the failed French attempt to build a canal and concludes in 1914 when the first ships steamed between the canal's massive locks. While fulfilling, McCullough's work implies that the landscape remained static from 1914 on. The continual presence of entropy in Panama challenges this assumption. Ashley Carse first voiced this concern in *Beyond the Big Ditch*, arguing that the Canal's reliance on a steady supply of water (the average ship requires 52 million gallons of Gatun Lake water per trip) suggests that the story of the Panama Canal is not one of human conquest of nature, but rather the construction of an infrastructural system which requires constant maintenance.[11] I believe that Carse's argument is reflective not only of the hydrological demands of the Canal, but also its energetic needs as well. Coal, oil and human bodies did not stop coming to the Transit Zone after 1914, suggesting that just like water, energy continued to play an integral role in the management of the local environment.

Concerns regarding energy dominated the Isthmus long before a canal was built and long after it was completed. Consequently, I also examine the creation of the Panama Railroad, which shaped Panama in the decades prior to canal construction and the discussions about alterations to

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Christine Keiner and Megan Raby amongst others, Ashley Carse et al., "Panama Canal Forum: From the Conquest of Nature to the Construction of New Ecologies," *Environmental History 21, no. 2 (April 1, 2016*): 206–87, doi:10.1093/envhis/emv165. This roundtable outlined many upcoming projects on the Isthmus and suggested just how fertile the state of environmental history in Panama is.

[11] Carse, *Beyond the Big Ditch,* 5.

the Canal that pestered the waterway throughout its existence.[12] My hope is that energy provides a continuity between the pre and post-canal eras and suggests that the Canal, while essential to Panama's history, is merely a single manifestation of several attempts to utilize energy to alter the environment and cross the Isthmus. My project then is not on the Panama Canal, but rather the Panama "Transit Zone," both a physical place which has roughly the same geographical borders of the Canal Zone, and an ideological construct which represents the cultural ideal of minimizing travel time to expedite the movement of goods and peoples.

It's worth mentioning that in addition to focusing specifically on the "Transit Zone" this dissertation also focuses primarily on the experiences of Americans in Panama. As a result, it mentions the pre-colonial, Spanish colonial, and French construction eras of the Transit Zone only in passing. This is certainly a limitation in some ways, as it overlooks the contributions that indigenous Panamanians, the Spanish, and the French made to development of Panama as a site of transportation. Despite this fact, a focus exclusively on American perspectives provides a degree of unity for the dissertation and also indicates a continuity in cultural assumptions about energy and environment. As this project develops past the dissertation stage it will grow more inclusive, encompassing the French, Spanish, and Panamanian perspectives that it currently lacks.

My focus on energy regimes is drawn from the developing field of energy history. My conceptualization of energy relies on Richard White's *The Organic Machine*. While White's

[12] While many Panamanian historians have provided brief examinations of the Isthmus prior to the creation of the Canal, most tend to focus primarily on the Panama Canal itself. The most comprehensive approach to pre-canal Panama is McGuinness*, Path of Empire*. The most successful books in examining both pre and post-Canal Panama have tended to be foreign policy studies of the relationship between Panama and the U.S. Examples include LaFeber's *The Panama Canal*: *A Crisis in Historical Perspective;* and, Michael L. Conniff*, Panama and the United States: The End of the Alliance,* (Athens: University of Georgia Press, 2012).

definition, that energy is the capacity to do work, may be simple, its elegance lies in its capacity to connect seemingly unrelated energy flows on the Columbia River, be they the calories stored in salmon or the watts generated by a nuclear power plant. This allowed environmental historians to bridge the nature vs. culture debate that had defined environmental history for decades by recognizing that both natural and cultural forces were connected by energy. Similar energy connections characterize human attempts to shape the Transit Zone. While 19th century mule trains and 20th century nuclear explosions may seem alien to one another, they both provided a means of bringing human aspirations of pan-Isthmian transit to fruition through complex and expensive infrastructural improvement. White's definition of energy provides me with the freedom to compare these and other energy regimes and their shared "capacity to do work."

My project will also recognize that the emergence of new energies played an essential part in the development of the Panamanian Transit Zone. The adoption of coal, oil, and nuclear energy provided new ways to cross the Isthmus and hence signal shifts in the energy history of the Panamanian Transit Zone. Numerous scholars have dealt with the social, political, diplomatic, and environmental consequences that have accompanied the adoption of new energy sources.[13] Of particular interest is Christopher Jones' *Routes of Power.*[14] Jones suggests that new energy regimes only flourish when humans make a decision to utilize them in a particular way.

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[13] There are a slew of historians who have examined the consequences of energy transitions in the last few decades. Among the most comprehensive are: Daniel Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*, (New York: Penguin Books, 2012); David E. Nye, *Consuming Power a Social History of American Energies* (Cambridge, Mass.: MIT Press, 1998); Martin V. Melosi, *Coping with Abundance : Energy and Environment in Industrial America*, (Philadelphia: Temple University Press, 1985); Timothy Mitchell, *Carbon Democracy : Political Power in the Age of Oil*, (New York, NY : Verso Books, 2011); and Peter A. Schulman *Coal and Empire : The Birth of Energy Security in Industrial America*, (Baltimore: Johns Hopkins University Press, 2015) amongst others.

[14] This book examines the creation of energy transportation systems throughout the mid-Atlantic during the early and mid-19th century. These literal routes of power carried coal from Appalachia to urban centers like Philadelphia. Jones suggests that this process catalyzed an "energy transition" which saw a gradual shift from organic sources of energy such as human and animal muscle to inorganic sources of energy, in this case coal. Christopher F Jones, *Routes of Power: Energy and Modern America* (Cambridge, MA: Harvard University Press, 2014), pg. 5.

In doing so they create "Landscapes of intensification," locations where the concentration of energy allows humans to alter the landscape to make it more conducive to energy consumption, creating a positive feedback loop of exponentially growing energy usage.[15] Panama exemplifies this point. As Americans concentrated energy in Panama, they were able to create an infrastructural network of rail lines, power stations, coal and oil depots, and roads which facilitated the increased consumption of energy. This investment was crucial to dealing with entropy and maintaining their transportation networks, but also redoubled their reliance on energy by leading them to alter the landscape in increasingly dramatic and unstable ways.

This is not to say that shifts from one energy regime to the next were neat and compartmentalized. Indeed, nothing could be further from the truth. While it is useful to acknowledge that the emergence of new sources of energy such as fossil fuels ushered in radical changes in the human capacity to reshape the environment, too many histories have failed to acknowledge that energy transitions are messy, overlapping, and far more gradual than we tend to acknowledge. This disconnect has led to the misnomer of energy "revolutions," a label which implies immediate, radical, and unilateral shifts in human energy regimes. These processes are never so absolute. Energy transitions are entangled, and rarely result in the complete destruction of any singular energy source. Indeed, the creation of Panamanian infrastructural networks suggests that we should understand the emergence of energy regimes not as a process of revolution, but rather of proliferation. Ultimately the construction of the Panamanian transit networks challenges our assumptions about energy regimes and their development by suggesting that while coal, oil, and nuclear energy provided new possibilities for human movement across

[15] For a detailed description of "landscapes of intensification" see Jones, *Routes of Power.*

the Isthmus, their utility was always mediated by the necessity of those energy sources that predated them.

Energy transitions then were not so much revolutions as evolutions, gradual processes in which numerous energy sources existed in conjunction with one another. Panama in the spring of 1914 exemplifies this point. As construction of the Canal approached conclusion, coal fueled dredges removed silt from the bottom of its meandering waterways while human muscle put the finishing touches on a hydro-electric station at Gatun dam which would provide the electricity necessary to operate the Canal's gargantuan locks. This hydro-electric station was not to be confused with the oil-fueled generators located at sub-stations throughout the Canal Zone, which provided electricity for the towns that dotted the Panamanian jungle. While these developments seem to speak of the modernization of the Canal Zone's energy sources, it is worth noting that 1914 also saw the importation of more draft animals than any other year of canal construction. The completion of the Canal was not the result of a singular energy regime or revolution, but rather the confluence of numerous energies which each fulfilled a specific function. I want to challenge the traditional emphasis on energy revolutions by instead tracing this rich tapestry of entwining energy sources which together reshaped Isthmian landscapes.

My hope is that by embracing the relationship between energy and entropy I can move beyond the concept of "hybridity" that has defined environmental history recently. While Panama certainly is the site of a hybrid environment, hybridity is a problematic idea. For the past two decades, a push to perceive nature and culture not as separate entities, but rather as interconnected forces, has dominated environmental history. Thus, human interactions with landscapes do not yield conquest or control, but rather hybrid landscapes, places which retain both their made and unmade qualities.[16] Hybridity is a particularly relevant concept to the Transit Zone as incessant attempts to expedite travel across the Isthmus combined the cultural value of transportation efficiency with the natural realities of a dynamic landscape. While hybrid landscapes have been a useful concept for understanding environmental history, the term has grown relatively static over the past several years, with historian Paul Sutter going so far as to ask "If all landscapes are hybrid what are the useful distinctions to be made within this category?"[17] I argue that energy can help us move beyond the concept of hybrid landscapes by emphasizing the connection between energy and entropic forces that lie at the core of landscape alteration. If humans must do work to overcome entropy and create and maintain hybrid landscapes, and energy provides them with the capacity to do work then it seems only reasonable that we should focus on the relationship between entropy and energy and the overlooked role that they have played in this process. In this way we focus on how landscapes are altered and maintained, emphasizing the physical forces that enabled this process and connecting them to humanity's incessant need for increasingly more powerful sources of energy.

The Panama Transit Zone is also perfectly situated for the adoption of a transnational approach. The Panama Transit Zone was a place where American energy and technology met with Caribbean labor, Panamanian politics, and Euro-American visions of a global future. The result of this strange alchemy was the creation of a truly transnational environment in which all parties involved sought to capitalize on the energy needed in Panama and the capital interests that accompanied the Transit Zone. Americans were acutely aware of the connection between

[16] The best general overview of "hybrid landscapes" can found in, Richard White, "From Wilderness to Hybrid Landscapes: The Cultural Turn in Environmental History," *Historian*, 66 (Fall 2004), 557–64.
[17] Paul Sutter, "The World with Us: The State of American Environmental History," *Journal of American History 100, no. 1 (June 2013)*, pg. 96-97.

their energy production and Transit Zone energy consumption. Indeed, during the years of canal construction, lobbyists clamored at the opportunity to provide American energy in the Canal Zone. William MacCorkle, a West Virginian politician and coal lobbyist, believed "If the nations of the world approach this empire of commerce through our canal, it means millions of tons of productions for West Virginia, and a gold stream pouring into our beautiful valleys and amidst our people, which will be as unending as time." [18] While MacCorkle's dream for West Virginia went unrealized, his comments were a harbinger of the Alaska North Slope (ANS) oil trade that dominated the Isthmus between 1970 and 1990.

Underpinning these global structures was the continued role that human energy and labor played between 1848 and 1990. Richard White himself acknowledged the connection between energy, labor, and the environment by emphasizing the fact that the bulk of people know nature through work.[19] Numerous historians have taken White's observation to heart over recent years.[20] Perhaps the most impressive of these recent works has been Thomas Andrew's *Killing for Coal.* Andrew's description of coal's ability to dictate the living and working conditions of marginalized laborers provides a useful way of understanding the relationship between labor and energy in Panama. While coal, oil, and atoms catalyzed transportation revolutions on the

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[18] William MacCorkle, "'Relation of West Virginia Coals to the Panama Canal' Address Before the West Virginia Coal Mining Institute on the Relation of West Virginia Coals to the Panama Canal Delivered at Charleston, W. VA. on December 8, 1913" (Washington: Government Printing Office, 1914), pg. 4.

[19] White, *The Organic Machine*, pg. x; Among the most interesting angles taken in recent years has been Jeremy Zallen's dissertation "American Lucifers: Makers and Masters of the Means of Light, 1750-1900". Zallen argues that the process of obtaining energy sources such as whale oil, turpentine, coal gas and lamp oil was reliant upon the exploitation of marginalized workers, both free and unfree, who toiled in heinous conditions to provide the means necessary to light up American cities and home. Jeremy Benjamin Zallen, "American Lucifers: Makers and Masters of the Means of Light, 1750-1900" (Cambridge: Harvard University, 2014), http://gradworks.umi.com/36/27/3627322.html. Iii.

[20] While numerous historians have examined the relationship between energy and labor some of the best scholarship has come from Latin American scholars including Myrna I. Santiago, *The Ecology of Oil: Environment, Labor, and the Mexican Revolution, 1900-1938* (Cambridge; New York: Cambridge University Press, 2006); and Patricia I. Vasquez, *Oil Sparks in the Amazon: Local Conflicts, Indigenous Populations, and Natural Resources,* (Athens: University of Georgia Press, 2014).

Isthmus, human muscle always lay at the core of landscape alterations. Despite their importance, manual laborers found themselves marginalized by their more skilled peers. Numerous historians have looked at the experiences of the marginalized men and women who made transit across the Isthmus possible. Led by Julie Greene and Michael Conniff, these scholars have argued that the adoption of a segregated labor force composed of white "gold" laborers and primarily Afro-Antillean "silver" laborers created an easily exploitable labor pool capable of completing dangerous and dirty jobs.[21] While I agree, I also contend that if historians tap this vein of scholarship with an increased focus on energy they may be able to identify other forces that acted in conjunction with racial prejudices to help codify a racialized labor hierarchy.

It is worth mentioning that, despite my desire to write a bottom-up narrative, Panamanians are largely absent from this work, particularly the first four chapters. There are two reasons for this omission. First, sources authored by Panamanians themselves are challenging to obtain, particularly in the American archives which served as the basis for this project. In addition, this work seeks to focus specifically on the act of creating infrastructural networks. Panamanians often distanced themselves from this process. In the creation of the railroad there were a few Panamanians employed, but many of them decided to work in the transportation networks already in place. It was no accident that many laborers were recruited from South America and the Caribbean to construct the Panama Line. The same was true of the era of Canal construction. Indeed, Barbadians far outnumbered Panamanians in the Canal Zone. Due to the

[21] Conniff, *Black Labor on a White Canal*; Greene, *The Canal Builders*.

constraints of sources and the dissertation's focus on the Transit Zone, this work emphasizes the American perspective and should be read as such.[22]

While manual laborers played an important part in Transit Zone networks, energy flows tended to be directed by governments, administrators, and foremen. Consequently, my project will also include top down interpretations of energy history. For guidance on this subject I look towards Scott Kirsch's *Proving Grounds* which examines how political realities shaped "Project Plowshare," the US government's experimentation with nuclear engineering.[23] In addition to providing context for my analysis of Plowshare's proposed nuclear excavation of a new Isthmian canal, *Proving Grounds* expertly examines the relationships between energy and policy makers. Kirsch suggests that the unprecedented possibilities of nuclear explosions always existed in tension with the domestic and international concerns of American policy makers, environmentalists, and human rights advocates. Kirsch notes that more than anything else, the inability of scientists to control radioactive fallout doomed the project. I believe that Kirsch's top down approach, in conjunction with a bottom-up focus on human labor, will allow me to demonstrate that energy pervaded all levels of Isthmian transit and meant different things to different people.

By combining the insight of these historians with my focus on energy and entropy I can unify the history of American infrastructural networks in Panama by drawing attention to the continual role energy sources played in reshaping the Panamanian environment. The environmental realities of Panama forced Americans to import and deploy remarkable volumes

[22] There are some scholars who are making a point of providing an explicitly Panamanian perspective on Canal construction. For more information on the Panamanian perspective see, Lasso, Marixa. 2019. *Erased: The Untold Story of the Panama Canal*. Cambridge, Massachusetts: Harvard University Press, 2019.
[23] Scott Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, NJ: Rutgers University Press, 2005).

of energy to shape the Isthmus to their own ends. They managed to do so, and yet maintaining and preserving the landscapes they created was no small task. Panama then presents a wonderful microcosm to understand the struggle between energy and entropy that lies at the heart of landscape alteration, a relationship that has defined human landscapes with the natural world for millennia.

<u>Organization:</u>

To keep my dissertation focused, I will organize it around a series of episodic chapters, each of which will deal with a particular time period and the dominant energy sources during that era. Christopher Pastore's dissertation "'From Sweetwater to Seawater' An Environmental History of the Narragansett Bay, 1636-1849" provides an excellent guide for the method. This approach provides the benefit of observing changes in energy regimes, processes which can take centuries, while still reflecting the continuity of energy's centrality to Transit Zone transportation networks. Consequently, this dissertation is broken up into six chapters, each of which takes a snapshot of the Transit Zone under the sway of a particular source of energy. Flowing loosely chronologically, these chapters show the battles between energy and entropy that defined American attempts to cross the Isthmus.

I: "It Will Require all the Energy of Which Man is Capable": Human Energy and the Construction of the Panama Railroad, 1848-1854

Chapter one explores Americans' first attempt to use Panama's geographic position to promote transportation: The Panama Railroad. This chapter follows the triumphs and trials that accompanied railroad construction by focusing on Chief Engineer G.M. Totten who, more than any other individual, brought the vision of an Isthmian railroad to fruition. While the railroad grossly exceeded both its initial timeline and budget, it was an immediate success thanks in large part to the California Gold Rush. As news of the bonanza made its way back east, the Panama route emerged as the dominant means of transportation between New York and California.[24] Even before construction finished in 1855, prospective prospectors rode or walked along the tracks to the end of the line. The resulting transit system combined steam power and human labor to convey tens of thousands of Americans across the Transit Zone. Ultimately, interest in Isthmian transit unified American coal, Panamanian muscle, and a universal desire for profit to create the world's first transcontinental railroad. And yet this project also was bound by a unique tension. While the promise of the railroad and the steam power that would propel it gripped the imaginations of Americans and Panamanians alike, the awesome potential it held could not be actualized without the muscles of thousands of workers. These workers had minds and desires of their own and frequently exercised their autonomy, much to the chagrin of railroad administrators. This tension between the dream of a railroad across Panama and the reality of the need for human labor defined the creation of the railroad and foreshadowed the challenges that later construction efforts would face.

II: Black Gold: Coal, Infrastructure, and the Racialized Energy Hierarchy of the Panama Canal: 1904-1908

Chapter two deals with the first few years of Panama Canal construction. Initially work was overseen by John Findlay Wallace, who had a fantastic mind for engineering but proved incompetent at the task of arranging his labor force. Wallace's tenure as Chief Engineer was marked by disorganization, and progress was intolerably slow during this period. John Stevens, who took over construction of the line in 1905, turned the sputtering Isthmian Canal Commission into a model of efficiency. Stevens created a massive coal fueled infrastructure that could handle the task of excavating the extraordinary amounts of earth necessary to build the canal. In doing

[24] McGuinness, *Path of Empire*, 6.

so he also reorganized the human labor force working on the Isthmus. The increasing rigidity of the gold/silver labor rolls in Panama coincided with the coalification of the mechanical labor force and suggested a correlation between the growing importance of mechanical energy and the simultaneous devaluation of unskilled, primarily West Indian, manual laborers. By the time Stevens left his post in 1907 he had organized the Isthmian Canal Commission into a well-oiled (or in this case well coaled) machine, but in doing so had also created an energy hierarchy in which white, skilled machinists and engineers capable of harnessing and deploying coal-fueled machines were privileged while unskilled West Indians were increasingly marginalized, even though their energy was critical to the project.

III: Locks, Shocks, and Barrels: The Proliferating Energy Regime that Constructed the Panama Canal: 1907-1914

Chapter three examines the energy proliferation that enabled the construction of the Panama Canal. After the silver and gold labor system became entrenched in Panama, Chief Engineer George Goethals faced the unenviable challenge of constructing the Panama Canal, an accomplishment that had eluded several other engineers. Goethals capitalized on the infrastructure and energy he had at his disposal, diversifying and expanding American energy reserves in Panama and using a brute force approach to overcome the entropy that plagued the region. By implementing electricity and oil on unprecedented levels, Goethals was able to reshape the Panamanian environment and make it conducive to transportation. Using concrete, he, and the men who worked under him, established a degree of permanence that would keep Isthmian entropy at bay for decades to come. Ironically in doing so they also placed distinct limitations on canal expansion by forcing future engineers to deal with a concrete landscape that was meant by its very nature to resist change and alteration.

IV: The Canal, Fixed: The Limits of the Panama Canal: 1914-1947

Chapter four discusses how perceptions of the value of the Canal ebbed and flowed during the interwar years and in the immediate aftermath of WWII. The utility of the Canal always existed in a state of flux. World War One slowed traffic through the Canal, keeping it from meeting initial projections of traffic. The 1920s reversed this trend with staggering efficiency and brought up uncomfortable questions about the long-term viability of the waterway. While the depression muted these questions somewhat, the Second World War brought them back with resounding force. The development of large aircraft carriers that couldn't fit through the locks of the Canal, alongside the development of atomic bombs that could close a lock canal for years at a time, forced Americans to reckon with the distinct limitations of the waterway. This development forced the federal government to commission a comprehensive canal study in 1947 which sought to identify a means of increasing the Canal's capacity and security. Ultimately these examinations proved fruitless thanks in large part to the lack of an economical means of creating a new sea-level canal.

V: A Radioactive Flash in the Pan: The Atomic Canal: 1960-1970:

Chapter five continues the quest for a sea-level canal by examining the rise of a new source of energy. While oil and coal power had become staples in Panama by the 1960s, the potential of splitting, or fusing, the atom left fossil fuels in its radioactive dust. The "Atoms for Peace" movement led nuclear enthusiasts to propose *Project Plowshare*, a government program to gauge the feasibility of geographical engineering: detonating nuclear weapons to reshape the geography of a region. Panama soon drew the attention of Plowshare administrators, and studies into the possibility of a nuclear canal in Panama or Colombia were underway. After ten years of study experts determined that the technology simply wasn't practical in the fluid Panamanian environment. While seemingly obvious to the contemporary observer, this development was a monumental break in the arms race between energy and entropy in Panama. For the first time American engineers explored a new source of energy and decided not to use it. The dangers associated with nuclear explosives were simply too substantial to be overlooked and as a result they shied away from unleashing this volatile new form of energy.

VI: A Crude Form of Survival: Alaskan Petroleum and Panamanian Pipelines: 1945-1990

Chapter six asserts that despite the decision to avoid the deployment of nuclear explosions, Americans ultimately doubled down on their commitment to energy in Panama. The appetite for oil that emerged during the postwar years wedded the Canal to petroleum products, a development that was reinforced by the discovery of a massive oil field at Prudhoe Bay on Alaska's north shore. The transportation of Alaska North Slope (ANS) oil became a global imperative and Panama was seen as a route to facilitate the movement of this commodity. Ironically, in embracing the oil trade and, consequently, a bid for financial independence, Panama found itself at the whims of global forces beyond its control. Discussions regarding the creation of pipelines and other infrastructural networks between Panama and the United States were complicated by the simmering tensions between the two countries. While the negotiation of the Carter-Torrijos Treaties in 1977 alleviated these issues and allowed the ANS oil trade to explode, prosperity was fleeting. The rise of General Manuel Noriega in the late 1980s led to substantial sanctions and authoritarian economic policies which crippled the petroleum trade and heralded the end of American energy schemes in Panama, for the moment.

Over the 150 years that separate Totten's arrival in Panama and Noriega's ouster, Americans utilized a vast array of energy sources to reshape the Panamanian environment. The arms race between energy and entropy reshaped the landscape and deepened human reliance on energy sources and the often-unforeseen consequences of their deployment. These forces helped expedite transportation across the Isthmus, creating new global markets and commodity flows that shaped the world in the 20th century. And yet they also released instability, both in the Panamanian landscape and in the economic, political, and social forces that shaped America and Panama during the century.

Chapter I: "It Will Require all the Energy of Which Man is Capable": Human Energy and the Construction of the Panama Railroad, 1848-1990

When Chief Engineer George Muirson Totten set foot in Panama in the spring of 1849, he was convinced that the Panama Railroad could be constructed, but that, "it will require all the energy of which man is capable."[1] Totten's words proved prophetic, and far more literal than he anticipated. Throughout the five years of its construction, an incessant energy crisis plagued the railroad, suggesting that the dream of connecting Atlantic and Pacific remained just out of reach. Yet it was not shortages of coal, nor wood (the dominant source of energy for locomotives at the time) that vexed construction of the world's first transcontinental railroad, but rather a lack of human energy.[2] The awesome potential of the steam engine could not be actualized without the work of another prime mover, the human body, to contain the entropy of Panama and establish an infrastructure which harnessed and directed the combustion of cords and coals.[3] Human muscle acted as the vanguard of mechanized labor, clearing jungles, filling swamps, leveling hills, raising valleys, dividing tributaries, and bridging rivers to make the Panamanian environment conducive to rail-borne transit. [4] And yet the work done by humanity's first prime mover is shrouded by the smoke that issued from the engines of those that came after.

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[1] George Muirson Totten to J.P. Adams, 11 April 1849, U.S. National Archives (hereafter USNA), Record Group 185 (Hereafter RG 185) The Letters of G.M. Totten (Hereafter "Totten Letters") Volume 1.
[2] Sam H. Schurr, and Bruce Carlton Netschert, eds., *Energy in the American Economy, 1850-1975; an Economic Study of Its History and Prospects,* (Baltimore: Johns Hopkins Press, 1960), pg. 60.
[3] Richard White, *The Organic Machine* (New York: Hill and Wang, 1995), pg. 6.
[4] Like much of the historiography surrounding Panama, the story of railroad construction seems to have fallen victim to the Panama Canal. Shortly after the completion a flurry of works presented somewhat dramatized accounts of railroad construction. The most significant of which was Fessenden Otis, *Isthmus of Panama: History of the Panama Railroad and of the Pacific Mail Steamship Company,* (New York: Harper & Bros., 1867). The authoritative account of railroad construction didn't arrive until John Kemble's *The Panama Route, 1848-1869*. (Berkley: University of California Press, 1943). After Kemble the railroad was mostly relegated to an interesting precursor to the canal until Aims McGuinness's authoritative, *Path of Empire: Panama and the California Gold Rush.* (Ithaca: Cornell University Press, 2008). While these and other books have dealt with the challenges of constructing the railroad, historians have yet to detail the energy imperatives that shaped its construction.

The lack of attention paid to human energy, particularly during industrialization, is unsurprising. This is not to say that humans are absent from histories of industrialization. Labor historians have done a wonderful job of recognizing the ways in which the adoption of steam engines and fossil fuels impacted the lives of workers. However, these histories are tinged by an implicit assumption that the energy of human laborers was unimportant in relation to the awesome power of these new machines. This isn't necessarily an unreasonable assertion. The metabolism of calories and the oxidation of coal are wildly different chemical processes, and the gulf in the amounts of energy yielded by these reactions is so vast as to make any comparison between the two challenging. Indeed, when referencing "all the energy of which man is capable," Totten was not referencing the measurable energetic output of the human body, but rather a more abstract notion of vitality and vigor. Totten's definition was far removed from the thermodynamic understanding of energy that was germinating in the minds of European physicists like William Thomson and Macquorn Rankine.[5]

Ultimately, the need for human energy was predicated on the realities of the Panamanian environment. In effect, the creation of a rail line allowed for wheeled transit through the rugged interior. While the wheel had long been a staple of human society, its capacity to mitigate friction depended on the quality of the surface on which it traveled. On smooth, hard surfaces (such as a rail line) only 30 kg of force is needed to move a one-ton object, yet this figure could be four or even five times higher on loose soil and up to ten times higher in sand or mud, terrain common to Panama.[6] Unfortunately, Panama would not yield an efficient road easily. If the central challenge regarding interoceanic transit was finding or creating a route with minimal

[5] Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998), pg. 1.
[6] Vaclav Smil, *Energy: A Beginner's Guide, Beginners' Guides* (Oxford: Oneworld, 2006), pg. 76.

friction, Panama's only advantage lay in the fact that it was narrower than any other point in the Americas. By all other metrics Panama was a brutal country, possessing a remarkable variety of rocky hills, low lying swamps, dense jungles, and rushing rivers which made the Isthmus virtually unnavigable for bulky coal-fueled machines. The hostility of the Panamanian interior was so staggering that in 1811 Alexander von Humboldt was forced to concede that, "after the lapse of 300 years there neither exists a survey of the ground, nor an exact determination of the positions of Panama and Portobello."[7] The challenge of crossing the isthmus was such that, with the exception of poorly maintained mule roads and seasonally navigable rivers, it was next to impossible to carry large amounts of machinery and material into the interior. Bulky steam engines required a nimbler source of energy to clear them a path.

Complicating matters further was the fact that the unique hydrological conditions of Panama made stable infrastructural networks difficult to create. Torrential downpours and the resulting landslides exacerbated the entropy of the region, forcing Totten to continually hurl energy at the Panamanian environment in hopes of establishing permanence. Tracks, piles, and bridges were constantly under siege by erosion and, despite Totten's best efforts, it was impossible to entirely hold entropy at bay. Ultimately the tension between these forces shaped Totten's reliance on energy by forcing him to find ways to concentrate increasing volumes of energy in the Transit Zone, an unenviable task to say the least.

Panama's rugged environment dictated the railway's reliance on human energy's distinct advantage over mechanized energy, its portability. The line itself crossed diverse environments. The Atlantic terminus was the newly constructed town of Aspinwall on the small island of

[7] Alexander von Humboldt, transl by John Black, *Political Essay on the Kingdom of New Spain* (London; Longman, Hurst, Rees, Orme, and Brown, 1811), pg. 27.

Manzanilla located in Limon (or Navy) Bay. A piled line across the bay connected it with the Panamanian mainland, a swampy terrain where terra firma was scarce, and mosquitoes were abundant. The line meandered south through these swamps and jungles until it reached the Chagres river, roughly seven miles from Aspinwall. The next twenty miles of the line ran along the eastern bank of the Chagres, occasionally bridging its tributaries, but not crossing the river itself until reaching a 625-foot bridge at Barbacoas, roughly thirty-one miles from the Atlantic terminal. Upon crossing the Chagres, the line left the swampy lowlands to ascend the continental divide, a roughhewn landscape of rocky hills and valleys. At mile thirty-seven the line crested the Obispo Valley and started its rapid descent towards the city of Panama, only ten miles away. The descent presented its own challenges as the line wound back and forth through four miles of foothills to ensure that its maximum grade was only sixty feet per mile. As it approached its destination, the railroad again had to cross a quagmire of lowland swamps. All said and done the line snaked its way through forty-seven miles of some of the most rugged terrain in the world.[8] The inaccessibility of much of the line meant that in many circumstances human energy was the only source of energy capable of weaving its way through the swamps, forests, and mountains that stood in its path.

Despite being indispensable to the construction of the railroad, human labor was an unwieldy source of power. Workers engaged in leisure rather than labor, complained about the quality of food and drink, fell victim to the ravages of tropical diseases, or simply deserted in hopes of pursuing more lucrative endeavors. The central challenge in constructing the Panama Railroad was marshaling and deploying adequate stores of human energy. This is not to suggest

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[8] G.M. Totten and Panama Railroad Co, *Communication of the Board of Directors of the Panama Railroad Company to the Stockholders: Together with the Report of the Chief Engineer to the Directors: 1855* (Hereafter "Communication of the Board: 1855"), (New York: John F. Trow, 1855), pg. 21-23.

that human energy operated in a vacuum. Pile drivers helped the railroad overcome entropy and find stability as it made its way across swampy lowlands. An armada of steamships and sailboats carried the foodstuffs necessary to fuel human bodies and the shelter necessary to protect them from the dangers of the Panamanian environment. Ultimately the railroad itself would become essential to completing the line. The rapidity with which locomotive wheels could traverse the completed line made it the central artery upon which men and materials would reach and cross the Panamanian interior. Thus, the five years it took to construct the Panama railroad between 1849-1855 were not defined by an energy revolution in which steam power overcame the natural environment of Panama, but rather an energy proliferation in which human muscle, supported by an increasingly complex network of steamships, sailboats, locomotives, pile drivers, and mules, enabled the creation of steam energy-based infrastructure in the Isthmian interior. The entangled network of energies that resulted contained the entropy of the Panamanian isthmus and provided the first reliable means of crossing the Isthmus, bringing American visions of rail-borne transit between the oceans one step closer to reality.

Marshaling Manpower and Materials

To say that George Muirson Totten, or as he was more commonly known "Colonel" Totten, was frustrated would be a colossal understatement. Writing from Cartagena, New Grenada in January of 1849, he watched as the discovery of gold in the Sierra Nevadas enticed a swarm of prospectors, panners, and prostitutes to descend on the Isthmus of Panama en route to California.[9] The bulk of these prospective prospectors amounted to little more than paupers and panhandlers. By the time Totten wrote his letter, over three hundred passengers had arrived on

[9] "Colonel George M. Totten Obituary," The New York Times, May 20, 1884, http://query.nytimes.com/gst/abstract.html?res=9B03E0D9173FE533A25753C2A9639C94659FD7CF&legacy=true#

the Isthmus with hundreds more expected to follow. The US Mail Steamship Company and the Pacific Steamship Company were completely unprepared for this influx of travelers and Totten chastised the companies for double booking vessels, leaving passengers stranded on the Isthmus without adequate shelter. Compounding this logistical dilemma was the fact that few travelers brought the provisions necessary for the journey, and, furthermore, that comfortable shelter was hard to come by, leaving many to, "suffer the inclemency of the climate." "What is to become of them?" lamented Totten, "Suffering there must be among them, perhaps death."[10]

The acquisition of California and Oregon and the discovery of mineral wealth in the region demanded action. Totten rightly discerned that the United States' new possessions would radically alter development and trade in the Pacific and believed that the railroad was crucial to that trade's success. Having spent the bulk of his life working on railways and canals, Totten was uniquely qualified to understand the importance of expediting travel to and from the Pacific Coast. In 1831, at the age of twenty-two, Totten took a job as an engineer on the Delaware and Raritan Canal. For the next two decades, Totten established himself as a talented engineer on railroads and canals in Virginia, Pennsylvania, and North Carolina. Totten's major break came in 1843 when he was appointed Engineer-in-Chief of the Canal of Digue, a waterway which would connect the Magdalena River with Cartagena.[11] After seven years in Cartagena, the allure of constructing a railroad across Panama was enough to pull Totten away from the canal. "A year ago, I looked upon the result of this project as problematical," Totten wrote of the railroad in January of 1849 before concluding, "I now consider it necessary."[12] Within a year Totten found himself in Panama, and shortly thereafter named Chief Engineer of railroad construction.

[10] Totten to Adams, 2 January 1849, Totten Letters, USNA, RG 185, Vol. 1.
[11] "Colonel George M. Totten Obituary".
[12] Totten to Adams, 2 January 1849.

Totten's good fortune was in many ways the result of the fact that he shared the vision of a group of New York magnates interested in expediting trade between the east and west coasts of the United States. Led by William Henry Aspinwall, a partner in the largest import-export firm in New York and the inspiration for naming the Caribbean terminus town the unlikely name of Aspinwall, these businessmen came together to create the Panama Railroad Company.[13] The Company was founded in April of 1849, and in June of 1849 sold $1 million worth of stock to the public- although, due to low sales, the directors had to purchase half of the stock themselves.[14] The financial concerns of the railroad now dealt with, Totten could begin his work in earnest.

Totten's earlier experiences led him to understand that his chief obstacle was the lack of adequate laborers. Prior to being named Chief Engineer of the Panama Railroad Totten expressed his concern that "From the magnitude of that work, foreign labor will be necessary. It will be impossible to find a sufficient number of natives (Totten's term to refer to laborers from Panama and Colombia)."[15] Labor recruitment proved a double-edged sword. Native laborers were sparse, but Totten felt compelled to "impress upon the company, the necessity of using all the native laborers that can be obtained, in preference to foreigners, who I do not think can stand the climate."[16] While tinged by racially biased assumptions, Totten's comments reflected one of the challenges of obtaining energy in Panama. Despite being relatively efficient, human labor still possesses limitations. Healthy adults are normally capable of maximizing their energy output at a

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[13] Maurer and Yu, *The Big Ditch: How America Took, Built, Ran, and Ultimately Gave Away the Panama Canal*, Princeton, Princeton University Press, 2011,) 35.
[14] *Ibid*, 42.
[15] Totten to Adams, 11 April 1849.
[16] *Ibid.*

rate of roughly ten to twenty times their basal metabolic rate for short intervals.[17] Individual performance varies from person to person, but most able-bodied men are capable of maximum exertions of roughly 1 to 1.5 kW.[18] This level of activity is unsustainable, however, and over the course of a day most production falls in the realm of two times one's BMR or roughly 130 to 180 W. While Totten had no concept of basal metabolic rate, he was acutely aware of its consequence; more workers meant more work.

The problem of obtaining adequate laborers was complex and affected by biases toward particular ethnicities. In 1853, as railroad construction entered its final phase, Totten outlined his personal preference for laborers. Among the best workers were the Irish and "natives," particularly those from Cartagena. Totten admitted that the Irish, "are not so efficient on the Isthmus as in cooler and healthier climates." However, he suggested that "for periods of four to six months, which is the term of their engagement, they perform a fair amount of work." These limitations didn't apply to native Cartagenians who Totten noted were, "as accustomed to the pick, shovel, and wheelbarrow, as are Irishmen," and were also, "an elastic, hearty race, and in all respects the most efficient common laborers that can be employed on your work." Both Irish and native laborers were far superior to the imported Chinese laborers who Totten noted "are at first feeble and inefficient." And yet Totten was not above leveraging their comparatively ineffectual energy, suggesting that despite their shortcomings, "being steady workmen, temperate, and but little affected by the climate, as they become accustomed to the use of the

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[17] Basal Metabolic Rate refers to the constant minimum power required to energize its vital organs. For healthy humans, this rate can vary between 55-80 W for females and between 60-90 W for males. Human exertions vary wildly and for a sustained output the most active humans (a category which railroad laborers likely would have fallen into) can normally sustain about two times their BMR. For more information see Smil, *Energy,* pg. 45, 58-62

[18] Smil, *Energy*, pg. 59-61.

tools, and acquire strength from regular and wholesome food, they made useful workmen." [19] Totten established a clear hierarchy of laborers in which “native” labor was superior, followed by Irish, and finally Chinese labor.

Totten’s assumptions about the efficacy of his laborers suggested that his preferences, while certainly still reflective of contemporary racial biases, were also complicated by his experience in managing and deploying human energy. In essence, the factors Totten weighed reflected broader questions about the applicability of energy. Reliability, efficacy, ease of acquisition, and cost-effectiveness were qualities that were frequently applied to other sources of energy. Ultimately, Totten’s valuations were not only tied to racial assumptions, but also his personal assessment of each group’s capacity to do work.

With these preferences in mind, Totten began the arduous process of filling labor rolls, a task complicated by the fact that employment on the railroad was not the only line of work available in Panama. The discovery of gold in California lured thousands of men and women across the Isthmus, creating a transportation bonanza. Many of the laborers who came to Panama had no intention of swinging machetes through dense jungles, instead, they directed their body's energy towards the booming network of bongo canoes and mule trains that were already reaping the benefits of the gold rush. These enterprising energy entrepreneurs used the Panama Railroad Company to secure passage to the Isthmus. Upon their arrival, they vanished into swamps and forests, making their way towards interior villages that facilitated transisthmian travel. What drove them to forsake the railroad? Put simply: money. The adventurers making their way to California were willing to pay exorbitant prices to speedily traverse the Isthmus. The desertion

[19] G.M. Totten, “Report of the Chief Engineer to the Directors”, *Journal of the Franklin Institute* (Pergamon Press, 1854). Pg. 14-15.

problem grew so acute that Totten was forced to admit that, “We are not able to find labourers for our building and surveys at $1.12 per day, nor would $1.25 or $1.50 induce them to work for us with consistency."[20]

Totten found himself faced with a predicament. How was he to control the laborers making their way into Panama? Initially, Totten attempted to use force to prevent desertions. When a group of laborers who had signed six-month contracts deserted in the fall of 1850, Totten sent one of his assistants to track them down and reached out to local authorities for assistance. Unfortunately for Totten his faith was poorly placed. The local alcalde sent a group of armed men to apprehend the deserters; however, when Totten’s agent arrived to gather the wayward workers, he found that they had been allowed to escape by the guards. The experience was so frustrating that Mr. Michel, the assistant sent to find the laborers, decided to leave the Isthmus shortly thereafter. An aggravated Totten was forced to concede that, "Under such circumstances, although I see some of our deserters around here, it appears to me useless to try to retake them."[21]

Human energy proved far more challenging to control than coal or wood. For workers, the potential benefits of investing one’s energy in the transportation business far outweighed the rewards of laying track. Laborers were quick to recognize this and often directed their labor towards this more lucrative end. As a result, desertions plagued the railroad throughout its construction, sapping valuable stores of energy and hindering progress on the line. These individuals shrewdly used the transportation provided by the railroad company to fund their journey to Panama before abandoning their contracts and heading into the interior in search of

[20] Totten to Thomas Ludlow, 13 February 1850, Totten Letters, USNA, RG 185, Vol. 1.
[21] Totten to John L. Stephens, 25 August 1850, Totten Letters, USNA, RG 185, Vol. 1.

greener pastures. Totten had no illusions about the issue, writing in February of 1850, “We look to Cartagena and the neighboring provinces as our only resource for our laborers. There is no doubt that many of those we may bring here will desert us and enter the business of transportation upon the river and overland."[22] Ultimately, the railroad company decided that the best course of action was to allow those lured west by the promise of gold to pay the railroad company to walk along the unfinished tracks. Additionally, they sought partnerships with existing transportation companies on the Isthmus, subsidizing potential competitors' expenses in hopes of driving the muscle-powered transportation network in Panama out of business.[23] These aggressive policies indicated the lengths to which the railroad company was willing to go to ensure long-term, reliable access to human energy. Solving the energy crisis was paramount, even if it was done at great expense.

Driving the muscle fueled transit network out of business alleviated some problems, but it wasn't just desertions that made human labor hard to manage and direct. Like all prime movers, human bodies needed a steady source of fuel. Unlike steam engines, human bodies also demanded a variety of vitamins and minerals. As a result, ensuring a steady and varied supply of food was essential. Foods including beef, pork, cod, cornmeal, and potatoes made their way into Panama, providing calories that could be metabolized by human bodies.[24] The need for a steady supply of food emphasized connections between the Isthmus and the United States. Roughly every two weeks, ships made their way between Panama and New York, carrying rations of food and other essentials for construction work. Steamships tended to carry laborers and specie, while barks, schooners, and brigs- wind-powered vessels- were chartered to bring materials and

[22] Totten to Ludlow, 13 February 1850.
[23] *Ibid.*
[24] Totten to Stephens, 25 August 1850.

sustenance to the Isthmus.[25] The impermeability of Panama and the lack of local energy in the region meant that it was easier to import energy into Panama rather than obtain it from local sources, a trend which defined energy regimes in the Transit Zone throughout its existence. The result was an intimately connected energy network which saw calories grown on American farms fed to laborers imported from around the Americas, Europe, and later Asia. The energy network in Panama then was a messy collection of overlapping energy sources from its very inception.

The basic foodstuffs imported into Panama were supplemented by other items depending on the backgrounds of the workers in question. Because healthy and happy humans were so important, Totten had to provide not only an efficient source of fuel but also a palatable and culturally acceptable one. For his European and American workers, Totten made a point of obtaining pickles, a popular remedy for scurvy. Similarly, Totten requested 30 barrels of rice because "it is an article of prime consumption with the black laborers."[26] This cultural predilection towards different sources of fuel separated human labor from mechanical labor. While different varieties of timber and qualities of coal yielded variable amounts of energy, the utilization of a particular fuel was a product of cost and accessibility rather than cultural proclivities. Steam engines seldom made their displeasure known at consuming Pennsylvanian rather than Welsh anthracite, but human laborers frequently directed their energy at protesting substandard grub.

These challenges meant that work progressed slowly through the summer and fall of 1850. This was not surprising. Totten had only arrived on the Isthmus earlier that year and had spent much of his time trying to obtain a reliable store of human energy. The Panamanian

[25] Francis Speis, Minutes of the Meeting of the Board of Directors, 5 November 1853, USNA RG 185, Minutes of the Meetings of the Board of Directors (Hereafter "Board Minutes") Volume 1.
[26] Totten to Stephens, 11 December 1850, Totten Letters, USNA, RG 185, Vol. 1.

climate also hindered progress. The variances in weather led Totten to admit that, "a day's work is a very uncertain quantity."[27] Totten put these complications mildly. The wet season made work almost impossible, particularly in the swampy lands surrounding Limon Bay.[28] At their most extreme, these conditions could actively work against the maintenance of human labor. In September of 1850 Totten wrote that five or six of his Irish laborers had deserted as they were, "not pleased at being placed to work in the water."[29] These concerns were well founded. The combination of heavy rains and inadequate shelter made tropical disease a constant companion to the laborers. At times these outbreaks grew so pronounced that work on the railroad ceased altogether.

To deal with these challenges, the company grew increasingly aggressive in its attempts to provide Totten with the necessary manpower to create the railroad. A bevy of energy speculators saw the potential financial windfall that came from providing manpower to the Panamanian railroad. The financial incentives behind the trade of human energy have long been acknowledged by historians of slavery, and yet it is worth noting that energy tycoons often peddled their wares in other coerced labor markets as well. These manpower magnates signed contracts with the Railroad Company, promising to recruit laborers throughout the United States before transporting them to the isthmus. Successfully recruiting human energy could provide immense financial benefits. E.D. Baker signed a contract with the Company in July of 1850 stipulating that he would take down to the Isthmus roughly one thousand men, the bulk of whom were engineers and mechanics, on one-hundred-day contracts. In return, the company would pay

[27] Totten and Railroad Co., "Communication of the Board: 1853" 14.
[28] Totten to Ludlow, 27 July 1850, Totten Letters, USNA, RG 185, Vol. 1.
[29] Totten to Stephens, 9 September 1850, Totten Letters, USNA, RG 185, Vol 1.

Baker five-thousand dollars for the first fifty days of work and ten-thousand dollars of company stock at the conclusion of the hundred days.[30]

A few months later, the Company signed a contract with a Mr. Armstrong to ship twenty to thirty Jamaican laborers to the Isthmus so that "an early trial may be made of the value of their labor." Baker, Armstrong, and other middlemen like them capitalized on the energy needs of the railroad company by procuring, stockpiling, and distributing energy, reaping a tremendous profit as a result. Their business interests suggested that long before coal or oil bonanzas swept through the United States a vibrant energy market already existed, one driven not by fossil fuels but instead by human muscles.

Despite these ambitious attempts to provide the energy necessary to construct the railroad, progress remained elusive throughout the wet season of 1850, and optimism that the coming dry season heralded greater productivity proved misplaced. Diseases and deluges grew more manageable during the dry season, but transportation into the interior grew increasingly problematic. Totten frequently advocated for the creation of a dirt road along the proposed railway to ease the transportation of materials.[31] The initial period of construction saw such severe labor shortages that it was impossible to bring this plan to fruition. Additionally, as the company staged much of its work from the island of Manzanilla it still had to cross Limon Bay to reach the mainland. The answer to both challenges lay in the Chagres River. The Chagres was the largest river along the railroad line and had served as a major line of transportation across the

[30] Francis Speis, Minutes of the Executive Committee, 24 July 1850, USNA, RG 185, Minutes of the Executive and Finance Committees: 1849-1906 (Hereafter "Executive Minutes") Volume 1.
[31] Totten to Adams, 11 April 1849.

Isthmus for centuries. The company began employing steamers to take advantage of the minimal friction presented by the river and penetrate the Panamanian interior.[32]

While in principle this would overcome many of the challenges presented by the landscape, it proved far from easy in practice. As the rivers fell in the dry season, the bulky steamships drew too much of a draft to make their way upriver.[33] The combination of difficult access to the interior during the dry season and poor working conditions during the wet season led to the adoption of a cyclical labor schedule in Panama where the wet season would be used to marshal manpower and materials in Panama which could then be brought to bear on the work during the dry season. This was not a rigidly followed cycle, and often the railroad saw a more fluid application of human energy, however, the dry season was clearly understood as a period when work could be more easily accomplished if the necessary materials were available.

Ultimately the first year of construction made little headway. Distracted by attempts to obtain human labor, Totten brought little of this energy to bear on the Panamanian environment. Despite this, as 1850 concluded, Totten and the company were optimistic that their actions had not been in vain. Gradually men and materials made their way into Panama and soon construction would commence in earnest. Or at least that was the hope.

Reaching the Chagres

As the rainy season gave way to the dry season in late 1850 a sense of optimism settled over the line. In New York, company President John Stephens authorized the purchase of a second-hand locomotive to aid in the construction.[34] Meanwhile, on the Isthmus, Totten took

[32] McGuinness, *Path of Empire,* pg. 55.
[33] Totten to Ludlow, 13 February 1850, Totten Letters, USNA, RG 185, Vol. 1.
[34] Speis, Minutes of the Executive Committee, 7 November 1850, Executive Minutes, USNA, RG 185, Vol. 1.

steps to try to get roughly 600 men to the line by November, and, while desertions still plagued him, he finally seemed to be making headway in concentrating a store of human energy on the Isthmus. In addition, a steam pile driver arrived to help create a fixed line through the swamps surrounding Limon bay.[35] Unfortunately for Totten, this process proved to be as smooth as the vexing landscape he was trying to cross. Once again it was not concerns over coal or steam energy that complicated construction, but rather the difficulties of controlling and deploying human energy.

Caffeine addicts are quick to make their displeasure known if they fail to get their hands on a decent cup of coffee. The Irish laborers on the Panama railroad were no exception. Over the winter of 1850, a group of them decided not to work "on account of bad coffee and bad bread."[36] It is telling that these men were more outraged by the blasphemy of a bad brew than by the maladies of malaria and yellow fever. While quality coffee may not have been percolating on the Isthmus, discontent most certainly was. The strikers' frustration with the railroad's substandard joe was so pronounced that they threatened to use force to rectify the situation if necessary. Dr. Henry, the foreman overseeing the disgruntled and undercaffeinated rebels, warned railroad administrators to "look out for their own safety as he (Henry) would not prevent his men from coming over and redressing their own grievances."[37] Clearly both sides struggled to find common grounds. Totten felt compelled to chastise the United States' lack of preparation for such a crisis, writing, "I certainly think our government negligent by not having an armed vessel

[35] Totten to Ludlow, 27 July 1850.
[36] Pierce to Totten, 23 December 1850, Totten Letters, USNA, RG 185, Vol. 1.
[37] John Rockland to Totten, 23 December 1850, Totten Letters, USNA, RG 185, Vol. 1.

on this coast," before reassuring the Board of Directors that "I do not fear the revolvers or bowie knives of Dr. Henry's men."[38]

While the brewing revolution on the Isthmus never boiled over, it exemplified the challenges faced by administrators in trying to control laborers. Underlying questions of caffeine were questions of control, particularly between Totten and Henry. Henry asserted that Totten lacked the authority to direct his men and their energy, while Totten countered that Henry was "not capable of managing his men, but consults with and is controlled by them."[39] While the general laborers' disquiet may have been fueled by concerns over coffee, Totten and Henry grounded their conflict in questions over who had the authority to direct human energy, and the efficacy with which they deployed that energy. Ultimately, in the eyes of the railroad's directors, primacy lay with the man capable of maximizing the efficiency of laborers and so Totten was given power over Henry and his men, a decision which clearly implied that fomenting an energy crisis on the Isthmus was an egregious sin that bore serious repercussions.[40]

It's also likely that the climactic conditions of Panama exacerbated the labor conflict. Of the 150 men who followed Dr. Henry, Totten estimated that roughly 100 were laid low by diseases, and eight eventually died. Their suffering evoked little sympathy from Totten who suggested "if they had worked more and complained less" they may have been able to clear forests and swamps, erect shelters, and better protect themselves from the environment. This critique was somewhat misdirected however as, by January of 1851, complaints about the lack of quinine were springing up across the Isthmus.[41] Indeed, Totten's initial response to the strike was

[38] Totten to Stephens, 24 December 1850.
[39] Totten to Stephens, 6 January 1851, Totten Letters, USNA, RG 185, Vol. 1.
[40] Totten to Stephens, 24 January 1851, Totten Letters, USNA, RG 185, Vol. 1.
[41] Totten to Stephens, 6 January 1851.

not providing better quality food to the men, but instead obtaining mosquito nets for the men.[42] Regardless of where the fault lay on the matter the outcome was clear, and, by February, Dr. Henry and all of his laborers either voluntarily left the work or been asked to leave with the exception of a few men."[43]

The situation with Dr. Henry at an end and the dry season now arriving, 1851 presented Totten with the opportunity to finally make headway on the line. Totten's initial goal for the dry season of 1851 was to complete the line between Navy Bay (Limon Bay) and Gorgona, a town on the Chagres River more than halfway across the Isthmus. Totten pursued this ambitious objective through the sequential construction of the line. Surveyors first located the line, then general laborers cleared and graded it. If necessary, pile drivers next provided cribbing for landfill and the creation of solid ground. Finally, the track itself was laid and the line progressed north to south through the interior.[44] While perhaps overly ambitious, the plan seemed feasible to Totten. By February of 1851, he had 800 men on the road, expected an additional 400 to arrive presently, and 300 to trickle in over the coming months. With the help of this substantial influx of human energy, Totten was hopeful that the line to Gorgona could be completed by July, prior to the worst deluges of the wet season.[45]

Totten's spirits were further bolstered by the promise of the line's newly arrived steam fueled labor. In November of 1850, the company contracted with George Sellers, a renowned locomotive engineer, to create three locomotives in Cincinnati and ship them from there to

[42] Totten to Stephens, 24 December 1850.
[43] Totten to Stephens, 24 February 1851, Totten Letters, USNA, RG 185, Vol. 1.
[44] Totten to the President and Board of Directors of the Panama Railroad Company, 18 December 1850, Totten Letters, USNA, RG 185, Vol. 1.
[45] Totten to the Board of Directors of the Royal Mail Steam Packet Company, 6 February 1851, Totten Letters, USNA, RG 185, Vol. 1.

Panama, the first to be transported to Aspinwall, by June of 1851 and the other two the following month.[46] In order to unleash the potential of the locomotives, it was imperative that headway be made on the line. Anticipating this boom, the company purchased 10,500 yellow pine piles and 424,000 board feet of yellow pine from J.T. Gilchrist's lumberyard in Bangor, Maine and 1200 tons of iron from Caron Brothers & Co. of London. These materials were carried to Panama by privately chartered schooners and allowed construction of the line to begin in earnest.[47] Totten was optimistic that with the aid of another steam fueled component of his diversifying energy reserves, the piledriver, he could have the line ready for the locomotives.

A series of challenges soon proved Totten's faith misguided. Chief among these obstacles was a lack of foresight regarding the complications that accompanied Totten's increasing reliance on the pile drivers. The fluidity of the Isthmian landscape meant that it was next to impossible to find terrain capable of supporting the combined weight of track and train without shifting. To overcome the instability of the Panamanian environment, piles were driven deep into the swampy soils that flanked the Chagres in hopes of striking solid ground. This was a more challenging process than it seemed. Initially, the railroad used twenty-four-foot piles, but these proved too short and thirty-foot piles soon became the norm.[48] These piles formed an exoskeleton of sorts that was filled with soil and packed down until it was dense enough to lay track across. The lynchpin of this whole plan was the pile driver, a machine Totten had absolute faith in. In February of 1851, he bragged that he had five pile drivers on the road, each of which

[46] Speis, Minutes of the Executive Committee, 19 November 1850, Executive Minutes, USNA, RG 185, Vol. 1.
[47] Speis, Minutes of the Executive Committee, 4 January 1851, Executive Minutes, USNA, RG 185, Vol. 1.
[48] Totten to Stephens, 9 September 1850.

could lay a mile of track a month.[49] At this pace, construction could average roughly five miles of track a month, a clip that put them well on their way to reaching Gorgona by July.

Unfortunately, Gorgona remained out of reach. While the pile drivers had the potential to work at such breakneck speeds, such a pace was seldom realized. Totten failed to anticipate that by increasing the complexity of his energy regime he had simultaneously unleashed the potential for new challenges. The heavy rains and shifting soils of the Isthmus proved as conducive to machine labor as they had to human labor and soon mechanical issues crippled the promise of reaching Gorgona. In one instance, a second-hand machine died after driving only 76 piles.[50] Three weeks later a replacement hammer for another piledriver couldn't be lifted, weighing 2000 pounds rather than the machine's maximum of 1500 pounds. To make matters worse, the lack of freshwater near Manzanilla meant that alterations had to be made to the steam engines' boilers to allow them to run on salt water.[51]

The mechanical problems with the pile drivers pointed to another more serious issue that accompanied the diversification of the Isthmian energy regime. These finicky machines required a corps of engineers and mechanics to operate and maintain them, and workers of such quality were in short supply. As soon as the machines arrived on the Isthmus, Totten searched for suitable workers, admitting, "we have only one road pile engine at work at Navy Bay from the want of engineers to manage the other."[52] The issues accompanying the arrival of the steam engines pointed to broader shifts in the Panamanian energy regime and a reorientation of the importance of human labor.

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[49] Totten to Board of Directors of the Royal Mail Steam Packet Company, 6 February 1851.
[50] Totten to Stephens, 6 January 1851.
[51] Totten to Stephens, 23 January 1851, Totten Letters, USNA, RG 185, Vol. 1.
[52] Totten to Stephens, 7 February 1851, Totten Letters, USNA, RG 185, Vol. 1.

The productivity of steam engines outpaced even the most capable laborers. The sheer force exerted by the pile drivers proved as much. And yet actualizing this power relied on a new type of human energy, one defined not by the amount of work that it could do, but rather by the specialized type of work that it could do. As steam began to augment human energy in the Isthmus it meant that less human energy was required to complete a singular task, however, the complexities of directing steam energy required increasingly specialized mechanics and engineers capable of harnessing steam power and ensuring its reliability. These specialized laborers became essential to railroad construction, and Totten went to great lengths to obtain their services. The addition of steam energy to the Isthmus ultimately created an "energy hierarchy," a stratification of power and privilege directly tied to one's capacity to direct powerful sources of energy. During railroad construction, these hierarchies were certainly present but remained amorphous. Track layers, masons, and quarrymen, positions that gradually lost their significance in the coming decades, were still of tremendous value to Totten as mechanical labor lacked enough precision for these tasks. As humans developed more sophisticated prime movers and harnessed more powerful energies, they inadvertently created increasingly rigid energy hierarchies to ensure energy's effective deployment. The presence, or lack thereof, of engineers to direct the first manifestations of steam energy on the Isthmus was a testament to complexities that arose from a diversifying energy network.

The lack of engineers and the mechanical issues impacting the pile drivers led to work progressing slowly during the first few months of the dry season of 1851. As February gave way to March, enough engineers made their way to the Isthmus to render the pile drivers effective. The engineers also maintained the steamships that carried supplies up the Chagres. These developments sparked the return of Totten's optimism and he proclaimed to John Stephens that

“We have got a good start, and with a fair supply of laborers, can now make more progress in one month than we have done in the last two.”[53] The time had finally come to begin laying track.

As with the adoption of pile drivers, the process of laying track required the acquisition of new laborers. Like the engineers, track layers were valuable not so much for the quantity of energy they could direct at the work, but rather their precise application of energy towards skilled ends. The ranks of the track layers were filled with a variety of carpenters including ship carpenters, bridge builders, and millwrights. Interestingly, Totten attempted to avoid house carpenters who he believed “are of little use.”[54] In addition to manpower, Totten also tried to import more animal labor in the form of mules. Totten believed the mules were indispensable for the process of track laying, and that, for the purpose of moving materials through otherwise impassable terrain "one mule will count equal to three men."[55]

As late as the wet season of 1850, energy on the railroad had been almost entirely human in nature excepting the ships that carried materials to the Isthmus, and almost entirely unskilled apart from Totten and his assistants. By early 1851, the small unskilled force on the railroad had grown exponentially and variety of other prime movers had joined them. Five pile drivers added steam energy to the increasingly diverse energy network, and skilled laborers such as engineers, surveyors, and track layers now directed their energy towards precise tasks, allowing other sources of energy to work unimpeded. Meanwhile, ocean-going steamships and sailboats continued to provide material support from American ports while newly deployed river steamships used the Charges (as best they could) to gain access to the Panamanian interior. In those regions inaccessible to boats, a corps of muleteers provided overland transit. The once

[53] Totten to Stephens, 24 February 1851.
[54] Totten to Stephens, 24 February 1851.
[55] *Ibid*.

homogenous energy network in Panama had grown, and so too had its capacity to reshape Isthmian landscapes.

The increasing potential of energy on the Isthmus was not without its drawbacks. Increasingly complex issues accompanied the increasing complexity of the labor force. By June of 1851, Totten was content with the number of general laborers, mechanics, engineers, and surveyors on the work, but was having difficulty obtaining the necessary track layers. Many of the men who had agreed to go to Panama had lied about their credentials and lacked experience, leading Totten to deem them "good for nothing."[56] For qualified track layers, disease remained problematic, limiting their efficacy as sources of human energy. Even when tropical diseases declined over the dry season, the specter of pestilence haunted the Isthmus. Its impacts were felt as far away as New York where it hindered labor recruitment. In one instance, twenty-five well-regarded ship carpenters were on their way to the Panama Railroad Company offices to apply for employment when an anonymous interloper cut them off and proceeded to terrify them with tales of Isthmian hazards. All twenty-five men quickly rethought their decision and concluded that Panama simply wasn't worth the risk. The situation was so dire that when Totten sent an assistant to New York to recruit forty track layers he requested divine intervention. "God held him in his mission…" wrote Totten, "We are working at an awful disadvantage for the want of this craft."[57]

Work progressed inconsistently. Stretches of great productivity were accompanied by periods when work halted altogether. Mechanical issues with the engines of pile drivers, locomotives, and steamships meant that talented engineers were constantly in demand. As the summer of 1851 progressed, the pile drivers became increasingly troublesome. The scow pile

[56] Totten to Francis Speis, 28 March 1851, Totten Letters, USNA, RG 185, Vol. 1.
[57] Totten to Speis, 6 June 1851, Totten Letters, USNA, RG 185, Vol. 1.

driver at Mindee was "a snail," and another pile driver had become so problematic that Totten simply did away with it, characterizing “all machines of the kind on dry land perfect nuisances- inventions to retard the work."[58] The one exception to these piling problems, the pile driver at Gatun, was also removed from service after a flood damaged the piles crossing the Gatun River. These mechanical woes were accompanied by rampant sickness as the wet season returned. One of Totten’s foremen had to return home because of a case of dysentery and another poor laborer, one Mr. Niles, was in even worse shape, his leg having been amputated after it was crushed in an accident. As if to add insult to injury, Niles was then struck by a nasty case of lock-jaw before returning home.[59] Totten was particularly concerned by the high rate of sickness among his native force. By August of 1851, the situation was dire. Illness swept through the ranks, resulting in a few deaths and the departure of fifty of his native laborers, dropping their numbers to around 500.[60]

The result was a state of flux along the line as the wet season concluded. Surveying, clearing, and grading, work that could be done primarily with human and animal energy, nearly reached Totten’s intended target of Gorgona and yet the combination of disease and mechanical issues prevented piling and tracklaying from making any progress. Totten grew increasingly concerned as these issues progressed, feeling despair over the state of chaos on the line, and writing to President John Stephens:

> You must not think strange of my change of plans. This country does not admit of fixed plans. One is obliged to adapt himself to circumstances. Sickness is constantly breaking in upon one's intentions and thwarting all his best endeavors. I believe there are more causes for discouragement here than on any other work in the world. Sometimes I almost despair- and nothing but my most sanguine temperament keeps up my spirit. If I do not communicate these feelings to you it

[58] Totten to Stephens, 23 July 1851, Totten Letters, USNA, RG 185, Vol. 1.
[59] Totten to Stephens, 23 July 1851.
[60] Totten to Stephens, 9 August 1851, Totten Letters, USNA, RG 185, Vol. 1.

> is because I know that it would be of no use and therefore, I always try to pass on good appearances.[61]

Disease, environment, and the unpredictability of mechanical energy had pushed Totten nearly to the breaking point. The increasing complexity of the energy network in Panama had allowed for some progress to be made, but the issues that arose from it seemed insurmountable. It was at this moment, when it appeared the work might be doomed to fail, that Totten realized there may be a solution to his woes. He was simply going to make them someone else's.

Contractors and River Crossings

Totten's despair in August did not lead him to abandon the work. Indeed, over the next few weeks his resolve seemed hardened. By the beginning of September 1851, Totten was confident that he could open the line to Gatun by the end of the year if not sooner.[62] Despite continued challenges Totten reached his goal in December of 1851 and the railroad began service over the first seven miles of track between Manzanilla and Gatun.[63] While this section represented only a fraction of what was to come, the opening of the line to passengers ushered in a new stage in railroad construction on the Isthmus, suggesting that, despite all the difficulties presented by the Panamanian environment, rail-borne transit was a viable means of expediting transit between the oceans.

The creation of the first section of track aided the work immeasurably. In the dry season of 1852, Totten began employing the locomotive *Pottsville,* a second-hand locomotive purchased from the Pennsylvania and Reading Railroad Company, to pull dirt cars between Gatun and

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[61] Totten to Stephens, 9 August 1851.
[62] Totten to Stephens, 8 September 1851, Totten Letters, USNA, RG 185, Vol 1.
[63] Totten and Railroad Co., Communication to the Board of Directors: 1855, 9.

Manzanilla.[64] Again, Totten found that utilizing more complex forms of energy came at a cost. The *Pottsville* fell out of commission when an engineman burned out the engine, rendering it useless. As had been the case with the adoption of pile drivers Totten now had to find laborers capable of managing the locomotive. He told the company, "We are exceedingly in want of one or two good locomotive engineers, who are at the same time good machinists and can repair their engines. For want of which men the Pottsville is now laid up, when her services are daily required."[65]

Even as these hardships complicated the work, Totten remained enthralled by the potential of this steam fueled labor force and attempted to expand it as rapidly as possible. The arrival of a skilled machinist, Mr. George Nichols, in January of 1852 further accelerated this process, and upon Nichols' arrival Totten asked for "two Sellers locomotives and engineers to run them," accompanied by anywhere from fifteen to thirty dirt cars of the highest quality.[66] In response the company tested out the three Sellers locomotives it had previously purchased, preparing them for service in Panama, and contracted out the construction of thirty Boston Rocker dumping cars to carry dirt across the line.[67] These steam engines sped up the progress of construction during the dry season of 1852, allowing laborers to carry materials more easily between Manzanilla and their forward stations along the line. While human labor remained paramount in Panama, mechanical labor played an increasingly important role.

Despite these successes, the problems of the fall of 1851 remained in Totten's mind and he began insisting with increasing regularity that the Board explore the potential of contracting

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[64] Speis, Minutes of the Executive Committee, 9 August 1851, Executive Minutes, USNA, RG 185, Vol. 1.
[65] Totten to Speis, 21 November 1851, Totten Letters, USNA, RG 185, Vol. 1.
[66] Totten to Speis, 18 January 1852, Totten Letters, USNA, RG 185, Vol. 1.
[67] Speis, "Minutes of the Executive Committee, 31 December 1851", Executive Minutes, USNA, RG 185, Vol. 1; Speis, "Minutes of the Executive Committee, 2 February 1852" Executive Minutes, USNA, RG 185. Vol. 1.

out some, if not all, of the remaining work.[68] After a period of reluctance, the Board began seeking contracts in December of 1851. Initially, contracts covered specific tasks, such as the erection of a bridge over the Chagres River, but as time went on the Board warmed to the idea of contracting out the entirety of the remaining work. [69] Totten was making headway by the spring of 1852, but construction was far slower and more expensive than initial estimates suggested. In response, in April, the Board of Directors granted the executive committee the authority to contract out the Pacific half of the road from the Chagres River crossing to the Pacific terminus at Panama City.[70]

While the Board examined contracts in New York, Totten drew closer to the Chagres. By July of 1852, his goal was in sight as the line finally reached Barbacoas, the point at which the line crossed the river.[71] This was not to say that the work was completed. The entropy unleashed by heavily falling rains undid much of the energy laborers invested in reshaping the landscape. A series of deluges in May of 1852 proved particularly disastrous. For weeks laborers worked feverishly to prevent the newly laid track from shifting as rains bombarded the line. Despite their best efforts, several train cars were thrown off the tracks on May 24th, leaving nearly 400 passengers trapped at Frijoles station overnight.[72] The situation didn't result in any major injuries or damages but served as a sobering reminder of the Panamanian environment's entropic proclivities. The extension of the line placed additional burdens on Totten's already taxed labor force, requiring a corps of track gangs to maintain set rail lines. At times these small track gangs could not provide enough energy to overcome Panamanian entropy. After one particularly

[68] Totten to Stephens, 16 August 1851, Totten Letters, USNA, RG 185, Vol. 1.
[69] Speis, "Minutes of the Board of Directors, 9 December 1851", Board Minutes, USNA, RG 185, Vol. 1.
[70] Speis, "Minutes of the Board of Directors, 29 April 1852", Board Minutes, USNA, RG 185, Vol. 1.
[71] Totten to Alex Center, 14 July 1852, Totten Letters, USNA, RG 185, Vol. 1.
[72] Totten to Speis, 25 May 1851, Totten Letters, USNA, RG 185, Vol. 1.

devastating storm Totten was forced to reassign some of the laborers from the excavation corps to provide the energy necessary to right the tracks. This added another layer of complexity to the task of managing Isthmian energy stores and Totten requested “5 good repair gang foremen and 60 good track layers” to ensure that he had the energy on hand to keep the existing line stable.[73]

As Totten approached his objective so too did the Board approach theirs. At a meeting on May 7th, the Executive Committee met with Miner Story to go over the details of his proposal. After a month of negotiations and haggling, both sides agreed to terms and Story made his way down to Panama to commence the work.[74] Similar to Totten, Story’s previous experience made him well qualified for the task of completing the railroad. A career contractor and entrepreneur, Story made a name for himself working for the Portland and Montreal Railroad.[75] The Board placed faith in Story's previous experience; however, ominous signs accompanied the execution of the contract. Negotiations were almost derailed when the contract prepared by Story was compared to that prepared by the Board. The two contracts were "found to be different in form and arrangement so much as to be impracticable."[76] The two parties eventually found common ground, but the disagreement foreshadowed a series of contractual conflicts that undermined work on the Isthmus for over a year.

To fulfill the terms of his contract and complete the entirety of the line between Barbacoas and Panama, Story needed to overcome the chief obstacle lying in his path, the Chagres. Totten had long contemplated the best way to bridge the river, and while he had yet to settle on a final design, he knew a tremendous labor force was required to erect the bridge.

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[73] Totten to Center, 14 July 1852.
[74] Speis, “Minutes of the Board of Directors, 19 May 1852,” Board Minutes, USNA, RG 185, Vol. 1; Speis, “Minutes of the Board of Directors, 12 June 1852”, Board Minutes, USNA, RG 185, Vol. 1.
[75] McGuiness, *Path of Empire,* pg. 69.
[76] Speis, “Minutes of the Board of Directors,” 19 May 1852.

Totten was happy to wash his hands of the challenge of crossing the Chagres in the summer of 1852, but he too seemed uneasy about the way Story approached the task, noting that the contractor had little idea of where he was going to look for laborers.[77] Totten's concerns were soon forgotten amongst his other responsibilities. While he would not be directly overseeing construction of the track, Totten retained his post as Chief Engineer and focused on improving the existing line and preparing the Pacific terminus at Panama City.

Totten first directed his efforts towards the improvement of the Cruces Road, a mule road which connected the Chagres with Panama City. The Cruces had played an essential role in Panamanian transit networks for centuries, having been used to transport silver across the Isthmus since the 16th century. By 1852 the road was in a state of disrepair, a fact brought to light by a disastrous attempt to carry American soldiers across Panama. In July of 1852, the troops unloaded at the Atlantic Terminus and passed over the rail line without difficulty. They were supposed to be met by a muleteer at Barbacoas who would carry them the rest of the way to Panama City, however, the man fell ill and when the troops arrived there was no one to guide them to their destination. The results were disastrous. By the time replacement mules arrived many of the soldiers had been struck by cholera, several of them dying as a result.[78] The suffering of the soldiers pointed to the necessity of establishing a safe, reliable mule service over the line until the railroad was complete.

It was not only humanitarian concerns that dictated improvements to the Cruces Road. The Railroad Company also sought to transport mail over the Isthmus and recognized that it was reliant on the mule road to do so until railroad construction was complete. Frequent

[77] Totten to Stephens, 17 June 1852, Totten Letters, USNA, RG 185, Vol. 1.
[78] Totten to Stephens, 1 August 1852, Totten Letters, USNA, RG 185, Vol. 1.

conversations with steamship companies in the United States and England suggested that the Board was convinced of the railroad's potential not only as a conveyor of people, but also of parcels, packages, and posts.[79] Both Totten and the Board were acutely aware of the importance of reliable mule transit and so Totten spent much of the summer of 1852 improving the mule road.

Renovation of the Cruces became increasingly necessary by the fall of 1852. Freight increased dramatically on the rail line after it was opened to Barbacoas in the summer of 1852. A single trip in August saw over six-hundred express packages cross the Isthmus along with other freight. The repairs to the Cruces road progressed slowly and it was incapable of adequately handling such a volume of packages. A month earlier, a group of packages sat in Cruces for eight days waiting to be carried over the mule line. In another instance, parcels accompanied by a representative of the railroad arrived in Cruces to find no mules waiting for them. The unlucky representative had to carry the packages over the road piece by piece on a limited supply of mules, a process taking four days.[80] It was ironic that the completion of the railroad to Barbacoas exacerbated rather than diminished the need for animal labor.

The difficulties with the mule road paled in comparison with the growing tensions between Story and the company. Story initially seemed to be a good fit, but work had ground to a halt by December of 1852. Story's continued inability to obtain and maintain adequate stores of human energy particularly concerned Totten. "A large number of Mr. Story's men have deserted- both white men and Natives," Totten reported in October of 1852.[81] He felt compelled to point out that "the season has now arrived when that line should be covered with laborers. Not less

[79] Speis, "Minutes of the Board of Directors", 2 July 1852, Board Minutes, USNA, RG 185, Vol. 1.
[80] Totten to Stephens, 17 August 1852, Totten Letters, USNA, RG 185, Vol. 1.
[81] Totten to William Young, 20 December 1852, Totten Letters, USNA, RG 185, Vol. 1.

than 6000 men should be upon it in the month of January, where there will not be 1000."[82] In his next letter to William Young, the sitting President of the Company, Totten was even more blunt, writing, " It does not appear to me that Mr. Story has an adequate idea of the amount of work before him. He should have a force of 4000 daily laborers which will require a force of 6000 men on the work and recruits by every steamer to keep up the supply. The season for work is at hand and should be taken advantage of."[83] It was not Story's mechanical or engineering abilities that Totten questioned, but rather his ability to obtain and marshal the stores of human energy necessary for the work. Totten, having by this point spent years adapting to the unique energy needs of Panama, understood what Story failed to; in Panama the chief determinant of success was enough human labor to overcome the constraints of the Isthmian environment.

By February of 1853, the Board was openly criticizing Story's slow progress.[84] Concerns began to emerge that he was no longer actually fulfilling his contractual obligations. The Executive Committee remarked, "It is of course evident that the part of our contract with Mr. Story providing for the road being ready for the engine to run to Gorgona by the 1st February will not be complied with."[85] Totten echoed the Board's frustrations with Story's slow progress, writing, "I am greatly disappointed in the progress that has been made as well as in the prospects for the future."[86]

The flood of April 7th, 1853 made manifest the Board's and Totten's frustrations with Story. Seasonal flooding was common to Panama during the wet season and regularly derailed progress on the line. These floods, or "freshets" as they were called, served as a testament to

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[82] Totten to William Young, 20 December 1852.
[83] Totten to Young, 31 December 1852, Totten Letters, USNA, RG 185, Vol. 1.
[84] Speis, "Minutes of the Board of Directors, 22 February 1853", Board Minutes, USNA, RG 185, Vol. 1.
[85] Speis, "Minutes of the Executive Committee, 3 February 1853", Executive Minutes, USNA, RG 185, Vol. 1.
[86] Totten to Young, 17 February 1853, Totten Letters, USNA, RG 185, Vol. 1.

entropy's radical capacity to sow disorder in human organized landscapes. Small freshets plagued the work from its inception, shifting embankments, destroying piles, and hindering construction as the line made its way from Manzanilla to Barbacoas. Fortunately, these freshets had been on smaller rivers such as the Mindee and Gatun.[87] While still dangerous, the smaller size of these rivers and the fact that less energy and material had been invested in crossing them tempered their capacity for destruction. The same could not be said of the freshet of April 7th.

The widest and strongest river along the line, the Chagres could make or break railway construction. Even before arriving in Panama, Totten was acutely aware of this fact.[88] The bridge crossing it needed to be several hundred feet in length and exceptionally sturdy to deal with the floods that occurred during the wet season. To withstand the energy of the freshets, engineers proposed a foundation of stone masonry and wooden piles. As an additional precaution against nature's energy, the bridge was to be erected during the dry season. Story's initial contract stipulated that the bridge was to be finished by February 1st, 1853, yet by that date it was only a quarter complete.[89] The work continued to move slowly over the next several months. Story's inability to obtain adequate stores of human energy was acutely felt in the masonry corps, and between January and March, Totten's requests for quarrymen, masons, and carpenters grew almost incessant.[90] These shortages were not entirely Story's fault- a severe bout of sickness among the masons prevented them from bringing their skills to bear on the work. Yet ultimately, as the wet season approached, the bridge remained incomplete.

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[87] Totten to Stephens, 23 July 1851.
[88] Totten to Adams, 11 April 1849.
[89] Totten to Young, 17 February 1853.
[90] Totten to Young, 31 January 1853, Totten Letters, USNA, RG 185. Vol. 1; Totten to Speis, 19 February 1853, Totten Letters, USNA, RG 185, Vol. 1; Totten to Young, 4 March 1853, Totten Letters, USNA, RG 185, Vol. 1.

In the weeks leading up to the disaster, Totten grew increasingly optimistic about the completion of the bridge. By late March construction seemed to be going well despite the numerous setbacks and labor shortages that had hampered its completion. In a letter to William Young on March 30th Totten noted that the first span was almost completed as the track laying and advanced masonry neared completion. Totten suggested "These are all matters worthy of particular notice the remainder of the work being simply grading."[91] Totten's optimism proved short-lived. The freshet heralded the arrival of the rainy season in spectacular fashion. Rushing waters carried away the nearly completed first span of the bridge as well as temporary scaffolding and structures meant to support the second and third spans. The flood was so powerful that it washed away the gravel bed of part of the river. Construction on the bridge needed to start from scratch, the force of the rushing waters having entirely destroyed the structures bridging the river.[92]

The loss of the bridge brought the tensions between Story, Totten, and the Board to the breaking point. Culpability for the natural disaster, however, was far from obvious. Story felt that the Company should be liable for paying for the damages as they were outside of his control. Totten and the Company saw the matter differently and suggested that Story had broken the terms of his contract months earlier when he failed to complete the bridge and sections of track by the dates outlined therein.[93] While valid criticism, Totten had also missed several deadlines during his tenure leading construction without any punitive action. It was more likely that the

[91] Totten to Young, 30 March 1853, Totten Letters, USNA, RG 185, Vol. 1.
[92] Totten to Young, 11 April 1853, Totten Letters, USNA, RG, 185, Vol. 1; Totten to Young, 17 April 1853, from Totten Letters, USNA, RG 185, Vol. 1.
[93] Speis, "Minutes of the Board of Directors, 26 April 1853," Board Minutes, USNA, RG 185, Vol. 1.

destruction of the bridge provided a justification for the Company to act on their previous concerns about Story's slow progress and lack of labor recruitment.

The termination of Story's contract lingered on well into the summer, but the freshet of April doomed Story the moment it happened.[94] However, Story's most intolerable folly in the eyes of his employers was not the loss of the Chagres Bridge, but rather his inability to maintain enough energy to alter the Panamanian environment. Disease, landscape, entropy, and desertion: the four horsemen of the energy apocalypse in Panama, certainly deserved much of the responsibility for Story's ineffectiveness. However, whereas Totten tried to overcome these obstacles by increasing his available energy sources, be they human, animal, or mechanical, Story, at least in the eyes of the Railroad Company, looked on passively as his workers trickled away from the line. By the time of the April flood Story had only 811 men left on the work.[95] The Board acknowledged this issue, and, in an ultimatum delivered to Story in June of 1853, they suggested "that unless (Mr. Story and his legal representative, Mr. Law) proceed immediately with more energy and by a greatly increased force on the line of the road, that the company will find it necessary to take the work out of their hands and assume the completion of it on their own account."[96] Perhaps the most cutting criticism of Story came from Totten who suggested that Story himself was the root of the problem, writing, "the objection of the labourers appears to be to the treatment of the contractor, more than to the company or the climate."[97] Story's failure was not the result of the natural realities of Panama, but rather his inability to recruit and maintain an effective store of human energy. The result was a complete inability to

[94] Speis, "Minutes of the Board of Directors, 4 August 1853," Board Minutes, USNA, RG 185, Vol. 1.
[95] Totten to Young, 17 April 1853.
[96] Speis, "Minutes of the Executive Committee, 17 June 1853," Executive Minutes, USNA, RG 185, Vol. 1.
[97] Totten to Young, 3 June 1853, Totten Letters, USNA, RG 185, Vol. 1.

contain Panamanian entropy and the erasure of considerable investments of energy. Totten, once again in control of the work, quickly learned from Story's failures and took aggressive steps to avoid them.

The End of the Line

Story's failure initiated the final period of railroad construction. Story may have been the victim of poor circumstance, but his incompetence served as a lesson to Totten to redouble his own recruitment and retention efforts as he prepared to cross the Chagres and complete the line to Panama City. This period still possessed difficulties, particularly in relation to the adoption of Chinese laborers, but it was the smoothest period of railroad construction. The significant portions of the line already completed made it far easier to get materials into the Panamanian interior, and Totten and the Board's aggressive labor recruitment paid dividends as thousands of laborers made their way to Panama. A new era of Isthmian transit was on the horizon.

Construction of the line progressed slowly over the summer of 1853. Story's contract was not terminated until August, leading to substantial confusion over whether Totten or Story was in control. Despite this, Totten focused on preparing the Atlantic terminus of the line: Aspinwall. Located on Manzanilla Island, Aspinwall became the headquarters for many of the railroad's operations as well as the point of departure for Atlantic steamers. As a result, the quality of the city directly correlated with the efficacy of pan-isthmian transit. Totten improved the city over the summer of 1853, constructing wharves, a machine shop, and buildings for several other auxiliary services.[98] Simultaneously, he maintained track between Aspinwall and Barbacoas, filling cribbing and reinforcing embankments to prepare the line for the rains of the wet season.

[98] Totten to Young, 30 April 1853, Totten Letters, USNA, RG 185, Vol. 1.

In addition to these physical improvements, Totten again filled out the labor rolls in anticipation of the coming dry season. While Story was still nominally in charge of railroad construction at the end of May, Totten began encouraging the Railroad Company to send agents to recruit laborers. Totten was particularly concerned by the fact that the bulk of Story's white labor force finished their labor contracts by July of 1853. "What are the prospects for a force hereafter?" he worried, "This is a question to which I must turn the attention of the board."[99] Recognizing Story's failures, the Board heeded Totten's warnings. They explored the potential of recruiting laborers from Ireland, Jamaica, and China, hoping that proactive action would generate a substantial labor pool in time for the dry season.[100] In July of 1853, they sent Francis Speis to England to obtain laborers and directed Henry Coit and George Lamar, fellow board members, to contract for Chinese workers.[101] These laborers were essential to the completion of the road and Totten was keenly aware of this, noting, "The time requisition for constructing this division must, of course, depend upon the amount of labor which can be thrown upon it."[102] By 1853, Totten fully recognized and accepted that the best way to reshape the Panamanian environment and contain entropy was by maximizing his available stores of human energy and hurling as much of it as possible at Panamanian landscapes.

In August 1853, Story left the Isthmus, leaving Totten once again the sole source of authority along the railroad. Totten predicted that with enough laborers he could complete the line by August of 1854. Calculating that Story had completed roughly eight miles of road with no more than 900 men, Totten believed that he required a force of roughly 5000. By November

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[99] Totten to Young, 26 May 1853, Totten Letters, USNA, RG 185, Vol. 1.
[100] Speis, "Minutes of the Board of Directors, 1 July 1853," Board Minutes, USNA, RG 185, Vol. 1.
[101] Speis, "Minutes of the Executive Committee, 8 July 1853," Executive Minutes, USNA, RG 185, Vol. 1.
[102] Totten, "Report to the Board of Directors of the Panama Railroad: 1853," 13.

of 1853, his force was already considerably larger than Story's had been, consisting of roughly 1200 Chinese and Jamaican laborers and 390 white men. He expected to receive roughly 2000 men from Cartagena in January 1854, with 500 more to follow in addition to roughly 1700 Chinese laborers and 1000 Irish laborers expected to arrive in early 1854. If all went well, this would yield a labor pool of roughly 6790 men.[103]

While he waited for more laborers to arrive, Totten directed the laborers he did have at his disposal to a series of tasks along the road. Among the most pressing issues was the continued improvement of the Cruces Road. By this point the Cruces was in such bad shape that it was harming the mules themselves. An exasperated Totten wrote, "Not a train of mules- treasure, mails, or any other- goes over it without a large number of them breaking down. The wonder is that they make the trips as well as they do."[104] While animal energy was more geographically liberated than steam energy, it could not contend with the poor state of the road. The problem became so pronounced that traversing the length of the road took 39 hours in the dry season and up to 57 hours during the wet season.[105] In August, the Railroad Company struck a deal with the Pacific Mail and US Mail Companies in which each party paid one-third of the expenses to repair the road. The companies were natural allies in this venture, and so the Railroad Company authorized Totten to spend up to $50,000 dollars on the improvement of the road. [106] This investment paid immediate dividends. Totten directed considerable resources towards the completion of the road. As his available stores of manpower increased, Totten placed

[103] Totten and Railroad Co., "Communication from the Board of Directors: 1853," 13-14
[104] Totten Young, 19 July 1853, Totten Letters, USNA, RG 185, Vol. 1.
[105] Totten Young, 19 August 1853, Totten Letters, USNA, RG 185, Vol. 1.
[106] Speis, "Minutes of the Board of Directors, 4 August 1853", Board Minutes, USNA, RG 185, Vol. 1.

150 men at work on the Cruces road, and by December they had successfully completed the repairs.[107]

Completion of the Cruces Road rehabilitation was a significant development for the Panama Railroad Company, but it paled in comparison to the task of finally completing the bridge over the Chagres. Reconstruction of the bridge commenced by the end of May 1853; however, the work moved slowly. Totten estimated that one hundred carpenters were required to complete the bridge- he had five. And not just any sort of laborer would do. Totten expressed his preference for American carpenters, once again suggesting that complex and specialized tasks demanded equally specialized and precise prime movers and energies.[108] This small labor force made gradual progress on the bridge and by the beginning of August they completed the scaffolding for the first and third spans of the bridge as well as the trestling for the track.[109] Gradually the labor situation improved and, with the arrival of a steamer in August, Totten believed that he had an adequate number of carpenters to complete the work, although he was still in want of quarrymen and masons to create the stone foundation for the bridgework.[110]

As more laborers arrived and the energy directed towards the bridge increased, the work progressed rapidly. By mid-September 1853 the first two-hundred-foot section of the bridge was complete and merely needed to have the track laid across it.[111] By the end of the month, Totten was confident that construction of the bridge could be finished by the beginning of December.[112] Excited by the potential of the bridge being completed, Totten also directed his expanding labor

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[107] Totten to David Hoadley, 22 December 1853, Totten Letters, USNA, RG 185, Vol. 1.
[108] Totten to Young, 26 May 1853, Totten Letters, USNA, RG 185, Vol. 1.
[109] Totten to Young, 1 August 1853, Totten Letters, USNA, RG 185, Vol. 1.
[110] Totten to Speis, 1 August 1853, Totten Letters, USNA, RG 185, Vol. 1.
[111] Totten to Young, 20 September 1853, Totten Letters, USNA, RG 185, Vol. 1.
[112] Totten to Young, 1 October 1853, Totten Letters, USNA, RG 185, Vol. 1.

force to clear and grade the line on the other side of the river. Prior to the bridge's completion they had laid three miles of track on the far side of the river and graded several more miles.[113] The bridge itself was completed by the beginning of December, and, more importantly, withstood several freshets without issue. Immediately upon completion of the bridge, the railroad carried riders to Gorgona and only the final stretch of track needed to be completed.[114]

Totten and the Company's recruitment techniques proved quite effective. While the labor force failed to reach the 6000 men Totten desired, by the end of December it sat at 2110 with the promise of an additional 700 Irish laborers set to arrive in January.[115] This energy influx was not without complications. The increase in personnel demanded an equally massive increase in calories. Totten requested 800 barrels of beef, 900 barrels of pork, 157,000 pounds of bread and 154,000 pounds of rice to feed his expanding labor pool.[116] These resources required the company to begin chartering more vessels to keep its workforce on the Isthmus supplied. By November of 1853 schooners and steamers were relying on currents and coal on a nearly weekly basis.[117] This solidified the expanding energy network in Panama by increasing both its regularity and efficacy, further enabling the rapid construction of the road.

The influx of human energy expanded the Company's ability to restructure the environment, and within a year the line was complete. This process went smoothly excepting the importation of Chinese laborers. Small numbers of Chinese laborers had been employed since early 1853 without incident. This changed as their numbers increased in 1854. The central concern Totten held regarding Chinese laborers had always been their adaptability to the climate,

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113 Totten to Young, 29 October 1853, Totten Letters, USNA, RG 185, Vol. 1.
114 Totten to Hoadley, 22 December 1853, Totten Letters, USNA, RG 185, Vol. 1.
115 Totten to Speis, 22 December 1853, Totten Letters, USNA, RG 185, Vol. 1.
116 Totten to Speis, 14 November 1853, Totten Letters, USNA, RG 185, Vol. 1.
117 Speis, "Minutes of the Board of Directors, 5 November 1853", Board Minutes, USNA, RG 185, Vol. 1.

an issue compounded by the poor conditions in which they were transported to Panama. Regardless of the cause of their illness, the problem grew so pronounced that by the spring of 1854 the Board of Directors examined the potential of setting up special treatment facilities for Chinese workers on the islands of the Bay of Panama.[118]

The Chinese laborers, disdained from the moment they arrived in Panama, continued to be the target of hostility. The marginal steps taken by the Board did little to improve the physical and emotional hardship Chinese laborers faced. Disease, death, and an exceptionally high number of suicides soon took their toll. Concerned only with their capacity as a source of energy, the Board saw the destitute Chinese as nothing more than an inefficient tool to be replaced by a more fit and effective one. In response, the Board adopted a policy of trying to remove as many of the Chinese laborers as possible from the Isthmus. They implemented a variety of practices to this end, including lowering fares to transport Chinese workers away from the Isthmus, buying out their contracts, or selling them outright.[119] Eventually, in November of 1854, the Board worked with the government of Jamaica to send the remaining one-hundred ninety-seven Chinese laborers to Jamaica in exchange for a corps of Jamaican laborers at a cost of $17.77 each.[120]

The exploitation and brutalization of Chinese workers indicated the complicated issues that developed from the increasing devaluation of unskilled human labor. The growing importance of specialized human energy in Panama reinforced the biases that dogged Chinese laborers. The difficulties Chinese laborers faced in dealing with the climate of Panama and the

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[118] Speis, "Minutes of the Board of Directors, 24 March 1854", Board Minutes, USNA, RG 185, Vol. 1.
[119] Speis, "Minutes of the Board of Directors, 24 June 1854", Board Minutes, USNA, RG 185, Vol. 1; Speis, "Minutes of the Board of Directors, 16 August 1854", Board Minutes, USNA, RG 185, Vol. 1.
[120] Speis, "Minutes of the Board of Directors, 14 November 1854", Board Minutes, USNA, RG 185, Vol. 1.

terrible conditions they were kept in served as justification for the assumption that they were an inferior source of energy, valuable only for their cost-effectiveness.

Such perceptions cannot be explained by racial biases alone. Totten's distaste for Jamaicans was quite clear. In a letter to John Stephens, he wrote of how they required "driving or tasking" and that if placed with other laborers they would become dissatisfied with their lower wages.[121] When a new cohort of Jamaicans arrived in Panama in December of 1850, Totten admitted they were “a little better lot than the former” but that they were still “not the kind of labourers one requires.”[122] It is remarkable then that Totten willingly accepted Jamaican laborers in exchange for Chinese laborers. Prejudices impacted his perceptions of both groups, but his valuation of the energy each could contribute led him to conclude that Jamaican laborers were more valuable. No explanation exists for this decision other than the fact that Jamaicans were healthier and hence were more reliable. While he neglected to keep figures of deaths amongst the non-white labor force, Totten did acknowledge that, “the proportion was greater among Coolies and less among Jamaica men and natives.”[123]

Despite the hardships faced by the Chinese, work progressed rapidly during 1854. The combination of increased human energy on the Isthmus and the completion of the bridge over the Chagres meant that, while still arduous, the work faced less unpredictability than it had in earlier years. In addition, Totten’s experience allowed him to direct his stores of human and mechanical energy with greater competency than ever before. In the fall of 1854, laborers cut through the Obispo valley, summiting the continental divide nearly 300 feet above sea level. From there they made their way down the Pacific slope, careful to maintain a maximum grade of 60 feet per mile,

[121] Totten to Stephens, 21 September 1850, Totten Letters, USNA, RG 185, Vol. 1.
[122] Totten to Stephens, 22 December 1850, Totten Letters, USNA, RG 185, Vol. 1.
[123] Totten and the Railroad Co., “Communication of the Board of Directors: 1855”, 15.

lest the combination of gravity and the limited friction of the rail line brew a recipe for runaway locomotives. As they continued towards the Pacific terminus, they crossed more swamps, but with the added manpower the labor force overcame the ravages of disease.[124] And so, in January of 1855, the task was completed. The track ran 47 miles and 3,020 feet from Aspinwall to Panama City. The world's first transcontinental railroad was complete.

Opening a Line and Ending an Era

Getting George Law and his eighteen companions to the Isthmus in February of 1855 proved far easier than it had been to get laborers there. The men, officials and guests of the Panama railroad, were furnished with free passes by the U.S. Mail Steamship company to travel from New York to Aspinwall. Upon their arrival they boarded the train and rode it the length of the line, officially recognizing the railway's opening.[125] By the time of their arrival the line had been running for over a month, so the trip was more pomp than substance, and yet it reflected the entangled energy network of Panama perfectly. The men likely took horse-drawn carriages or walked to the steamships, nestled in their berths in New York's harbor. Their luggage was carried on board by human muscle, and they were carried to Panama by the combustion of coal, a process overseen by a specialized group of mechanics, engineers, and sailors possessing the skills and knowledge necessary to direct and control steam energy. Upon their arrival in Aspinwall they made their way to the train station while a group of laborers transported their luggage. From there the steam engine of the train drove pistons, allowing the train's wheels to travel along tracks which minimized the friction of the Panamanian environment. Behind the scenes, a supplementary force of men and mules worked to ensure that the heavy rains of

[124] Totten, "Report of the Chief Engineer to the Board of Directors." Included in, Totten and the Railroad Co., Communication of the Board of Directors: 1855, 23-27

[125] Speis, "Minutes of the Board of Directors, 3 February 1855", Board Minutes, USNA, RG 185, Vol. 1.

Panama didn't erode any embankments or shift the tracks. After a few hours the men arrived in Panama City where, if they so desired, they could board a Pacific Mail Steamship Company Steamer and make their way to California, going from sea to shining sea via the Panama Route.

Eventually, the Panama route was overshadowed, a victim of entropy. The irony behind the creation of such a massive energy infrastructure was that it was a relatively static landscape. The sheer cost of obtaining the energy and material necessary to create the Panama route meant that it was impractical to alter the railroad after its completion, and, aside from work done to maintain the line against landslides, little energy was invested in its development. The lack of investment in energy meant that the line suffered distinct limitations in the types of locomotives it could accommodate, and it became increasingly obsolete. The creation of a new transportation network, the American transcontinental railroad, in 1869 undermined the primacy of Panama as the central conduit between East and West. Goods and materials from Central and South America still made their way through Panama, but American ridership dwindled. As convenient as Panama was, the Isthmus failed to rival the Transcontinental railroad as an overland route of personal transportation across the United States. Yet this did not mean all hope was lost. Indeed, as the 19th century closed and the 20th opened, many Americans would look not forward, but backward, towards visions of an interoceanic canal, a scheme that had been associated with Panama since the days of Spanish colonization.

The energy sources that held entropy at bay and created the railroad reflected important trends that would continue to define transit across Panama. The challenges faced by Totten in controlling human energy indicated the importance human muscle would play in shaping Isthmian transit. Coal alone did not fuel this passage. Even after the completion of the line in 1855, The Panama route was a transportation network in which coal, wood, and human muscle all played crucial roles. The proliferation of these various energy sources rendered the Panama railroad a success and brought visions of pan-isthmian transit to fruition.

This, however, was not a "revolution." There was no moment of disruption that radically altered the status quo. Instead, a massive proliferation of energy sources saw older sources of energy such as animal, muscle, and wind power joined by the emergence of the world's first fossil fuel, coal. The energy regime that powered the Panama Railroad suggested that while monumental, the shift to coal energy was neither immediate nor absolute. The creation of a coal-fueled transit network was facilitated by the bodies of laborers who altered landscapes and countered entropy in ways that enabled coal to flourish. Even when coal seemed ascendant, muscular and mechanical energy sources worked in symbiosis, reinforcing the effective deployment of one another. This trend was not isolated to the construction of the railroad. As visions of an empire danced in the heads of American leaders, and Panama again became the site of a massive infrastructural project, the fusion of human and mechanical energy lead to an even more massive energy proliferation and an even more complex energy network, one which once again had to contend with entropy.

Chapter II: Black Gold: Coal, Infrastructure, and the Racialized Energy Hierarchy of the Panama Canal: 1904-1908

When Canal Zone Policeman Harry Franck first caught sight of the Culebra Cut, the point at which the Panama Canal crossed the Continental Divide, in January of 1913, the mechanization of the Canal Zone labor force enthralled him. Franck wrote with awe of "pounding rock drills" and "belching locomotives." He described, "the rattle and bump of long trains of flat cars on many tracks, the crash of falling boulders, the snort of the straining steam shovels, heaping the cars high with earth and rock." Franck ended his depiction of the Cut by noting that "over all the scene hung a veritable Pittsburgh of smoke."[1] Franck's wonder of the steam-fueled behemoths is not surprising. Indeed, most historians of the Panama Canal cannot help but emphasize the significance of the steam shovels, dredges, and locomotives that gouged out and moved nearly 200,000,000 cubic yards of earth and rock.[2] And yet, Franck noticed something which historians have largely overlooked. The mechanized labor force that parted the Isthmus and connected the seas was useless without energy and the haze of smoke it left in its wake.

Coal's importance came as no surprise to the builders of the Canal. Decades of familiarity with the hazards and unpredictability of the Panamanian environment had germinated a degree of cynicism when it came to landscape alteration. The Panama railroad proved that Panama was a rugged country with an entropic landscape that often shifted in unanticipated ways. The failed French attempt to build a sea-level canal across the Isthmus in the 1880s

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[1] Harry Franck, *Zone Policeman 88: A Close Range Study of the Panama Canal and Its Workers* (New York: The Century Company, 1920), pg. 17.

[2] Isthmian Canal Commission, *Panama Canal Record* vol. 1 no. 1. September 4th, 1907, (Ancon: Isthmian Canal Commission Printing Office, 1997), pg. 4.

reinforced these difficulties and suggested the limits of humanity's ability to enforce its will on Panama. If Americans were to succeed where Suez Canal engineer Ferdinand de Lesseps had failed, they needed to harness and direct remarkable amounts of energy.

Steam shovels, dredges, and locomotives formed a coaly trinity that gouged out and carved up hundreds of thousands of tons of rock. While a variety of steam shovels were used on the Isthmus, the machine most synonymous with canal excavation was the 95-ton Bucyrus. The Bucyrus was a marvel of modern technology, hauling up to five cubic yards (roughly eight tons) of material in a single scoop. When operating at its peak efficiency, a ninety-five-ton Bucyrus filled an entire dirt car on its own in about eight minutes.[3] Locomotives enabled the remarkable efficiency of the Bucyrus by conveying dirt cars from the canal bed to dumping sites scattered throughout the Canal Zone. The lack of progress made by steam shovels in the years before the railroad was improved served as a testament to the importance of the line. Prior to the railroad renovation in 1907, steam shovels operated at barely a quarter of their capacity.[4] While steam shovels and locomotives carved up the Isthmus on dry land, a variety of dredges removed material from the aquatic landscapes of Panama. These ladder, dipper, and suction dredges failed to garner the celebrity that accompanied the Bucyrus, but they were indispensable in countering the entropy of the Panamanian landscape. These three coal-fueled harbingers of modernism and other machines including pile drivers and track layers revolutionized construction, turning the dream of a canal into a reality.

Before they could make the dirt fly, American engineers and machinists had to create an infrastructure capable of enabling the remarkable amounts of energy imported into Panama.

[3] David G. McCullough, *The Path between the Seas: The Creation of the Panama Canal, 1870-1914* (New York: Simon and Schuster, 1977), pg. 491-492.
[4] *Ibid*, pg. 447, 471.

Prime movers needed to be regimented, organized, and placed in a system that allowed them to work efficiently and effectively. The inability to accomplish this task ultimately vexed construction during its first several years as a feckless John Wallace struggled to deal with the entropy presented by the Isthmian environment. John Stevens, who took over for Wallace in July of 1905, proved far more effective in organizing and deploying the energy he had at his disposal. Beginning in 1905, he set about restructuring the obsolete Panama railroad, turning it into an efficient, modern line capable of hauling thousands of dirt cars.

And yet it wasn't enough to restructure his mechanized labor pool. Stevens also understood the essential role that a substantial pool of human energy was to play in canal construction. Between 1904 and 1914, tens of thousands of laborers were recruited to the Canal Zone by labor agents in the West Indies, America, and Europe.[5] The result was an energy regime that combined human muscle and coal energy to counter the entropic landscapes of Panama. And yet the relationship between human labor and coal energy became increasingly complicated as canal construction progressed. Gradually, human energy too was restructured and reorganized, often by its perceived value to the construction of the Canal.

As construction progressed, humans found themselves increasingly toiling away in the shadow of coal-fueled machines. The landslides, shifting landscapes, diseases, and derailments that characterized canal construction amplified the importance of coal in Panama. By 1907 over 20,000 tons of coal were consumed monthly.[6] The unprecedented ability of steam shovels and train cars to remove soil ultimately made machines more important than the men who scurried

[5] Devol, C.A. "Annual Report of the Quartermaster's Division for the Fiscal Year Ending June 30, 1912," July 1, 1912. Box 514: Folder: Annual Report Quartermaster's Department (ICC), Record Group 185. US National Archives, pg. 378.

[6] Isthmian Canal Commission, *Panama Canal Record* vol.1 no. 3, September 18th, 1907, pg. 2

alongside them. Harrigan Austin, a silver laborer who came to the Isthmus in 1905, spoke of working "Day and night, sun or rain; for they were times when it was compulsory to go through the rain in order not to hold up the shovels or the trains things had to be on time." [7] The implication was clear, coal energy, not human energy, was the key to dividing the Isthmus and uniting the world. As a result, human labor and life played second fiddle in an orchestra of mechanized labor.

Ultimately, the importance of coal-fueled machines in the construction of the Canal privileged those workers who had the skills and training necessary to operate such machines while simultaneously devaluing unskilled labor. Generally, the ranks of the skilled laborers were filled by white American men who had training working with machinery. The Isthmian Canal Commission (ICC) preferred drawing its unskilled labor corps from the West Indies or South America. The result was that skin color became an easy way of distinguishing between skilled and unskilled laborers.

Many historians have addressed this tension and pointed to the classification of laborers into either "gold" or "silver" labor pools.[8] This process began in 1904 when the U.S. government took over the administration of the Canal Zone. The ICC adopted a policy practiced by the Panama Railroad Company of separating employees into gold and silver payrolls. Nominally this

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[7] Austin, Harrigan located in Ruth Stuhl, ed. *Isthmian Historical Society Competition for the Best True Stories of Life and Work on the Isthmus of Panama during the Construction of the Panama Canal* (Isthmian Historical Society: 1963), University of Florida Digital Collections, pg. 3.

[8] The literature on the men who labored to excavate the big ditch runs as deep as the canal itself, with both public and academic historians contributing to the historiography. For overviews of the entire labor system see Julie Green, *The Canal Builders: Making America's Empire at the Panama Canal*, (Penguin History of American Life New York: Penguin Press, 2009.) For perspectives on the Black experience in the canal see, Michael Coniff, *Black Labor on a White Canal: Panama, 1904-1981*, (Pittsburgh, Pa: University of Pittsburgh Press, 1985.) Bonham Richardson *Panama Money in Barbados, 1900-1920. (*Knoxville: University of Tennessee Press, 1985.) West Indian authors have also contributed to this literature, see Olive Senior. *Dying to Better Themselves: West Indians and the Building of the Panama Canal, (*Mona: University of the West Indies Press, 2014.) Velma Newton, *The Silver Men: West Indian Labor Migration to Panama, 1850-1914*, (Kingston: Ian Randle Publishers, 1984.)

system merely identified the type of metal in which laborers were paid. In practice the distinctions between groups was vast. Gold laborers were better paid, occupied separate housing and transportation facilities, tended to work on machines, and were almost exclusively white Americans. Silver laborers, on the other hand, were darker skinned, generally West Indian, lived in subpar facilities, performed dangerous, dirty labor, received less pay and were often transported in segregated rail cars.[9] Harry Franck succinctly described the gold and silver system as an "awful gulf that separates the sacred white American from the rest of the Canal Zone world." [10]

The evolution of the gold and silver system from a country of origin system to a racial system accompanied the increasing reliance placed on coal. Coal, and the machines that it powered, privileged those laborers who had the training and experience necessary to harness and direct coal energy. This development reinforced assumptions about Jamaican and Barbadian inferiority, providing an ideological justification for the entrenchment of the gold and silver system without the necessity of adopting an explicitly Jim Crow system of racial segregation. By the time the Canal Zone's mechanized labor force was restructured and deployed in 1908, the silver and gold system had become almost entirely racially defined.

By restructuring the energy infrastructure in Panama between 1905 and 1908, John Stevens created an environment conducive to the efficient use of energy to combat entropy. Coal provided the tremendous amounts of energy necessary to impose a degree of order over the entropic Isthmian landscape. And yet the importance of coal and the simultaneous devaluation of unskilled human labor combined American's insatiable appetite for energy and modernism with

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[9] McCullough, *The Path Between the Seas,* pg. 472.
[10] Harry Franck, *Zone Policeman 88,* pg. 12.

their longstanding racial biases, a recipe which created an energy hierarchy in which white Americans who had the training and ability to harness coal-fueled machines, stood on top.

Fueling the Imagination

For weeks Americans had waited with bated breath. On May 19th of 1898, they could relax, slightly. "OREGON IS SAFE," read the headline of the Duluth News Tribune. The *U.S.S. Oregon*, a state-of-the-art battleship completed just a few years earlier, had successfully reached the Caribbean after a treacherous 13,000-mile journey that took it from San Francisco, around the tip of South America and through Spanish controlled waters on the eve of the Spanish American War.[11] Newspapers around the country watched the *Oregon's* progress with rapt attention. From Minnesota to Georgia, Pennsylvania to Idaho, and everywhere in between newspapers chronicled the trip of America's most expensive vessel. [12] The *Oregon* completed the trip in an amazing sixty-seven days, a testament to what the newest generation of coal-fueled warships could accomplish. In the nationalistic fervor sweeping through the nation, the *Oregon*, and the sailors aboard it, were never far from conversation. They were a physical manifestation of the emergence of America as a global power. While readers were primarily concerned with the role the *Oregon* was to play in the war with Spain, the *Oregon*'s journey also emphasized the need for a quicker passage between the Pacific and Atlantic. In the period leading up to American acquisition of the Canal Zone, coal dictated the naval, imperial, and economic concerns that ideologically legitimized the creation of an interoceanic canal.

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[11] "Oregon Is Safe: Long's Alarm About Fine Battleship Dissipated by Its Junction with Sampson," *Duluth News Tribune*, May 19, 1898, pg. 1; retrieved from Readex "America's Historical Newspapers 1690-1922" online database http://infoweb.newsbank.com.libproxy.unh.edu/

[12] "Anxiety About Man of War Oregon: Our Costliest Battleship Working Its Way Around the South," *The Columbus Daily Enquirer*, April 23, 1898, pg. 1; McCullough., *The Path Between the Seas*, pg. 254-255; "The Oregon Safe. Turns up All Right and May Now Be with Sampson," *The Philadelphia Inquirer*, May 19, 1898, pg. 1. "Oregon's Journey Ends. Probably Now with Sampson's Squadron," *Idaho Statesman*, May 19, 1898, pg. 1.

Coal's capacity to eradicate space and time proved essential to concerns over naval, colonial, and economic efficiency. In *Nature's Metropolis,* William Cronon argues that railroads "fundamentally altered people's expectations of how long it took to travel between two distant points on the continent," and consequently, "time accelerated and became more valuable the greater the distance one could travel." [13] Cronon's comments can apply to any coal-fueled transportation technology. Coal's substantial yields provided the power to move people, ideas, and goods through space more rapidly than ever before. Coal was also geographically liberated; useable anywhere humans could carry it, making it a perfect source of energy for transportation. These two characteristics allowed coal to radically shrink the world by expediting transit and opening new possibilities for globalization. This smaller world emphasized the importance of a canal to further expedite transportation times.

The journey of the *Oregon* exemplified the increasing importance placed on naval power and the rapid deployment of America's military might. While naval prowess had long been tied to military success, a strong naval fleet became the chief characteristic of an international power in the late 19th century. Coal provided new possibilities for the movement and range of naval vessels and advocates such as Alfred Thayer Mahan and future President Theodore Roosevelt clamored at the opportunity to increase naval spending and bolster the United States' fleet.[14] This naval fervor gave rise to new ships like the *Oregon,* which heralded the rise of the United States as a global power. However, the U.S. was not alone in its desires. Russia, Japan, Germany, the United Kingdom, and even China sought to emulate America's naval expansion by creating state-of-the-art ships of their own. Russia went as far as to invite Irving Scott, the designer of the

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[13] William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W.W. Norton Co., 1991). Pg. 74-76

[14] Alfred Thayer Mahan, *The Influence of Sea Power Upon History, 1660-1783*, 12th ed. (Boston, MA: Little, Brown and Co, 1918); Theodore Roosevelt, *The Naval War of 1812 or the History of the United States Navy during the Last War with Great Britain* (New York: G.P. Putnam's Sons, 1902).

Oregon, to Russia to contract for battleships of their own. [15] This nascent naval arms race caused military strategists and politicians alike to clamor for the tactical advantages provided by an interoceanic canal.

The expansion of naval power also promoted canal construction by emphasizing the geographic shortcomings of coal. While coal was a spatially liberated source of energy and could be carried to any location, it did possess its own set of challenges. Increasingly large naval vessels required increasingly large stores of coal to fuel their voyages, more than could be carried on board. To cope with these natural limitations, governments provided coaling stations at which ships could refuel. The *Oregon* stopped at coaling stations in Peru, Chile, Brazil, and Barbados before reaching the Florida Keys.[16] The construction of a canal limited the need for coaling by shortening travel distances and minimizing the amount of energy consumed over the course of a voyage. The successful completion of the Canal negated these concerns by shortening trips and utilizing the United States' coaling stations exclusively.[17]

Questions of naval efficiency and coaling stations were directly tied to the expanding role of the United States as an imperial power.[18] Imperialism carried both militaristic and ethical demands that the Canal and coal could help America meet. Joseph Bishop, a journalist who later became Secretary of the ICC, described America's imperial obligations, writing, "We have shown we are exceptionally fit for the work of colonization... and we have honored ourselves in

[15] "Likes the Oregon: Russian Government Will Probably Contract for Vessels Like Our Splendid Battleship," *Helena Independent*, June 9, 1898, pg. 1.
[16] "Captain Clark Could Make a Good Guess: Commander of the Battleship Oregon Let Slip a Significant Word," *Idaho Statesman*, May 27, 1898, pg. 1.
[17] "59th Congress Senate Document No. 313. Reports of the Various Coals 1896 to 1898. Expenses and Equipment Abroad 1902-1903 and Recent Chemical Analyses of Coal at Navy-Yard, Washington, D.C." (Government Printing Office, 1906), pg. 115.
[18] For a comprehensive discussion of this topic see, Peter Shulman, *Coal and Empire: The Birth of Energy Security in Industrial America*, (Baltimore, US: Johns Hopkins University Press, 2015.)

the eyes of the world for the way in which we have performed it." The success of America's imperial mission in Cuba and the Philippines wasn't solely the result of alleged moral righteousness; military force was intimately tied to these ventures. It was no accident that in his book, *Issues of a New Epoch,* Bishop combined coal shortages, the Panama Canal, and American imperialism. Militaristically, the Philippines presented a unique challenge. Sitting thousands of miles west of America's west coast, it was difficult for naval forces concentrated in the Atlantic to reach. In June of 1901, over 70,000 troops occupied the Philippines, and traversing from the Philippines to America's other colonial outpost in Cuba was impractical. Without the completion of a canal, these two holdings were isolated from one another, complicating imperial cohesion.[19]

The militaristic concerns of empire were combined with a focus on uplifting native populations. Indeed, one of the greatest objectives of the American colonial mission was allegedly to prepare Cuba and the Philippines for self-governance.[20] Coal was essential to this mission. William MacCorkle, ex-governor of the state of West Virginia, expressed the value of coal as a social equalizer in the aftermath of the Canal's construction, arguing that countries, "yellow, brown, and white- filled with the desires of new commerce, fired with new hope by the touch of the West, thrilled with new ideas of government and religion are all mingled in one tremendous combat for the mightiest markets vouchsafed to man since the stars sung together."[21] MacCorkle suggested that through the utilization of coal transportation, these nations could reach these markets as civilized, democratic, and friendly entities. The Canal could expedite this process by more rapidly conveying these goods and ideas around the world, benefiting both

[19] Joseph Bishop, *Issues of a New Epoch: The Coal Strike, Panama, The Philippines and Cuba* (New York: Scott-That Company, 1904). Pg. 23, 26.
[20] *Ibid,* pg. 23.
[21] MacCorkle, "'Relation of West Virginia Coals to the Panama Canal' Address Before the West Virginia Coal Mining Institute on the Relation of West Virginia Coals to the Panama Canal Delivered at Charleston, W. VA. on December 8, 1913" (Government Printing Office, 1914), pg. 4.

America and the peoples it was destined to uplift.

The most alluring argument for the construction of the Canal was the potential economic benefit Americans could reap. An American canal teeming with coal-fueled ships could provide tremendous financial benefit to the United States. Americans had already toyed with the idea of creating coaling stations in Panama in the 1880s.[22] While the idea didn't come to fruition at the time, a canal made a coaling station a far more intriguing opportunity. If international commerce was funneled through a single point, whoever controlled energy distribution in that location would have access to a remarkable number of potential customers. A canal with suitable coaling stations could give Americans a virtual monopoly on the oceanic energy trade, guaranteeing money would flow north into America as ships flowed through the Canal.

Coal provided opportunities for the expansion of American naval, imperial, and economic interests that were too enticing to be overlooked. As the United States expanded its empire and global influence, the Canal moved from a pipe dream into a reality. The only lingering question by the dawn of the 20th century was where and when this structure would be built. Canal proponents had ample fodder to graze on. Pitches for interoceanic canals sprung up every few years during the second half of the 1800s. Boosters suggested Nicaragua, Mexico, Panama, and Colombia amongst other Central and South American nations as potential sites. In the 1880s, the French went so far as to begin construction of a sea-level canal in Panama under the guidance of Ferdinand de Lesseps, the national hero who had been the brains behind the Suez Canal. All these ventures ended in failure. And yet the enthusiasm they garnered proved invaluable to canal

[22] Lindsay-Poland, John. *Emperors in the Jungle: The Hidden History of the U.S. in Panama*. (Durham [N.C.]: Duke University Press, 2003), pg. 18.

lobbyists.[23]

By the end of the 19th century, the chorus of voices calling for a new canal had reached a crescendo. The American government, under the leadership of President McKinley, responded with the creation of the Isthmian Canal Commission (ICC) in 1899. The Commission, often known as the "Second Walker Commission" thanks to its chair, Admiral John G. Walker, intended to once and for all determine the most feasible route for the creation of a canal. The ICC studied the canal question for two years and initially suggested Nicaragua was the best location for a canal thanks in large part to the $109 million price tag *La Compagnie Nouvelle du Canal de Panama* (New Panama Canal Company), the French firm that had failed to build a canal in Panama, had placed on its assets. After a protracted negotiation, the New Panama Canal Company agreed to slash its price to $40 million. At the behest of President Roosevelt, the I.C.C reconvened, this time recommending that Panama be the site of the Canal. After some political wrangling, Roosevelt was able to get Congress to support the idea as well. The U.S. next pursued negotiations with Colombia to obtain the concession necessary to construct the Canal. Despite the best efforts of diplomats, the Colombian government rejected the Treaty. Not one to be deterred by such a trifling matter as sovereignty, Roosevelt decided to support the fledgling Panamanian independence movement, determining that fomenting a rebellion was a far easier course of action than diplomatic negotiation. After a quick coup and some strong-arming of the newly formed Panamanian government, the US obtained its concession and was set to begin

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[23] Various authors have tackled both the French attempt to build a Panamanian Canal and some of the other American schemes that were explored during the second half of the 19th century. The most comprehensive of this remains McCullough's *The Path Between the Seas* which provides a thorough account of both the French attempt to build a canal and several canal speculation projects. Other works of note are Todd Balf*, The Darkest Jungle: The True Story of the Darién Expedition and America's Ill-Fated Race to Connect the Seas*, (New York: Crown Publishers, 2003), Lindsay-Poland, *Emperors in the Jungle,* and Noel Maurer and Carlos Yu.,*The Big Ditch: How America Took, Built, Ran, and Ultimately Gave Away the Panama Canal*, (Princeton, N.J: Princeton University Press, 2011), among others.

work on the Canal.[24]

Encountering the Limits of Power

On May 4, 1904, the whistles blew at Bas Matachin for the first time, and "the old French workers and other nationalities such as Jamaican and a few native, danced and jumped about 2 feet high when they understood that the American government were in charge of the new undertaking."[25] The euphoria in the Canal Zone was matched by that back in America. Thanks to the seemingly unlimited potential of coal, America was picking up where the French left off. Yet the question remained: could Americans overcome the entropy of the Panamanian environment and succeed where the French had failed?

Initially, the question of American success was very much in doubt. As Americans arrived in Panama in the spring and summer of 1904, they had no idea what type of canal they wanted to construct, let alone how they would go about constructing it. Consequently, the first year of canal construction was beset by nearly continual delays, both bureaucratic and energetic. John Wallace, the first Chief Engineer of the Panama Canal Company, knew that he had to bring human and mechanical energy to bear on the Panamanian environment if it were going to yield a feasible waterway, and yet the chasm between intent and reality was wider than the Canal itself. Wallace's tenure was marred by marked difficulties in deploying energy thanks to the lack of a tangible infrastructure to support coal's utilization.

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[24] As was the case with early canal ventures there is a considerable volume of literature detailing the tumultuous process of determining the site for the canal. McCullough's *The Path Between the Seas* remains a comprehensive account of this process. Additionally, readers may want to examine, Michael L. Conniff, *Panama and the United States: The End of the Alliance*, (Athens: University of Georgia Press, 2012), Ovidio Diaz Espino, *How Wall Street Created a Nation: J.P. Morgan, Teddy Roosevelt, and the Panama Canal*, (New York: Four Walls Eight Windows, 2001), and Walter LaFeber, *The Panama Canal: A Crisis in Historical Perspective*, (New York: Oxford Univ. Press, 1977). All these works provide tremendous insight into the discussions and debates surrounding the location of the Canal and the political machinations of canal lobbyists.

[25] Amos Clark, *Best True Stories of Life and Work,* pg. 1.

The ICC was tasked not only with determining the site for the Canal but also bringing the vision of Isthmian transit to fruition. Members of the ICC made their first visit to Panama on April 8th, 1904.[26] The scene that greeted the Commission when they landed in Cristobal was not encouraging. Colon and Panama, the two major terminal cities on the Isthmus lacked water and sewage systems. The harbor facilities at Cristobal, the major port on the Atlantic side of the Isthmus, were incapable of receiving the tremendous amount of equipment necessary for the excavation. The force still at work under the French Company consisted of a mere 700 laborers and a few obsolete steam shovels. The ICC conceded that "Neither the equipment nor the organization of the force could be considered adequate, or in any way fitted for the prompt removal of the great mass of material in the Cut."[27] Housing facilities were dilapidated.[28] Machine shops and machinery "had practically remained idle for over sixteen years, and was almost entirely concealed by the jungle."[29] Tropical diseases remained troublesome both to the effective utilization of human energy and as a deterrent for labor recruitment.[30] If Americans were going to carve a canal out of the rugged Panamanian landscape, they had a lot of work to do.

These initial obstacles to the creation of a canal reflected a broader lack of knowledge about the conditions of work in Panama and realities of the Panamanian environment. The first Americans deployed to the Isthmus were mostly surveyors and engineers meant to provide a

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[26] Isthmian Canal Commission. "Annual Report of the Isthmian Canal Commission for a Portion of the Current Year to November 30, 1904.," December 1, 1904. Retrieved from USNA, RG 185, Collection PL 153 31 Annual Narrative Reports, Box 507: Folder: Annual Reports of the Isthmian Canal Commission Part 1 for the Year 1904. pg. 28.
[27] *Ibid*, pg. 28.
[28] Wallace, John. "Report of the Chief Engineer of the Isthmian Canal Commission: June 1, 1904- February 1, 1905," February 1, 1905. Retrieved from USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chief Engineer, Department of Construction and Engineering FY 1905-1906, pg. 2.
[29] *Ibid*, 12.
[30] ICC "Annual Report of the Isthmian Canal Commission to November 30, 1904," pg. 20.

better understanding of how and where the Canal would be constructed. In May of 1904, the first engineering party left New York for Panama. Their primary objective was to determine whether the best course of action was the creation of a sea-level or lock canal. A sea-level canal required more substantial amounts of energy to excavate, but upon its completion would be far easier to operate. A lock canal required less intensive excavation but presented several engineering challenges including finding a suitable water supply, constructing large enough locks, and providing the energy necessary to operate the locks. The design of the Canal was not the only charge given the engineers. The ICC mandated that "At the same time the great question of water supply of the canal, the control of the Chagres river, especially when in flood, and certain larger details of alignment, section of the prism and plans of harbor at the two termini of the canal and other questions of less magnitude, are to be conclusively settled."[31]

In some ways, these men had learned from their forebears working on the Panama Railroad and the French Canal. The emphasis placed on containing the Chagres River was a testament to this fact. The Chagres and its seasonal freshets had the potential to destroy any major infrastructural network, and Wallace was acutely aware of this fact. Indeed, the Chagres became such a priority that a special party of engineers was created by the ICC to determine the best site to dam it.[32] Preliminary studies suggested either Tiger Hill, Gatun or Bohio, on the Atlantic side of the Transit Zone, or Gamboa closer to the Pacific terminus. Damming the Chagres also had the potential to turn a liability into an asset. Wallace hoped that a hydroelectric station at the dam could harness the kinetic energy of the rushing Chagres and convert it into electricity. Wallace went so far as to suggest that damming the river was a panacea of sorts, as a

[31] ICC "Annual Report of the Isthmian Canal Commission to November 30, 1904", pg. 31.
[32] Wallace, "Report of the Chief Engineer: June 1, 1904- February 1, 1905", pg. 34-36.

dam might "solve the problem of the control of the Chagres River, the provision of water for any low-level lock canal designed, and the supply of efficient electric energy for lighting purposes, railroad operation, or the operation of machinery use in the construction of the canal; and incidentally a water supply for the towns and villages situated along the line of the canal, and for supply of the work."[33] Wallace was ahead of his time. It took ten years, but the creation of a hydroelectric station at the Gatun dam eventually provided the energy necessary to operate the locks on both ends of the Canal. In these early years, however, a hydroelectric solution to the ICC's energy woes was far from realistic.

The objective of taming the Chagres was admirable and pointed to a growing realization of the challenges presented by Panama's hydrological conditions, but it also emphasized a failure of imagination that plagued much of Wallace's tenure as Chief Engineer and continued to vex those who came after him. While coal energy allowed humans to alter the environment in exponentially greater ways than ever before, it also had the potential to destabilize Panama's entropic environment in exponentially greater ways than ever before. Damming the Chagres provided an answer to the issue of flooding and freshets, but removing and redistributing tens of millions of cubic yards of material exacerbated Panama's frequent landslides, the first of which occurred on September 23rd, 1904 in the Culebra Cut.[34] Throughout the years of excavation, it was not flooding but landslides and unstable soils that became the chief obstacles to the successful completion of the Canal.

While engineers toiled and trudged through the mountains and valleys of Panama, Wallace took Roosevelt's mandate to "make the dirt fly" to heart. Wallace immediately sought to

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[33] Wallace, "Report of the Chief Engineer: June 1, 1904, to February 1, 1905", pg. 10.
[34] Dose, H.F. "Annual Report of the Culebra Division for FY 1905," July 7, 1905. Retrieved from USNA, RG 185, Collection PL 153 31, Box 505: Folder: Annual Reports of the Culebra Division: FY 1905-1906, pg. 2.

set his motley collection of men and machinery to work in the Culebra Cut. This task was challenging. The bulk of the French machines remaining on the Canal had fallen into disrepair. The 465 machinists in the Canal Zone worked tirelessly to bring them back into working order, but even when these machines were fixed, their productivity was marginal at best.[35] Wallace was adamant that work be continued in the Cut. From the inception of the work, he believed that "The time and cost of excavating that section of the canal embraced in the Culebra Division, through the Continental Divide, will be the controlling feature in determining the time and cost of completing the canal."[36] Gumption could only take one so far on the Isthmus, however, and the rocky terrain proved difficult for the French engines to penetrate. Between the start of excavation on May 4th and December of 1904, only 243,472 cubic yards of material was removed from the Cut.

Recognizing that the French machines could not provide enough power to make headway in the Cut, Wallace contracted for fourteen American steam shovels in the fall of 1904, and by December 31st three were already on the work.[37] Despite this, energy consumption remained relatively low during the first year of construction. The Culebra Division consumed only 5584 tons of coal over the course of the year, a figure considerably less than the 8818 tons of coal used by the defunct French Company in 1900.[38]

While these new machines proved far more adept at cracking Culebra, the energy of steam shovels did not exist in isolation. The increased capacity to remove earth was useless

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[35] Wallace, "Report of the Chief Engineer: June 1, 1904, to February 1, 1905," pg. 12.
[36] *Ibid*, pg. 16.
[37] *Ibid,* pg. 18.
[38] Dose, "Annual Report of the Culebra Division for FY 1905", pg. 13; Tobey, E.C. "Annual Report of the Bureau of Materials & Supplies from May 1904 to June 30, 1905," July 8, 1905. Retrieved from USNA, RG 185, Collection PL 153 31, Box 507: Folder: Annual Reports (ICC) Division of Materials and Supplies, pg. 5.

without an equally massive increase in the capacity to transport earth and a place to deposit it. To bring the full power of the new American steam shovels to bear on the Panamanian environment, it was necessary to exponentially increase the available stores of energy in the infrastructure that supported the shovels. Wallace was aware of this fact. Towards the end of his tenure, he wrote, "One thing I have clearly demonstrated, and that is that we have so far not even approximated the average potential capacity of our steam shovels. The largest output and most economical results can only be obtained with these shovels are at work to their full capacity continuously. Of course, this simply depends upon the shovel being continuously and constantly supplied with cars to load."[39]

This was no small task. A regular supply of cars required: enough cars to load, the power to transport these cars, enough trackage to handle the cars, facilities to keep the cars in working order and properly arranged dumping sites, amongst other concerns.[40] Complicating matters further was the fact that even if all these conditions were met the rail lines were continually vexed by the fluid landscape of Panama. The Belgian locomotives that Americans inherited from their French forebearers were extremely rigid and could be derailed by the slightest shifts of the track. Panama’s spongy soils often settled and moved due to rains and excavation, leading to inconsistencies in the track. Division Engineer H.F. Dose complained that “The result has been that numerous derailments have taken place daily, causing serious interruptions to the work.”[41] The Canal effectively faced an energy bottleneck throughout 1904. The lack of a modernized transit network meant that constant derailments slowed the work, and slow progress assembling

[39] John Wallace, “Letter from Chief Engineer John Wallace to Isthmian Canal Commission Chair John Walker, March 7, 1905”, March 7, 1905. Retrieved from USNA, RG 185, Collection A1 121 General Correspondence Files: 1904-1914, Box 210, pg. 2.
[40] *Ibid*, pg. 3.
[41] Dose, “Annual Report of the Culebra Division for FY 1905,” pg. 5.

newly arrived machines caused the mechanical labor force on the Isthmus to grow slowly. The answer to the ICC's burgeoning energy problem lay in the same place it had for G.M. Totten half a century before, in the demand for human labor to create an infrastructure necessary for coal labor to thrive.

The human labor necessary to create the Canal was in short supply during the initial phase of canal construction. When work began in July of 1904, the ICC had roughly 2,392 men on its rolls. By the middle of February of 1905, that number had reached only 3,620.[42] The slow growth in human energy was problematic, hindering the deployment of mechanical energy thanks to the lack of personnel to erect machines and lay track. The Engineering Committee of the ICC suggested that successful completion of the Canal required roughly ten years work by 100 steam shovels and that it was imperative that this mechanical labor force be installed within two years.[43] A dejected Wallace complained that this required his men to receive, assemble, and deploy a shovel every week. "They could be installed and put to work at the rate of one a week," lamented Wallace, "but owing to the difficulty in securing necessary labor of all classes, together with the shortages of track tools and track material, one every two weeks will be about the best we can do."[44] Unless the labor shortage was dealt with, it was impossible for the Canal to be constructed.

The challenge in obtaining human energy foreshadowed the entwining of energy and racial biases in the hierarchization of the labor force. In general, Americans were reluctant to make their way down to Panama, and, as a result, the ICC relied on West Indian labor to fill the

[42] Wallace, "Report of the Chief Engineer: June 1, 1904 to February 1, 1905" pg. 15.
[43] Wallace, John. "Letter from Chief Engineer John F. Wallace to ICC Chairman John Walker, February 28, 1905," February 28, 1905. Retrieved from USNA, RG 185, Collection A1 121, Box 210, pg. 1.
[44] *Ibid*, pg. 2.

bulk of its labor rolls. These West Indians faced marginalization from the moment the work began. The first annual report of the Bureau of Materials and Supplies complained, "The greatest difficulty has been experienced in securing a laboring force sufficient to meet the needs and requirements of this Bureau, and it can be said that at no time has it been adequately supplied. The Jamaican is shiftless and lazy and returns but a small measure of work for his wage."[45] The ICC was caught between a rock and a hard place. They could not recruit enough skilled American laborers, and while they could obtain scores of West Indians, they believed these men lazy, unskilled, and, most egregiously, a completely inefficient source of energy for the price. This marked a longstanding tradition of valuing human labor based primarily on its relationship to energy. Those workers who directly enabled coal energy were in high demand; those who only tangentially aided in the unleashing of coal were not. Thanks to discrepancies in training opportunities in and between the US and the Caribbean, these qualifications were perceived to fall along racial lines, a distinction that was quite palatable to white American administrators.

The chief deterrent to the acquisition of skilled, American labor in Panama during the first year of construction was the constant specter of tropical disease. These microscopic murderers had defined the efficacy of human energy on the Isthmus for centuries and in the process created a "reputation of the Isthmus of Panama for unhealthfulness."[46] These diseases significantly limited the effectiveness of human energy. The problem grew so pronounced that the Commission was forced to adopt a policy that all employees of the Commission received free healthcare and medicine.[47] Additionally, they frustrated recruiters' attempts to bring Americans to the Isthmus. W.E. Dauchy, a senior engineer with the ICC, suggested that "Yellow fever scares

[45] Tobey, "Annual Report of the Bureau of Materials and Supplies from May 1904 to June 30, 1905", pg. 21.
[46] ICC "Annual Report of the Isthmian Canal Commission to November 30, 1904", pg. 45.
[47] *Ibid,* pg. 47.

have done a great deal towards keeping such men away."[48] The ICC looked to the eradication campaigns launched in Cuba and Puerto Rico as models that may be applicable to Panama.[49] The rub was that enacting such an insecticidal campaign required a substantial sanitation force stocked with considerable stores of human energy, a resource that was hesitant to come to the Isthmus due to the presence of mosquitos to begin with. As the dry season of 1905 progressed and the labor shortage continued to fester, Wallace's inability to overcome Panama's energy bottleneck came under increasing scrutiny.

The ongoing energy crunch, culicidaec crisis, and mechanical issues pushed Wallace to the brink, but the curse that damned the tenure of Chief Engineer Wallace was the bureaucratic logjam that rendered progress on the Canal a logistical impossibility. Throughout the dry season of 1905, Wallace's letters to the ICC grew increasingly combative. The main point of contention was the anemic pace at which material was imported to the Isthmus. In February, Wallace warned the Commission that, "Delay in the filling of requisitions, or delay in providing the necessary number and kind of men when needed, will result in the holding back of some particular part of the work, which in turn will impede and delay the organization and progress of the work in some other direction."[50] The Commission did little to heed these concerns and shortages in machine parts, timber, tools, oils, paints, coal, tracking, and personnel continued to plague progress.[51] By June of 1905, Wallace's patience had run its course. Burdened by the magnitude of the work and disenchanted by the bureaucratic hurdles he faced; Wallace resigned

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[48] Dauchy, W.E. "Letter from Acting Chief Engineer W.E. Dauchy to Isthmian Canal Commissioners General Peter Hains and Major B.M. Harrod Addressing the Work Accomplished Under Chief Engineer John Wallace Date July 14, 1905," July 14, 1905. Retrieved from USNA, RG 185, Collection A1 121, Box: 210, pg. 10.
[49] ICC "Annual Report of the Isthmian Canal Commission to November 30, 1904", pg. 20.
[50] Wallace, "Letter from John Wallace to John Walker, February 28, 1905", pg. 2.
[51] Wallace, "Letter from John Wallace to John Walker, March 7, 1905", pg. 2; Dose, "Annual Report of the Culebra Division for the Fiscal Year 1905, pg. 8; Dauchy, "Letter from Acting Chief Engineer Dauchy", pg. 9.

his post on June 26. The first phase of canal construction had come to an end. With little progress to show after a year of work, the fate of the Canal hung in the balance.

Getting on the Right Track

As Wallace's tenure in Panama came to an end, Americans had been at work in Panama for over a year and had shockingly little to show for it. There were a few areas of optimism. Coal consumption had exploded throughout the zone from 3,496 tons between May and December 1904 to 8,123 tons between January and June of 1905.[52] Many French machines had also been rehabilitated by the mechanical division, and surveys were providing considerable amounts of information to the ICC. Yet these minor victories were completely overshadowed by the laundry list of issues that remained unresolved. Labor recruitment sputtered along, and while the number of laborers on the isthmus had grown to 8,706 men, nearly every department was still clamoring for more.[53] Tropical diseases wreaked havoc on human bodies, a problem worsened by the fact that many of those who made their way to Panama with the promise of suitable quarters found deteriorating shacks waiting for them.[54]

The hardships faced by human energy reflected and compounded the hurdles Panama's environment placed in front of the ICC's mechanical labor force. A year of hard work saw the rehabilitation of 58 French engines and 980 French dumping cars, and the assembly of ten new American steam shovels, the bulk of which were at work in the Culebra Cut. And yet this Frankenstein French force succeeded in removing only 741,644 cubic yards during a year of

[52] Tobey, "Annual Report of the Bureau of Materials and Supplies from May 1904 to June 30, 1905", pg. 30.
[53] Stevens, John. "Report of the Chief Engineer for the Three Months Ending September 30, 1905," September 30, 1905, Retrieved from USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Reports of the Chief Engineer Department of Construction and Engineering FY 1905-1906, pg. 109.
[54] Dauchy, "Letter from Acting Chief Engineer Dauchy, July 14, 1905," pg. 9.

work.[55] At this pace it would take nearly 300 years to excavate the Canal. And yet the work could not expand without substantial preliminary work to modernize and restructure the infrastructural network supporting these machines. Dauchy cut to the core of this issue, writing,

> At Culebra, the work has reached a stage where no great expansion is possible without a large amount of preliminary work being done. This preliminary work consists of the construction of a large amount of railroad track, for which a corresponding amount of grading has to be done. Also, the diversion of certain streams preparatory to carrying on excavations on a large scale; the building of roundhouses for the care of locomotives, the construction of storage yards, and numerous connections between the existing tracks and tracks to be construction, with the Panama Railroad; also the double-tracking of the latter and the preparation of numerous dumping grounds and of tracks leading to them; also the installation of modern drilling machinery. All of this work requires a large number of preliminary laborers. Five thousand additional laborers could be used to advantage at once and have been asked for for some weeks.[56]

While he didn't explicitly state it, the implication of his comment was clear; the Panama Railroad was the weak link. The lack of track and the inferior quality of the track that existed rendered progress untenable. What the Panama Canal needed was someone who understood railroads and had extensive experience in their construction and administration. Fittingly enough that was exactly who they received.

John Stevens had made a name for himself working for the Great Northern Railroad where he rose through the ranks from a locating engineer to the Chief Engineer of the railroad in just over five years.[57] His insight and engineering aptitude led him to be named the Chief Engineer of the ICC on July 1st, 1905, a few days after Wallace's resignation, and by the end of the month he had departed for the Isthmus.[58]

John Stevens' greatest contribution to the excavation of the Panama Canal was likely his

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[55] Dauchy, "Letter from Acting Chief Engineer Dauchy, July 14, 1905," pg. 4.
[56] *Ibid*, pg. 6.
[57] McCullough, *The Path Between the Seas,* pg. 461.
[58] Stevens, "Report of the Chief Engineer for the Three Months Ending September 30, 1905", pg. 108.

decision to halt the excavation of the Panama Canal. Upon arriving in Panama, Stevens quickly obtained the lay of the land, and within a few months he expressed his plan for how the work should proceed. Stevens discontinued the practice of rehabilitating and utilizing French machines, a task which he saw as pointless. Stevens criticized the work done in the Culebra Cut, dubbing it, “largely in the nature of experiments” which were useless, “owing to several causes, among these causes being poor equipment, poor tracks, unsuitable dumping grounds, and piecemeal work generally."[59] Stevens recognized what Wallace had struggled to come to terms with. It was not enough to throw continually increasing amounts of energy at the Canal and expect it to be built. Organization of energy was just as important as its volume. To this end, Stevens began contracting for a tremendous amount of new American plant including 300 steel flat cars, 120 locomotives, 800 wooden flat cars, 6 earth spreaders, 6 heavy unloaders, and 31 steam shovels. The acquisition of these new machines reflected the general restructuring of the line. What had previously been a quagmire of energy incompetence was evolving into a model of efficiency.

The desire for modern and efficient material transcended the machines that removed and distributed earth and rock. Stevens’ chief contribution to the work was the overhauling of the Panama Railroad. The importance of the railroad to canal construction wasn't a novel realization. Wallace clearly expressed the importance of the railroad in conveying spoil. The ICC had gone to extreme lengths to ensure that they obtained the railroad when they purchased the resources of the French company, writing, " It was admitted on all sides that the railroad was an essential instrument to be used in the construction of the Canal. If there had been no railroad in existence, one would have had to be built over which to distribute material for the construction of the

[59] Stevens, “Report of the Chief Engineer for the Three Months Ending September 30, 1905,” pg. 108.

Canal."[60] Despite this knowledge, the railroad's condition was abysmal by 1905. When Stevens shared his professional diagnoses of the railroad, he disdained it as "lines which, by the utmost stretch of the imagination, could not be termed railroad tracks."[61] He felt the inadequacies of the railroad were so pronounced that on August 15th, within two weeks of arriving on the Isthmus, he halted all excavation work in the Canal Zone and focused all of the energy at his disposal on the task of rebuilding the railroad, thus creating an infrastructure for the deployment and augmentation of mechanical energy.[62] This involved laying new stronger track that resisted shifting Isthmian soils, strengthening bridges, adding more signals and building more support facilities including a coaling plant at Cristobal.[63] While the work took time, the shift in priorities inaugurated a considerably more optimistic and productive era of canal construction.

To construct the new Panama railroad, Stevens had to continue to develop the human labor stores on the Isthmus. The number of laborers on the Isthmus ballooned from 8,706 on July 1, 1905, when Stevens was named Chief Engineer, to 12,977 three months later on September 30th.[64] As the year progressed, this number continued to grow and by June of 1906, there were 16,145 men employed by the ICC[65] The substantial growth in energy reflected the priority placed on obtaining human labor. More importantly, the expansion of the human energy stores in Panama allowed Stevens to more aggressively implement coal energy as well.

The little black rock accompanied the human bodies flowing into Panama, creating a

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[60] Shonts, Theodore. “Memorandum of Comment on the Letter of Honorable L.M. Shaw to President Roosevelt, Dated October 17th, Relative to Panama Canal Politics,” October 30, 1905. Retrieved from USNA, RG 185, Collection A1 121 General Correspondence Files: 1904-1914, pg. 1.
[61] Stevens, “Report of the Chief Engineer for Three Months ending September 30, 1905”, pg. 117.
[62] *Ibid*, pg. 118.
[63] *Ibid*¸ pg. 122.
[64] *Ibid,* pg. 109.
[65] Stevens, John. “Report of the Chief Engineer for Fiscal Year Ending June 30, 1906,” August 11, 1906. Retrieved from USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chief Engineer, Department of Construction and Engineering FY 1905-1906, pg. 114.

broad network of interconnected energy sources capable of bridging the oceans. Between July of 1905 and June of 1906, the Culebra Division, the chief coal consumer along the line, used 25,033 tons of coal by itself. Of this, more than 13,532 tons of coal were used in transportation.[66] As the rail lines in the Culebra Cut expanded, more locomotives were put to work, which in turn could haul more cars, thus allowing more shovels to work more efficiently. This positive feedback loop of energy consumption was responsible for the progress made during the fiscal year. The work accomplished during the first year of Stevens' tenure was preparatory in nature, but it yielded an infrastructure capable of supporting the demands of construction. The Mechanical Division had been hard at work erecting machinery and by June 30th 1906 the ICC's mechanical labor force included: one 45-ton shovel, fifteen 70-ton shovels, 23 95-ton shovels, 100 French locomotives, 39 American locomotives, 541 French dumping cars, 324 American dumping cars, 1061 American flat cars, twelve Lidgerwood unloaders, thirteen bank spreaders, and 22 unloading plows.[67] Thanks to the expansion and modernization of the Panama Railroad these machines could now commence canal construction.

Distinguishing Between Silver and Gold

And yet machine labor also needed men to operate it, particularly white American men on the gold rolls who had both the experience and training to direct coal-fueled machines. As employment increased, the ICC increasingly focused on trying to obtain and appease these workers. The ICC was concerned that "Most of the men who come down here from the States are isolated from their homes and families. There is practically nothing in the way of amusements or

66 Dauchy, W.E. "Annual Report of the Culebra Division for the Fiscal Year ended June 30, 1906," July 11, 1906. Retrieved from USNA, RG 185, Collection PL 153 31, Box 505: Folder: Annual Narrative Reports of the Culebra Division from Fiscal Year 1905 to Fiscal Year 1906, pg. 13.

67 Stevens, "Report of the Chief Engineer for Fiscal Year Ending June 30, 1906," pg. 108.

anything to occupy the time of the men when they are not at work."[68] These gold laborers presented the ICC with a unique challenge. Their skill and technical training qualified them for the most important positions on the Isthmus, ranging from clerks and stenographers to steam shovel engineers and machine shop foremen, but they were also among the toughest laborers to maintain as they came from good paying jobs and stable conditions in the United States. The ICC and Stevens were aware of this fact and attempted to incentivize living and working on the Isthmus. Stevens authorized a raise for his mechanics in December of 1905 and created a variety of venues for their entertainment, including restaurants and commissaries peddling high-end meals and luxury goods, as well as club houses and community centers that provided amusements for off duty laborers.[69] In those areas the ICC could most easily control, the lived environments of canal employees, they created a segregated landscape which privileged the gold laborers who controlled and directed coal energy.

The privileging of gold laborers was tied to the crucial role they played in enabling machines. In 1907, as excavation began in earnest, D.W. Bolich, a senior Division Engineer, estimated the amount of manual labor required to equal the Canal's mechanized labor force. Bolich believed that it would take 124 laborers to match the pace set by a single steam shovel. Since there were roughly 44 shovels regularly at work in the Canal Zone that year, Bolich suggested that 5,456 laborers were needed to match this output, not mentioning foremen to oversee their work. This figure contrasted starkly with the 298 men who actually operated the steam shovels. A similar trend emerged when looking at the disposal of dirt. Bolich found that seven mechanized unloaders and plows could handle the duties of unloading train cars for a day.

[68] Dauchy, "Letter from Acting Chief Engineer, July 14, 1905", pg. 10.
[69] Stevens, "Report of the Chief Engineer for Fiscal Year Ending June 30, 1906", pg. 115, 116.

This mechanized labor force required just under 70 men to operate. Bolich suggested that this work would require 2,660 laborers as well as foremen to be done manually.[70] Mechanized labor so far transcended human capabilities that individual laborers, particularly those who didn't operate machinery, became increasingly irrelevant.

Due to this shift, West Indian laborers, who formed the bulk of the Canal Zone labor force, were not privy to the same benefits and perks as their American counterparts. Indeed, the men who made up the common labor pool of the ICC were often viewed with scorn and distaste by those that hired them. Dauchy, who administering the Culebra Division, described his common laborers as “an un-ambitious, inefficient and worthless class,” and wrote that they may have worked more effectively if Dauchy had foremen who “had a knowledge of this negro labor" at his disposal.[71] Dauchy’s opinion was shared by nearly all American ICC administrators. Stevens himself said of West Indians in comparison to common laborers in the United States, “I doubt their efficiency can be rated at more than 33 percent."[72] The stigma attached to West Indian laborers in conjunction with the burgeoning importance of mechanical labor rendered them increasingly interchangeable.

The developing energy hierarchy in Panama was most pronounced in the lived environments both sets of workers faced. By 1906 and 1907, work on the Isthmus had progressed to the point that most men were no longer living in the ramshackle quarters that had greeted the first labor crews. The scale of improvement was more pronounced in the gold laborers’ quarters, where both the variety and quality of housing afforded these important energy

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[70] D.W. Bolich “Machine Efficiency” in Isthmian Canal Commission, *Panama Canal Record*, Vol. 1 No. 6. October 6, 1907, pg. 44.
[71] Dauchy, W.E. “Annual Report of the Culebra Division for the Fiscal Year ended June 30, 1906,” pg. 7.
[72] Stevens, “Report of the Chief Engineer for the Three Months Ending September 30, 1905,” pg. 120.

enablers far outstripped anything offered to the expendable human energy of silver laborers. While gold laborers seldom accounted for more than ten percent of the Canal Zone's total labor force, the Division of Building Maintenance consistently poured more resources into the construction of gold quarters. In 1907, the Division spent only $482,502.88 on silver quarters in comparison to $1,432,415.51 for gold quarters.[73] This level of investment directly reflected the priority placed on gold laborers and indicated the solidification of their superiority in the energy hierarchy of the Canal.

Silver laborers frequented labor camps which were often only refurbished boxcars filled with bunks. Joseph Gard, who journeyed from Barbados to the Canal Zone in 1906, was promised a bunk by his recruiter, but when he arrived, "it was not so. There was some large wooden bunks, three (workers) leaves I took one the night we had no light and for a whole week I had all restless night."[74] Even if one found a bunk he could find himself crammed into a single car with 83 other men. Unsurprisingly, the converted cars lacked latrines and cleansing stations, so workers had to walk to other buildings, often through the rain, to reach what laborer Aaron Clarke jokingly dubbed, "our office for sanitary convenience."[75]

The ICC also found it easier to keep accurate counts of employee numbers when they resided in these camps. To enforce their oversight, the ICC provided meal tickets for unmarried silver employees living in the labor camps. At the end of each day, a foreman provided tickets to those men working below him.[76] Laborers brought these tickets to dinner where they received

[73] ICC. "Annual Report of the ICC Division of Building Construction FY 1907," 1907. Retrieved from USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports of the ICC Division of Building Construction from 1906-1908, pg. 4.
[74] Joseph Gard in Stuhl, *Best True Stories of Work and Life,* pg. 1.
[75] Aaron Clarke in Stuhl, *Best True Stories of Work and Life,* pg. 3.
[76] Isthmian Canal Commission, *Panama Canal Record*, vol. 1 No. 19 January 8, 1908, pg. 152.

breakfast and lodging tickets for the following day. Dinners generally consisting of rice, red beans, and meat. Vegetables, in short supply throughout the Canal Zone during the early years of construction, were a rarity.[77] The ICC adopted policies which essentially forced laborers to eat in sanctioned mess halls. If laborers wanted to live in the labor camps, they needed to receive a lodging check, given to them at the mess hall. The ICC justified this practice by claiming that they wanted to prevent unemployed workers from taking advantage of their facilities. However, sick workers who were unable to work and obtain meal tickets were often removed from camps as a result.[78] In many cases, the punishment for being found in a labor camp without a lodging check was a thirty-day stay in a jail cell.

The meal ticket system forced segregation by mandating West Indian workers who lacked the time to prepare meals live in labor camps. In addition, it sought to provide administrators with complete control over West Indian bodies and the energy they possessed. The smallest infractions or misuse of one's own energy by missing work, even for legitimate reasons, was grounds for removal. Perhaps the greatest indictment of the living conditions accorded silver employees was the fact that very few silver employees decided to utilize them, preferring instead the freedom that came with living in Panama City or other communities outside the ICC's jurisdiction. A frustrated John Stevens was forced to concede that, despite the best attempts of the ICC to control human bodies, West Indian laborers would often work long enough to bank up some money and then disappear into the bush for weeks at a time until they needed to restock their coffers. The result was that while there were well over 20,000 West Indians on the Canal by June of 1906 only about 10,000 actually worked each day.[79]

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[77] Aaron Clarke in Stuhl *Best True Stories of Life and Work,* pg. 1
[78] *Ibid,* pg. 3.
[79] Stevens, "Report of the Chief Engineer for the Fiscal Year Ending June 30, 1906", pg. 115.

The ICC consistently provided better quarters for their gold employees, valuing their labor and contentment above all else. The comforts accorded individual gold laborers depended on their position. Low-level gold employees often found themselves sharing rooms in houses of over twenty employees. Despite the cramped conditions, they had access to beds with mattresses, personal storage and basic comforts including furniture.[80] Men who held more prestigious positions generally resided in better quarters. An anonymous steam shovel operator spoke enthusiastically about his living arrangements, claiming, "We have nicely furnished rooms with baths, electric light, and toilet rooms, and the board is exceptionally good. In fact, everything is done to make it as pleasant as possible for the man, and I have not seen a man that was not satisfied; as for myself. I like it very much."[81]

The greatest privilege accorded to gold workers was their access to family quarters. By 1910, out of 4,646 gold employees, 1,737 resided in family quarters. Comparably, of the 25,044 silver employees on the ICC's rolls, only 1,341 lived in family quarters.[82] The quarters were the most spacious that the ICC offered. A description of family quarters under construction in Balboa in February of 1914 claimed that they included a living room, kitchen, two bedrooms, and a bathroom along with decks and verandas for socializing. These spaces provided a greater amount of comfort to gold employees and the advantage of having family nearby allowed for the completion of domestic tasks and familial structures that silver laborers could not easily access.[83]

The differences between silver and gold laborers were perhaps most stark when it came to mitigating the impacts of mosquito-borne diseases, particularly malaria. Yellow Fever was also

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[80] Leon Hallett to Ida May Richards, February 27, 1913 "Leon Forest "Slim" Hallett, Sr. Papers" University of Florida Digital Collections http://ufdc.ufl.edu/AA00025618/0000.
[81] Isthmian Canal Commission, *Panama Canal Record*, vol. 1 No. 3, September 18, 1907, pg. 23
[82] Isthmian Canal Commission, *Panama Canal Record*, vol. 4 No. 18, December 28, 1910, pg. 139.
[83] Isthmian Canal Commission, *Panama Canal Record*, vol. 7 No. 27 February 25, 1914, pg. 253.

problematic in the Canal Zone, particularly during 1904 and 1905, but by 1906, an aggressive sanitary campaign effectively eradicated the disease by wiping out *Aedes aegypti*- the mosquito species serving as a vector for the transmission of yellow fever- preventing it from being the scourge it had been during the construction of the railroad and the French attempt to build the Canal.[84] Malaria was far more problematic. Unlike *Aedes aegypti*, which tended to thrive in stagnant water left by humans, *Anopheles* mosquitos- several of which could serve as vectors for malaria- proved far more difficult to control. Due to the high heat and heavy rainfall in Panama they could breed year-round.[85] As a result, malaria ran rampant throughout the Canal Zone and it was silver men who most frequently fell victim to the disease.[86]

Malaria permeated every component of life in the Canal Zone. And as Stevens attempted to bring more men into the Isthmus, the disease spread. In 1906 alone, 21,736 workers were admitted to hospitals for treatment of malaria out of a workforce of 26,000.[87] William Gorgas effectively combated the disease through the removal of stagnant water, fumigation, and the erection of mosquito netting and by 1912 only 5,580 were treated for the disease.[88] Still, malaria remained the most common affliction in the Canal Zone. It was not uncommon for a single individual to be treated for malaria multiple times in the span of a few weeks. Allen Belgrave, a Barbadian general laborer, described his experiences with malaria while working in the Canal Zone in 1906, writing, "Malaria fever began to worry me, I went to the rest camp, got quinine

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[84] The Best account of the eradication of Yellow Fever in Panama can be found in Sutter, Paul S. "'The First Mountain to Be Removed': Yellow Fever Control and the Construction of the Panama Canal." *Environmental History* 21, no. 2 (April 2016): pg. 250–59.

[85] Paul S. Sutter, "Nature's Agents or Agents of Empire?: Entomological Workers and Environmental Change during the Construction of the Panama Canal." Isis 98, no. 4 (2007): 724-54. doi:10.1086/529265, 742.

[86] McCullough, *Path Between the Seas,* pg. 409.

[87] Gorgas, *Annual Report of the Department of Sanitation 1907,* (Washington DC: Government Printing Office, 1908) pg. 7.

[88] Gorgas, *Annual Report of the Department of Sanitation 1912,* (Washington DC: Government Printing Office, 1913) pg. 18.

treatment for two days, I return to work the fourth day, could only work two hours, six to eight, fever and my bowels took me in such a way that I had to be taken back to the rest camp." Belgrave was laid low by malaria two more times over the next few months before being offered a job in the relative safety of a hospital. [89] His experience was far from unique.

While malaria impacted all laborers in the Canal Zone, the burden of death lay heaviest upon the silver community, particularly before Gorgas' sanitation department made headway against the disease. Much of the inequity stemmed from the geography of the Canal Zone. Elevation varied wildly along the path of the Canal as rolling hills were interspersed with lowland swamps that became breeding grounds for mosquitoes.[90] Frequently, silver labor camps lay close to these sources of stagnant water, providing a buffet of blood for disease carrying mosquitoes. The result was that in 1906 black laborers died from malaria at a rate of almost eight per thousand while white laborers died at a rate of only two per thousand. These figures declined over time, largely equalizing by 1908, yet by that point in time hundreds of black laborers had died of malaria and tens of thousands more experienced the hardships of the disease.[91]

The focus on providing lodging and eradicating tropical diseases in gold labor camps reflected the ICC's acknowledgment of the importance of the energy provided by gold laborers. These men, thanks to their training and experience in tasks ranging from bookkeeping to operating the controls of steam shovels, provided a specialized energy that was in short supply in the Transit Zone. This reality, combined with preexisting beliefs about the inferiority of West Indian labor, led the ICC to create an environment which consistently provided better diet, living

[89] Allen Belgrave in *Best True Stories of Life and Work*, pg. 1-3
[90] Bennett, *The Agricultural possibilities of the Canal Zone*, (Washington DC: Government Printing Office, 1912) pg. 6.
[91] Gorgas, *Annual Report of the Department of Sanitation 1907,* pg. 7.

conditions, and medical care to gold employees. As Stevens restructured the infrastructure and mechanized labor force of the Canal Zone, he also reinforced this fledgling energy hierarchy by creating environments and conditions which reinforced the superiority of white American laborers on the gold roll. However, these benefits extended primarily to the environment that the ICC could most easily control, the living quarters of employees. As workers made their way into the ditch itself, the distinctions between silver and gold remained ideologically present, but the unpredictable energy at work in the Cut subjected men to many of the same dangers, and challenges.

Unpredictable Equality

Gold and silver laborers were on their most equal footing when they stood on the sloped banks of the Canal itself. While the ICC could exercise considerable control over the lived environments of gold and silver men, the injection of tremendous amounts of energy into the Cut's already entropic environment was a recipe for chaos. Men and machines toiled side-by-side, attempting to excavate and move tons upon tons of rock. Aiding them in this venture was the energy of chemical explosives. While dynamite could be directed and unleashed, the sheer violence and speed with which its reaction took place meant that it could never be completely controlled. Compounding these issues were the unstable tendencies of the Panamanian environment itself. As excavation commenced and banks became steeper, slides became increasingly problematic. Gold and silver men both encountered these realities in the Canal as they physically occupied the same space. The unpredictable energy at work in the canal bed presented perhaps the greatest challenge to the developing silver and gold system, impacting the lives of all laborers with equal tenacity.

By January of 1907, Stevens was ready to put his newly renovated railroad to the test by reinitiating excavation of the Canal. Between July 1906 to June 1907 excavation removed 5,570,432 cubic yards of material, 4,047,071 cubic yards of which was removed between January and June 1907.[92] This increased productivity was primarily due to a substantial increase in the amount of mechanical labor and energy directed towards the work. In June of 1906, the Department of Excavation and Dredging averaged just under ten shovels at work per day. By June of 1907, that figure was up to 29.03 shovels at work per day.[93] Dredging also increased during the year. The Atlantic terminal only had one French ladder dredge in June of 1906. In September, a 16-inch suction dredge joined the work and in March these two machines were joined by a 5-yard dipper dredge. Recognizing the importance of dredges to the work, the ICC made a point of contracting for two oceanic seagoing dredges, the *Ancon*, and the *Culebra*, with the Maryland Steel Company at the end of the year.[94] While dredges were never as numerous as steam shovels, they were far more efficient. The three dredges at work on the Atlantic had removed 1,112,321 cubic yards of material by the end of the year.[95]

Enabling this increased productivity was a substantial investment in coal energy. During this period the ICC consumed 116,586 tons of coal. This figure was in addition to the 86,865 tons of coal consumed by the Panama Railroad and various steamship companies supplying materials to the isthmus. The 203,451 tons of coal imported to the Isthmus between July of 1906 and June of 1907 more than doubled the previous maximum of 99,438 tons brought to the

[92] Goethals, William. "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1907," October 17, 1907. Retrieved from, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer of the ICC, pg. 3.
[93] Gaillard, D.D. "Annual Report of the Department of Dredging and Excavation for FY Ending June 30, 1907," August 21, 1907. Retrieved from USNA, RG 185, Collection PL 153 31, Box 505: Folder: Annual Reports of the Department of Engineering and Dredging for Fiscal Year 1907 and 1908, pg. 39, 41.
[94] *Ibid*, pg. 49.
[95] *Ibid,* pg. 50.

Isthmus the previous year.[96] This energy did not come cheap. The Culebra Division paid an average of $6.48 per ton for the 79,500 tons of coal its consumed over the course of the year. Costs more than doubled the average of $3.00 to $3.25 per ton for domestic coal consumption in the United States.[97] Despite this, the Culebra division was lucky in comparison to some of its counterparts. The La Boca Dredging Division, working at the Pacific terminus of the Canal, was forced to pay an average of $7.50 per ton.[98] The fact that the ICC was willing to pay such exorbitant prices for coal indicated the importance of the little black rock.

Despite its primacy, there were some tasks that coal simply was not cut out for. Shattering the rocks that littered the Canal Zone was one such task. To break apart rock and soil, particularly in the Culebra Cut, it was necessary to rely on a far more violent combustive reaction. Dynamite was the primary explosive of choice. More powerful than black powder, dynamite's chief benefit to the builders of the Canal was the inherent instability of nitroglycerine. An incredibly reactive compound, nitroglycerine released enough energy to shatter rock formations. This power was essential to excavation in the rockier areas of the Cut. Between July 1906 and June 1907, a total of 1,998,655 pounds of dynamite and 408,385 total pounds of black powder were used to loosen 3,291,856 cubic yards of rock.[99]

The tremendous amount of variance in Panama's landscapes demanded this broad array of different energies. Steam shovels and human muscle removed loose materials from the canal

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[96] Board of Directors, Panama Railroad Company. "Annual Report from the Board of Directors of the Panama Railroad Company to the Stockholders for the Year Ending June 30, 1907," July 1907. Retrieved from USNA, RG 185, Collection PL 153 31, Box 510: Folder: Annual Reports of the Panama Railroad Company from Fiscal Year 1900-1909, pg. 15.
[97] Gaillard, "Annual Report for the Department of Dredging and Excavation for the FY ending June 30, 1907," pg. 47.
[98] *Ibid*, pg. 52.
[99] *Ibid*, pg. 41.

prism and loaded it on to locomotives that carried it to dumping sites where it was deposited. For rocky areas like the Culebra Cut, where steam shovels were unable to work effectively, chemical explosives provided a rapid, violent reaction capable of breaking up rock so steam shovels could remove it. In swampy and oceanic environments, dredges used coal energy to remove soft sand and muck from the approaches of the Canal and deepen harbors for incoming vessels. None of these actions were possible prior to Stevens' tenure on the Canal. The restructuring of the Canal Zone's infrastructure provided enough support to mechanical energy to allow it to thrive. And yet infusing the Panama environment with an unprecedented amount of energy injected chaos into the workscape. Laborers now needed to contend with both natural and unnatural dangers.

One of the most dangerous components of the literal powder keg at the bottom of the Canal was the unpredictability of explosives. In the early years of canal construction, blasting crews relied on blasting batteries and fuses to detonate their charges. The high humidity and moisture content of the Canal Zone wreaked havoc with firing mechanisms, often preventing the ordinance from exploding.[100] Unexploded sticks of dynamite needed to be removed before excavation could continue, but due to the shifting of the ground during explosions it was difficult to account for every device. Laborers and shovelmen needed to navigate a literal minefield, lest they inadvertently set off a catastrophic explosion.

James Lewis of Antigua was working in Pedro Miguel, one of the lock sites on the Pacific end of the Canal, in 1906, helping steam shovels load soil onto dump cars. Powder gangs set off dynamite, loosening the soil so that the steam shovels and Lewis' crew could load the cars. On one occasion, after loading a car, Lewis and his crew moved down the line to continue

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[100] Gailliard, D.D. "Annual Report of the Central Division FY 1909," July 27, 1909. Retrieved from USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Report of the Central Division FY 1909-1913, pg. 70.

their work. Fifteen minutes later a deafening explosion rent the air; the entire powder gang they had been working with was gone. Lewis remarked, "On the track lines you could see parts of a man's body. It's an awful sight to see." Lewis was spared physical injury over the course of his canal career, but many others weren't so lucky. A single explosion on December 12, 1908, at Bos Obispo took the lives of over twenty men. Canal Zone employees could only mourn from behind the controls of a steam shovel, or while tying a fuse themselves. Death simply became another part of the Canal Zone environment.[101] Dynamite was crucial to the excavation of the Canal, but it also suggested the limits of human control over energy.

In addition to the immediate dangers presented by explosions, the injection of energy into the Isthmus also destabilized the shifting landscape of Panama. One of the ironies of canal construction was that to impose a static order on the Canal Zone, humans first had to loosen, shift, and redistribute the land. In doing so they unleashed the entropy bound in Panama's landscape by catalyzing slides and slope failures that toppled machines, derailed equipment, and injured the unwary. As time went on slides became increasingly common along the Isthmus. The Cucaracha Slide, which began in 1904, remained problematic in 1907, and continued to vex excavation until the Canal was finished in 1914 when the Culebra Cut was flooded and dredges were brought in to deal with it once and for all.[102] Major landslides didn't appear until late 1908 and 1909, but slides occurred with increasing regularity as the work progressed and more energy was brought to bear on the Panamanian landscape.[103] These slides may have lacked the violence of unexpected explosions, but they still threatened both silver and gold men alike.

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[101] James Lewis, *Best True Stories of Work and Life*, pg. 1.

[102] Goethals, William. "Annual Report of the Isthmian Canal Commission and the Panama Canal for the Fiscal Year Ending June 30, 1914," USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer, pg. 39.

[103] Goethals, "Annual Report of the Isthmian Canal Commission for Fiscal Year Ending June 30, 1907", pg. 3.

Landscape alteration made unnatural threats such as train derailments, flying rocks, premature or delayed explosions, overturned machines, and drowning normal occurrences in the canal bed environment. The spontaneity of workplace accidents prevented administrators from controlling these events and, consequently, they impacted gold and silver laborers with equal ferocity. In 1907, for example, 55 white laborers and 87 black laborers were killed by "accidental traumatisms" (workplace accidents).[104] In 1908, 79 white laborers and 111 black laborers lost their lives to "violence."[105] These tragedies emphasized that, in the chaotic environment created by the energy pouring into the Isthmus, gold and silver men were at their most equal. Indeed, gold men may have been at even greater risk due to their proximity to machines. Explosions didn't differentiate between skin color or rank. Ironically it was here, in the very area that Canal Zone administrators sought to most dramatically alter the environment, that they also encountered the most substantial limits to their control.

Administrators' answers to these issues was simply to inject more energy into the Isthmus. The aforementioned escalation in energy and progress between July 1906 and June 1907 indicated that Stevens' infrastructure and organization could be scaled to deal with any challenges Panama could throw at the Commission. Entropic forces such as landslides and explosions accompanied this increase in energy but were seen as necessary evils of restructuring the Panamanian landscape, and the more energy that the ICC had at its disposal, the more effectively it could deal with these inconveniences. Thanks in large part to the efficacy of

[104] William Gorgas, *Annual Report of the Department of Sanitation of the Isthmian Canal Commission for the Year 1907,* pg. 12.
[105] William Gorgas, *Annual Report of the Department of Sanitation of the Isthmian Canal Commission for the Year 1908* (Washington, D.C.: Government Printing Office, 1909), pg. 9.

Stevens techniques, the Panama Canal seemed feasible, and yet as it drew closer to reality, the distinctions between gold and silver laborers grew increasingly stark.

Good as Gold

Few images reflected the growing chasm between silver and gold laborers as dramatically as one taken during Theodore Roosevelt's visit to the Canal in the fall of 1906. In November, Roosevelt visited the Canal Zone to observe excavation first hand. In typical Rooseveltian fashion, the trip oozed charisma. The President traveled by rail across the Canal Zone, stopping to interact with countless workers, silver and gold alike, during his journey.[106] Excitement accompanied Roosevelt wherever he went, but few moments were as iconic as when Roosevelt took the controls of a Bucyrus Steam Shovel in the Culebra Cut. A photograph of that moment shows Roosevelt sitting easily atop the massive piece of machinery. A slew of other men watch as he reclines behind the controls of the all-important machine, a king atop an anthracitic throne. The image conveys Roosevelt's persona, and perfectly embodies the labor hierarchy of the Canal Zone. Roosevelt, clad entirely in white, looks down from the Bucyrus. To his right, a group of men, including several black laborers, wait, ready to assist the operator of the machine. Roosevelt's coat, hat, and positioning convey a simple fact: control of a Bucyrus, and control over coal energy more broadly, was reserved for men as white as the outfit worn by the President on that November day. [107]

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[106] "President and Party Are Enjoying Trip: Messages by Wireless Have Been Received from Battleship Louisiana," *The Lexington Herald*, November 12, 1906, pg. 1.

[107] *President Roosevelt running an American steam-shovel at Culebra Cut, Panama Canal*. [November 26, 1906]. Prints and Photographs Division. Library of Congress. http://www.theodorerooseveltcenter.org/en/Research/Digital-Library/Record.aspx?libID=o275881. Theodore Roosevelt Digital Library. Dickinson State University.

Roosevelt's visit marked the end of the preparatory phase of canal construction. Under John Stevens, the energy infrastructure of the Canal Zone had been entirely restructured. The revitalized Panama Railroad carried tons upon tons of material, allowing steam shovels to work at peak efficiency. Human labor was also reorganized to meet the demands of the coal-fueled labor force. Initially, the distinctions between American laborers and West Indian laborers were reflected through their different experiences in the lived environments. As the labor force grew throughout 1907, however, these distinctions become increasingly encoded in the formal hiring and employment policies adopted by the ICC Over the course of 1907 and 1908, the ICC enshrined their racially defined labor classes through explicit policies that clearly asserted that recruitment and promotion within the gold roll was a benefit reserved for white Americans. In hiring, wages, advancement, and position the "awful gulf" was excavated thanks in large part to coal energy.

Ironically, the catalyst for the adoption of such formal pro-American policies was not West Indians, but instead, the influx of Europeans who came to the Isthmus between June 1906 and June 1907. In June of 1906, there were only about 500 Europeans on the work; by the following year that number had reached 4,317, most of whom were Spaniards or Italians.[108] Europeans were seen as better laborers than West Indians, but still not as essential to construction as mechanically savvy Americans. To deal with this tension, the ICC placed Europeans on the silver roll but provided them with nearly double the wages, better living conditions, and more benefits than West Indian laborers.[109] The only complication was that the ICC could no longer rely on complexion alone to distinguish between the tiers of its energy

[108] Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1907," pg. 28.
[109] Gaillard, "Report of the Department of Dredging and Excavation for the Fiscal Year Ending June 30, 1907," pg. 43.

hierarchy. Formalizing the gold and silver system became essential to reinforce the distinctions between Americans and the rest of the Canal Zone world. Policies adopted by the ICC during 1907 and 1908 ensured that while they made up a minority of the labor force, Americans and their ability to fulfill essential functions in the coal energy regime of the Canal Zone were placed well above their non-American counterparts.

While the ICC had implicitly relied on the employment of skilled laborers from the United States since construction began in 1904, it formalized this process in 1907, decreeing, "employments of unskilled laborers are not made in the United States. Neither are persons employed who have followed no regular trade or profession or who have not specialized in one particular kind of work."[110] The policy reflected the fact that it was simply cheaper and easier to obtain unskilled labor from the West Indies and Europe, and simultaneously ensured that Americans would seldom be placed in the unskilled labor pool. Furthermore, the important role that these individuals were to play in canal excavation demanded far more vetting than that required for an expendable and replaceable common laborer. In the employment process "Agents of the Commission receive applications for all outside positions, personally examining the individual, and looking into his previous service record. This includes trainmen, steam shovel operators, foremen, and mechanics."[111] The ICC hoped that this intensive review ensured that only the most talented and qualified men operated the controls of a steam engine. The Commission went so far as to adopt a policy that should a position open in the Canal Zone which could not be filled by internal promotion, Americans would be given priority over foreigners.

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[110] Isthmian Canal Commission, "Letter Regarding Questions of Employment," pg. 1907.
[111] Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1907," pg. 28.

The implication was clear. Americans possessed better qualifications and abilities to operate machinery than their counterparts.[112]

It was not only in hiring that these distinctions were drawn. Promotion also favored American laborers. The ICC's employment practices allowed “authorities on the Isthmus to fill the position of foreman by the promotion of journeymen who have rendered faithful and satisfactory service on the Isthmus and are otherwise qualified.”[113] Because the ICC went out of its way to hire white American journeymen, the individuals who moved up the ranks into positions of greater importance were also invariably American. Indeed, when making promotions the ICC stated its considerations as, “A. Efficiency. B. Conduct. C. Length of Service. D. American Citizenship.” This is not to say that silver laborers, primarily of European descent, were completely absent from supervisory roles, however as one ventured up the labor hierarchy their presence became increasingly rare.[114]

Nothing so aptly captured the distinction between American and foreign laborers as the practice of replacing foreign employees with American employees. In August of 1908, in accordance with an order from the Secretary of War, the ICC began a process of retaining American employees through the termination of foreign clerks. In a circular in the *Panama Record,* William Goethals, Chairman of the ICC, wrote that foreign employees must be replaced with Americans, and further, “The retention of aliens now employed in clerical positions paying $1,500.00 per annum or more will be authorized only in exceptional cases where it is shown to my satisfaction that the duties of the alien employee demand peculiar qualifications, which he

[112] Isthmian Canal Commission, *The Panama Canal Record*, Vol. 1 No. 35 April 29, 1908, pg. 274.
[113] Isthmian Canal Commission, “Letter Regarding Questions of Employment.”
[114] Isthmian Canal Commission, *The Panama Canal Record*, Vol. 1 No. 35 April 29, 1908, pg. 274.

alone possesses, and could not be satisfactorily discharged to any available American." [115] The wording adopted by Goethals made it all but impossible for foreign workers to remain in the valued position of clerk, further reinforcing the boundaries in place in the Canal Zone.

Despite the rigidity of the ICC's policies, there remained rare situations in which a white American and a black West Indian may have been employed in the same line of work. This was particularly true in mid-level positions. In these situations, American laborers made more than double the wage commanded by their West Indian counterparts. Thomas Gittens came to the Canal Zone from Barbados in 1905. By 1907 he was employed as a rodman for the Panama Railroad. While not technically employed by the ICC, Panama Railroad employees were subject to similar treatment as their ICC counterparts. Gittens recollected, "I started to work with the railroad and with the sivel (civil) engineers work as rodman for $30.00 a month, in those days a rodman from the states was paid $83.33."[116] Gittens was still better off than many of his counterparts. Amos Clarke noted that many Americans were salaried employees, making sixty-five to seventy-five dollars monthly, whereas "West Indians were paid 10 cents per hour, Italians, Greeks, and Spaniards 20 cents per hour."[117] Ultimately Americans held positions of dominance even when employed in the same positions as their West Indian or European counterparts.

The true scope of this racialized labor force was seen in the descriptions of how the coal-fueled machines operated. White men were expected to operate most machines in the Canal Zone. 298 laborers served as pitmen and firemen for steam shovels in the Culebra Cut in 1907,

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[115] William Goethals, Isthmian Canal Commission, *The Panama Canal Record*, Vol. 1 No. 51, August 19, 1908, pg. 401.
[116] Thomas Gittens, *Best True Stories of Life and Work*, pg. 1.
[117] Amos Clarke, *Best True Stories of Life and Work*, pg. 1-2.

clearing track and shoveling coal into the machines while a crew of "two white men" served in the positions of engineer and cranesmen, the most skilled jobs on the shovel. This type of labor arrangement was not unique to steam shovels. A track throwing machine, which helped settle the railroads and move unnecessary soil, was "handled by three white men and six laborers." Operating the plows and unloaders that removed soil from train cars took "28 white men" to operate the machinery as well as "43 laborers and firemen."[118] This experience was echoed by West Indians working in the Canal Zone. John Prescod came to the Canal in 1906 from Barbados and worked alongside a steam shovel. Prescod never sat behind the controls, instead, he served in a support role, trudging through mud and water daily, noting, "one pair of boot last me one day."[119] George Morgan had a similar experience working for the Panama railroad where he served as a fireman, stocking the train's coal reserves for hours on end. In each case silver men didn't interact directly with technology, instead, they supported the trains and steam shovels while white men operated the machines themselves.[120]

Wages also reflected the value of American laborers. The all-important cranesmen and engineers mentioned by Bolich were acutely aware of their importance to the Canal Zone. While Morgan, Prescod or any of the nameless silver laborers who toiled next to their machines could be easily replaced, engineers possessed the ability to direct and maneuver mechanical energy and thus could negotiate from a position of strength. Interestingly these laborers were among the most difficult for administrators to keep happy. In December of 1906, the steam shovel operators and cranesmen working in the Culebra Cut asked for raises. When the ICC suggested a five

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[118] D.W. Bolich "Machine Efficiency" in Isthmian Canal Commission *The Panama Canal Record* Vol. 1 No. 6 October 6, 1907, pg. 44.
[119] John Prescod, *Best True Stories of Life and Work*, pg. 1.
[120] George Morgan, *Best True Stories of Life and Work*, pg. 1.

percent raise after the first year and a three percent raise every following year, the incensed operators resigned en masse even though they were making $210 and $185 a month respectively, figures between 40 and 70 percent higher than those same positions would pay in the United States. Most of these malcontent mechanical manipulators returned to work after a brief hiatus after receiving more modest raises. Their ability to petition for, and receive, higher wages indicated the unique power they held on the Isthmus.[121]

Thanks to the policies adopted by the ICC during 1907 and 1908, the reorganization of the Panama Canal's human energy regimes came to fruition. As Theodore Roosevelt sat atop the Bucyrus, his white coat and hat starkly contrasting with the mud and dirt adorning the laborers around him, he came to embody the superiority of Americans in the Canal Zone. A year after Roosevelt left the Canal Zone, the gold and silver system was almost completely racially defined. A coal-fueled mechanical labor force presented a reliable means of codifying these implicitly racial distinctions while explicitly tying them to the experience and training of American laborers. Gold laborers were valuable thanks to their ability to operate the heavy machinery essential to the construction of the Canal. The coal-fueled machinery that was constructing the Panama Canal thus created a racialized, exploitable, and expendable labor force defined by de facto segregation between white American and Black West Indian laborers; it was an energy hierarchy in which white Americans, like Roosevelt, sat on top.

Making the Dirt Fly

Despite the tremendous progress that characterized his tenure as Chief Engineer, Stevens abruptly resigned from his post in February of 1907. While no concrete reason has ever been

[121] Gaillard, "Annual Report of the Department of Dredging and Excavation for the Fiscal Year Ending June 30, 1907," pg. 46-47.

provided for his decision to leave the work, the most likely scenario was that he was simply overburdened by the scope of the undertaking.[122] Stevens' decision was a blow to the progress of the Canal, particularly on the Isthmus itself where many laborers saw the railroad man as a force of nature. And yet Stevens' departure contrasted starkly with Wallace's departure two years earlier. Wallace had left a floundering mass of energy lacking any sort of cohesion or organization, an unnecessarily complex monstrosity, completely unfit for the task of creating the Canal. Stevens, on the other hand, bequeathed his successor a well-oiled machine capable of rapidly and effectively moving and deploying energy to just about any point on the Isthmus. While the scale and scope of excavation grew exponentially between 1908 and 1914, the foundation laid by Stevens allowed escalation to take place smoothly and efficiently.

The key to this transition lay in Stevens' decision to discontinue digging and focus work primarily on the modernization of the Panama railroad. While not digging seemed blasphemous to many, Wallace included, it provided the resources and focus necessary to turn the antiquated railroad into the circulatory system of the Canal Zone. By 1908 the Culebra Cut alone contained over 151 miles of track.[123] The exponential growth of the transportation network in the Canal Zone allowed steam shovels to work at their full capacity, removing tons upon tons of material from the Cut. Plows, unloaders, and spreaders used their coal energy to remove and deposit this soil at dumping sites far away from the canal bed. Meanwhile dredges removed silt, sand, and soil from the waterways of the Canal Zone. This interwoven network of coal-fueled prime movers provided the labor necessary to excavate the Isthmus and bring the dream of interoceanic

[122] McCullough, *The Path Between the Seas*, pg. 505.

[123] Gaillard, D.D. "Annual Report of the Department of Excavation and Dredging for the Fiscal Year Ending June 30, 1908," July 21, 1908, Retrieved from USNA, RG 185, Collection PL 153 31, Box 505: Folder: Annual Reports of the Department of Excavation and Dredging for Fiscal Year 1907 and 1908, pg. 39.

transit to fruition.

And yet the very success of coal energy also catalyzed changes within the human energy at work on the Isthmus. ICC administrators conflated the need for technically savvy laborers with their racial prejudices and biases to create a hierarchy of labor. American laborers, who had training and experience utilizing coal-fueled machines, occupied positions of prestige in the Canal Zone. Initially, this manifested itself in better living conditions, food, and wages. As time went on this system became increasingly entrenched. In 1907 and 1908, as Stevens' tenure came to an end, the ICC began codifying the energy hierarchy in Panama, creating policies that permitted the hiring of skilled laborers only in America, and purging non-Americans and African Americans from the gold roll. These actions reflected the new reality in Panama. While Jim Crow may never have explicitly made his way down to the Canal Zone, he cast a shadow over the work.

The restructuring of both the mechanized and human labor pools in Panama was due in large part to the indispensability of coal. The creation of a stable transit network in Panama required remarkable amounts of energy to overcome the entropy of the Isthmus. Coal was the only fuel capable of providing such quantities of energy. As a result, it was necessary to create a landscape conducive to the deployment of coal-fueled prime movers and obtain human energy capable of facilitating its implementation. The wedding of the demand for coal energy and the creation of the tiered labor system in Panama reflected the complex and unanticipated consequences that accompanied energy proliferation.

And yet the energy proliferation in Panama was not done. As William Goethals took over the work, he escalated all facets of canal construction, pouring even more energy into the Isthmus in hopes of forcing it to yield a passage. In doing so he destabilized the already entropic tendencies of the region precipitating a complex series of challenges that required an increasingly diverse array of energy sources to create. Oil, electricity, and animal labor gradually joined coal, and human muscle in the Isthmus, broadening the spectrum of energy Americans had at their disposal and carving a path between the seas.

Chapter III: Locks, Shocks, and Barrels: The Proliferating Energy Regime that Constructed the Panama Canal

It started simply enough. On October 10th, 1913, President Woodrow Wilson pressed a button in the White House. From there it got complicated. The push of the button sent an electric charge along telegraph lines running overland from Washington, D.C. to Galveston Texas. The electrical current was then channeled south, through the Central and South American Telegraph Company's submarine cable, before being diverted to the company's Transisthmian cable. Finally, the current traveled down a local circuit near Gamboa Dam, a dyke which prevented the waters of the artificially constructed Lake Gatun from entering the Culebra Cut. In August, over a month before the current arrived, engineers drilled holes into the Gamboa Dam and, in preparation of the current, carefully packed these holes with explosives. When the current reached the Gamboa dam it closed a local circuit and tripped a weight connected to a switch. The second the switch was thrown a massive explosion gouged a 125-foot opening in the dam. Water rushed into the Culebra Cut, flowing across the last stretch of land blocking the aquatic highway. The Panama Canal was finally complete… kind of.[1]

The official inaugural voyage through the Canal didn't take place until August 15th, 1914, nearly a year after Wilson triggered the demolition of the Gamboa Dam.[2] And yet the fact that it was the President himself who sent the signal that destroyed the last major obstacle in the path of the Canal was telling. The complexity surrounding the detonation of the Gamboa Dam reflected the intricacy that defined the energy regimes at work in Panama. Coal remained paramount to

[1] Goethals, William. "Annual Report of the Isthmian Canal Commission and the Panama Canal for the Fiscal Year Ending June 30, 1914," September 20, 1914. Retrieved from USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Reports of the Chairman and Chief Engineer of the Isthmian Canal Commission, pg. 38.
[2] Isthmian Canal Commission, *The Panama Canal Record*, Vol. 7 No. 52, August 19th, 1914, pg. 521.

canal construction in 1913. Part of the incentive for flooding the Cut was that coal fueled dredges could easily remove the material remaining in the Cut.[3] Despite coal's continued centrality, the energy sources at work in Panama in 1913 were far different from those that were in place when John Stevens had left the work six years earlier. It was fitting that it was an electrical current that triggered the blast at Gamboa. Electricity now powered locomotives and cranes at Miraflores and Gatun and provided power throughout the Canal Zone. Meanwhile, oil powered fixed engines at the major machine repair shop in Gorgona and 40,000-gallon storage tanks were being constructed at terminal sites to provide oil for passing vessels. The Canal of coal had become the site of a massive energy proliferation that saw oil and electricity join the coal and human muscle powering Panama.

As the energetic infrastructure that was installed by John Stevens expanded under the guidance of George Goethals it diversified, adding new sources of energy to deal with the variety of tasks that accompanied the expansion of excavation and the commencement of construction. This transition defined the second half of canal creation and heralded the increasing diversity that came to define energy regimes in general over the 20th century. Yet it is worth remembering that this was by no means a revolution in which the combined forces of electricity and oil usurped the throne of coal. Instead, all three energy sources saw rapid growth in their use, plateauing only when construction was ending.[4]

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[3] Goethals, William. "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1913," September 15, 1913. Retrieved from USNA, RG 185, Collection PL 153 31, Box 503: Folder, Annual Reports of the Chairman and Chief Engineer of the ICC, pg. 41.

[4] Board of Directors, Panama Railroad Company. "Annual Report of the Board of Directors of the Panama Railroad Company to the Stockholders for the Fiscal Year Ending June 30, 1910," July 1910. Retrieved from USNA, RG 185, Collection PL 153 31, Box 510, pg. 22; Board of Directors, Panama Railroad Company. "Annual Report of the Board of Directors of the Panama Canal Company to the Stockholders for the Fiscal Year Ending 1914," July 1914, Retrieved from USNA, RG 185, Collection PL 153 31, Box 510, pg. 33.

The increasing consumption of energy in the Canal Zone embodied what Christopher Jones has dubbed a "landscape of intensification," a location where the influx of tremendous amounts of energy allowed for the creation of an environment more capable of harnessing and deploying energy through positive feedback loops. The creation of the Panama Canal was reliant on this process and suggests further that even as fossil fuels were ascending to dominance in Panama, a complex web of supplementary energies and prime movers remained essential to canal construction. As coal, oil, electricity, and muscle shifted the earth, creating a passageway for water to flow between the seas, they also provided the energy to construct a fixed landscape of concrete capable of, at least temporarily, countering entropy in Panama.

It was the fusion of these various sources of energy that allowed the completion of the Canal. As the tasks necessary for the Canal's completion grew increasingly complicated and specialized so too did the energy sources used to complete these tasks. Ironically, this process liberated canal construction from the challenges of Panama's entropic environment, while simultaneously enslaving it to expanding energy regimes and a static structure and size. The massive energy proliferation that took place between 1907 and 1914 pointed to both the promise and challenges of energy expansion. Navigating this task was crucial to the successful completion of the Canal and reflected a broader reliance of constantly expanding energy regimes that came to define American energy consumption in the Canal Zone and beyond.

Table 1. Fossil Fuel Consumption in Panama: 1907-1913

Year*	Coal Consumed (in tons)	Barrels of oil consumed	Oil Consumed (in tons of coal)	Total Coal and Oil (In tons)	Difference from previous year	Oil % of total energy
1907	203,451**	N/A	Not tracked separated	203,451	N/A	N/A
1908	380,792**	N/A	Not tracked separately	380,792	+177,341	N/A
1909	292,608	290,958	88,796	381,404	+612	23.3%
1910	398,719	463,186	141,292	540,011	+158,607	26.2%
1911	415,199	784,642	196,160	611,359	+71,348	32.1%
1912	401,385	876,325	219,009	620,394	+9,035	35.3%
1913	371,764	904,917	226,229	597,993	-22,401	37.8%

*Information listed in Fiscal Years (running July 1-June 31st)
**Note that oil was not tracked separately from coal until 1909

Table 2: Electrical Generation in Panama: 1908-1912

Year*	Electricity Produced (in Kilowatt Hours)	Difference from Previous Year
1908	984,744	N/A
1909	3,703,407	+2,718,663
1910	9,500,000 (number not exact)**	+5,800,000
1911	24,671,095	+15,171,095
1912	30,857,213	+6,186,118

*Information listed in Fiscal Years (running July 1-June 31st)
**The energy produced at the newly opened Gatun and Miraflores plants could not be tracked conclusively during the year

Inherited Energy

When George Goethals was named Chief Engineer of the Isthmian Canal Company following the resignation of John Stevens, he inherited a force remarkably effective at the task of excavation. Steam shovels, railroads, dredges, and bodies all worked in concert with one another to dig the big ditch. Goethals also acquired a tangible plan for the construction of the Canal. In addition to restructuring the labor force, Stevens had been a staunch advocate for the construction of a lock style canal, believing such a structure was the only way of completing the herculean task. While Stevens wasn't the architect of the plan, his convictions eventually rubbed off on Canal Zone administrators and the American government and on June 19, 1907 the decision was made to commit to a lock style canal once and for all.[5]

While the lock style canal required less excavation than a sea-level canal, it also mandated more construction work. The Isthmian Canal Commission (ICC) had to find a way to raise boats nearly 100 feet above sea level while also creating a structure capable of withstanding the Isthmus' entropic tendencies. Goethals' central challenge then was taking an energy infrastructure adept at excavation and converting it to one capable of the equally demanding task of construction. The key process in this transformation was the broadening of the energy regimes at work in the Canal Zone. Human muscle, coal, and explosives were tremendously effective at destroying landscapes, but they faced limitations when it came to constructing them. To overcome these challenges Goethals began a gradual process of energy proliferation, which relied upon the emergence of oil and electricity.

This process was already beginning during the end of Stevens' tenure. By mid-1907 the excessive price of coal caused some to consider whether it might be more prudent to begin converting some engines to run on fuel oil instead. Coal was effective for mobile engines thanks to its portability. A fireman could easily keep a coal-fueled boiler stoked with little more than a shovel. As a liquid, oil needed to be loaded and transported in cumbersome barrels that were difficult to handle, particularly on mobile engines. When it came to fixed engines however, oil's cheap price and great efficiency made it a compelling choice, particularly considering the

[5] David McCullough, *The Path Between the Seas: The Creation of the Panama Canal, 1870-1914*, (New York: Simon and Schuster, 1977), pg. 488.

massive quantities of energy being consumed on the Isthmus. This Culebra Division alone consumed 79,500 tons of coal in the fiscal year 1907, a total that cost $515,453.[6] Due to the difficulty of transporting coal to the interior and Pacific coast in particular, it was among the chief expenditures of the Division. Oil proved far more economical thanks to an 8-inch pipeline Union Oil constructed across the Isthmus to carry its oil from California to the east coast, precluding the exorbitant shipping costs that accompanied the importation of coal.[7] Starting in 1907, oil consumption on the Canal grew rapidly. Energy proliferation was percolating in Panama.

The growth of oil occurred because of coal, however, not in spite of it. As excavation expanded in 1907 Stevens, and later Goethals, constantly augmented their mechanical labor force. The Excavation and Dredging Division had 39 shovels on the work in July of 1906. A year later that number jumped to 63.[8] The additional shovels paid immediate dividends. In August of 1907, shovel No. 211 appeared on the front page of the *Panama Canal Record,* celebrated for moving a record 29,604 cubic yards of soil.[9] The addition of more mechanical energy, however, also added additional challenges, namely, the need to maintain and service more machines. In the fall of 1907 Shovel No. 222, which was damaged in an explosion. Interestingly, Shovel No. 222 was not described as "damaged" but instead "injured," anthropogenic terminology which

[6] Gaillard, D.D. "Annual Report of the Department of Dredging and Excavation for FY Ending June 30, 1907," August 21, 1907. Retrieved from USNA, RG 185, Collection PL 153 31, Box 505: Folder: Annual Reports of the Department of Excavation and Dredging for Fiscal Years 1907-1908, pg. 45.
[7] *Ibid*, pg. 45.
[8] *Ibid*, pg. 39.
[9] Isthmian Canal Commission, *The Panama Canal Record* vol. 1 No. 2. September 11th, 1907, (Ancon: Isthmian Canal Commission Printing Office, 1907), pg. 1.

suggested a degree of empathy with the machine itself.[10] Doctoring these new industrial patients forced the ICC to broaden its support facilities and the energy they consumed.

The Division of Municipal Engineering, Motive Power, and Machinery expanded its facilities to deal with this task. The principal facility on the Isthmus remained in Gorgona (or as it was known prior to December 24, 1906, Bas Matachin); however, the Division began renovating its facility at Empire to deal with the influx of new shovels. The installation of an expanded power station formed a key component of this overhaul. The power facility contained two 100-kilowatt generators direct connected to a 160-horsepower tandem compound ball engine, as well as a 200-kilowatt generator connected to a Harrisburg engine, all of which were fueled by oil.[11] In fixed locations like the Empire shop, it was far easier to use oil-fueled generators to create electricity and rely on wiring to deploy the electricity to machines as it was needed. The same principle held true for providing the power to light the townsites constructed throughout the Canal Zone.

Powerplants were springing up throughout the Isthmus in 1907, providing a more stable and accessible form of energy for those individuals working in fixed facilities. Of particular importance during 1907 was providing lighting for the townsites constructed in the Panamanian interior. In addition to powering the Empire shop, the power plant at Empire also provided enough electricity to power roughly 4000 lights. Ten miles of transmission lines ran from the Empire station, powering nearly all the lights in Empire and in the surrounding communities of Culebra, Rio Grande, Enterprise, Cerro, and Lirio. Meanwhile, the ICC constructed a

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[10] Isthmian Canal Commission, *The Panama Canal Record,* Vol. 1 No. 13, November 27, 1907, pg. 98.
[11] ICC "Annual Report of the Department of Municipal Engineering, Motive Power and Machinery, and Building Construction for the Fiscal Year Ending June 30, 1907," July 1907. Retrieved from USNA, RG 185, Collection PL 153 31, Box 509: Folder: Annual Reports of the Department of Municipal Engineering, Motive Power and Machinery, and Building Construction for Fiscal Years 1905-1907, pg. 22-24.

supplementary lighting plant at Gorgona which was placed in operation in May of 1907. This plant sustained 2000 lights and was connected to a three-mile transmission line which provided lighting throughout Matachin and Gorgona.[12] While these two shops were modest, they pointed to a broader trend of energy diversification in Panama.

This is not to suggest, however, that the energy proliferation in Panama was relegated to fossil fuels and electricity. The adoption of novel sources of energy in Panama was predicated on expanding organic energy sourced as well. In addition, the previously discussed human labor that came to the Isthmus in 1907, pack animals grew increasingly commonplace. In June of 1907, a force of 600 mules and horses provided a reliable means of transportation across the Isthmus. Pulling wagons, carts, and even ambulances, these animals engaged in tasks ranging from the transportation of goods and materials to the construction of roads and other public utilities.[13] While their labor was highly specialized and far less voluminous than the power provided by mechanical prime movers, horses and mules remained integral to the broadening energy regime at work in the region. The fact that they remained relevant while oil and coal consumption increased suggests that they were not subsumed by the energy proliferation taking place in Panama, but rather were part of it.

The growth of oil, electricity, and animal labor between 1906 and 1907 was modest. Coal and human labor dwarfed these initial forays into energy diversity, and yet they served as a harbinger for what was to come. The economic benefits of oil made themselves readily apparent by early 1907 and the ease of deploying and utilizing electricity suggested that it too had a key

[12] Goethals, William. "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1907," October 17, 1907. Retrieved from USNA, RG 185, Collection PL 153 31, Box 503: Folder Annual Report of the Chairman and Chief Engineer of the Isthmian Canal Commission, pg. 12.
[13] *Ibid,* pg. 15.

role to play in the coming years. While a bit of a statistical outlier, animal muscle also fulfilled specific tasks along the Canal Zone. As the work expanded over the summer of 1907 so too did the consumption of oil and electricity. Indeed, these two forces played crucial roles in the completion of the Canal, particularly as construction became more prevalent.

Tipping the Scales: 1908-1909

When George Washington Goethals took charge of the work on March 31, 1907, he was focused on only one thing: growth. Starting in June of 1907, the Isthmus saw a marked uptick in energy consumption across all fronts as coal, oil, electricity, and human labor were brought to the Isthmus in remarkable quantities. Stevens had crafted an infrastructure that could excavate the Canal. Goethals initiated an energy explosion that expanded excavation and constructed the facilities that would make up the Canal. The early years of this process were still dominated by coal energy, but electricity and oil left their mark in increasingly tangible ways as electrical lights, fixed motors, and the expansion of electrically powered facilities brought modernization and convenience to workers on the Isthmus.

Goethals' appointment to the position of Chief Engineer was emblematic of Roosevelt's frustration with his inability to maintain consistent leadership. While Stevens' tenure as Chief Engineer had been quite successful, Roosevelt took his decision to leave the work as a personal affront. Goethals, a Colonel in the Corps of Engineers, already had a distinguished career by 1907, having overseen coastal construction projects for nearly two decades before being named a member of the inaugural General Staff in 1903. Goethals' keen unyielding resolve and consummate professionalism drew the attention of William Taft who recommended the young officer to Roosevelt. Roosevelt, impressed by Goethals directness and sheer force of will, and still smarting from what he perceived as Stevens' betrayal, believed he had found in Goethals the man who could complete the Canal. Goethals possessed a singular vision and an incessant demand for perfection, and while he was an engineer first and a soldier second his organizational skills were remarkable. Perhaps most importantly, Goethals wasn't a civilian. Unlike Stevens, he could not leave Panama even if he wished to. The work was now his for better or worse.[14]

Goethals quickly put his logistical prowess to work, radically increasing the energy stores available on the Isthmus. Over the course of his first year as Chief Engineer, he nearly doubled the volume of coal consumed on the Isthmus and began gradually relying more on oil as a source of fuel.[15] While Goethals never explicitly stated a desire to specifically increase Panamanian energy reserves, he actively increased both the size and scale of the work. That energy would increase simultaneously was a foregone conclusion. This drastic escalation marked the initiation of several years of energy expansion in Panama. From the time Goethals took charge of the work, the total amount of energy imported to the would continue to rise before declining as work approached its conclusion in late 1913.

The escalation in energy use was unsurprising. Coal, which remained the most common source of energy on the Isthmus throughout the Canal's construction, was crucial to the successful removal of material and by the end of 1907 there were over 100 shovels at work on the Isthmus.[16] Over the course of the year shovels removed nearly 14,000,000 cubic yards from the canal bed while dredges at work on the Atlantic and Pacific terminals were able to remove

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[14] McCullough, *The Path Between the Seas,* pg. 509-510.
[15] Board of Directors, Panama Railroad Company. "Annual Report of the Panama Railroad Company to the Board of Directors for the Fiscal Year Ending June 30, 1908," July 1908. USNA, RG 185, Collection PL 153 31, Box 510: Folder: Annual Reports of the Panama Railroad Company from Fiscal Year 1900-1909, pg. 27.
[16] Rousseau, H.H. "Annual Report Division of Municipal Engineering, Motive Power and Machinery, and Building Construction for Fiscal Year Ending June 30, 1908," July 1908. USNA, RG 185, Box 509: Folder: Annual Report of the Department of Motor Power and Machinery, and Building Construction for the Fiscal Year 1908, pg. 10.

nearly 11,000,000 cubic yards for a collective total of 24,792,703 cubic yards.[17] While these figures were impressive, the increased scale of earthmoving also made instability far more problematic and pervasive than it had been in previous years. Issues started in early October 1907, when the Cucaracha slide slid nearly fourteen feet in a single day. While the slide eventually slowed to a rate of roughly four feet per day, the increased entropy unleashed by more invasive excavation presented a continual challenge.

The sheer scale of the slide made it difficult to deal with, spanning over 34,000 square feet and containing over 600,000 cubic yards of material. D.D. Gaillard, the head of the Department of Excavation and Dredging, went so far as to install electric lights at the slide so that steam shovels could work 24 hours a day to remove the material that slid into the cut.[18] Nor was the Cucaracha slide an isolated incident. A more concentrated slide of 140,000 cubic yards of material took place at Paraiso in April of 1908 and smaller slides at New Culebra and Las Cascadas complicated cleanup efforts further. The most troubling issue with these slides was that they took place in the dry season, a period when slides had previously been a rarity.[19] If the ICC wished to contain the increasing entropy it unleashed it needed to import and direct increasing amounts of energy at the landscape in hopes of establishing stability.

Excavation was also expanding at the terminal facilities by late 1907. The decision to commit to a lock canal the previous year had given construction a degree of direction that it had lacked, but it also created new issues. First and foremost, among these challenges was finding terrain suitably stable for the creation of the locks. To this end, coal-fueled drills made dozens of

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[17] Gaillard, D.D. "Annual Report of the Department of Excavation and Dredging for the Fiscal Year Ending June 30, 1908," July 21, 1908. USNA, RG 185, Collection PL 153 31, Box 505: Folder: Annual Narrative Report of the Department of Excavation and Dredging for the Fiscal Year Ending June 30, 1908, pg. 35.
[18] *Ibid*, pg. 41.
[19] *Ibid*, pg. 42.

exploratory drillings at both the Pacific and Atlantic ends of the Canal.[20] At Gatun, the site of the Atlantic terminus, the work progressed well, and despite and despite some minor tinkering to determine the best possible site for the locks, steam shovels and dredges removed 1,769,115 cubic yards of material from the lock site.[21] In addition to the material removed from the lock site, Two French ladder dredges, two dipper dredges, a sixteen-inch suction dredge, and the sea-going suction dredge Ancon all worked in concert to remove 5,087,623 cubic yards of material from the waterways near the Atlantic locks.[22]

The ICC was not as lucky at La Boca, the planned site for one of the two sets of locks on the Pacific terminus. The underlying material at La Boca was too soft and shifted considerably whenever weight was applied to it. The engineers at the site described it as, " an unctuous blue clay without grit, possessing very little supporting power, instead of a stiff clay as indicated on the profile."[23] Structures in the region would simply sink into the muck, so the site of the locks was shifted to Miraflores.[24] By January 1908, two steam shovels arrived at Miraflores and began excavation in earnest.[25] As was the case in the Atlantic, it was the dredges however that were the main source of landscape alteration at the Pacific locks as well. Here four French ladder dredges and the sea-going suction dredge “Culebra” worked together, removing 5,273,369 cubic yards of

[20] William Sibert, “Annual Report of the Department of Lock and Dam Construction for the Fiscal Year Ending June 30, 1908,” July 1, 1908, USNA, RG 185, Collection PL 153 31, Box 507: Folder: Annual Report of the Department of Lock and Dam Construction Fiscal Years 1907-1908, pg. 57.
[21] *Ibid*, 58.
[22] George Goethals, “Annual Report of the Isthmian Canal Commission for Fiscal Year Ending June 30, 1908,” August 25, 1908, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer of the ICC, pg. 7.
[23] *Ibid,* pg. 10.
[24] Sibert, “Annual Report of the Department of Lock and Dam Construction”, pg. 63.
[25] *Ibid*, pg. 64

material.[26] While completion of the Canal was still far away, coal provided the energy to bring it closer to reality.

Despite its primacy, coal alone did not account for the exponential increase in energy that swept through the Isthmus in late 1907 and early 1908. Newly initiated construction projects required far less mobility than excavation and didn't require a highly portable source of energy like coal. Oil and electricity proved efficient and economical sources of energy for construction as Goethals endeavored to provide amenities for the laborers working in Panama. In particular, the expansion of electricity illuminated the working towns of Panama and ensured that workers could acquire luxury food items from the Commissary.

Illumination brightened the night sky of Panama on an unprecedented scale as 1908 dawned. While this development was not crucial to the completion of the Canal per se, it was part of a broader campaign of providing modern conveniences to laborers. Prior to 1908, lighting had been a combination of traditional oil-fueled lamps and electrical lighting. While this worked, oil lights required more maintenance than electrical lights and during 1908 the electrical subdivision mandated that all new lights would run on electricity with the exception of those located in areas that would be flooded by the Gatun Lake.[27] This mandate ushered in a rapid expansion in the lighting of the Panamanian countryside. Concentrating on worker towns in the interior and at terminal sites in Panama City and Balboa, the ICC installed 13,355 new lights during the year. This effort quadrupled the 3,381 electrical lights that had been installed on the Isthmus in prior years, bringing the new total to 17,186.[28] The lights comforted workers and their

[26] Goethals, "Annual Report of the ICC for the Fiscal Year Ending June 30, 1908," pg. 8.
[27] Rousseau, "Annual Report of the Division of Municipal Engineering, Motive Power, and Machinery and Building Construction for FY 1908," pg. 11.
[28] *Ibid*, pg. 11.

families and challenged assumptions about a wild and uncivilized Panama. The potential of this new technology to breed comfort was infectious and soon spread to other amenities.

Food distribution was also modernized by electrification. Panama had limited resources and while tropical fruits and plants could be found in abundance, American staples like meat were hard to obtain. The ICC and Panama Railroad quickly recognized that discontent could be mitigated with luxury food items that gave laborers a taste of the homes they had left behind. The ICC looked to the "Commissary" that had been operated by the Panama Railroad Company since the 1800s to provide American goods to its employees.[29] Working with the railroad, the Commission expanded the Commissary, using electricity to increase its offerings and storage facilities. The chief thrust of the Commission's efforts was to provide meat and dairy products that were difficult to obtain in local markets. Because these items spoiled rapidly it was necessary to use electrical energy to find ways to create cold storage spaces capable of processing and storing these valuable commodities. Starting in 1908, the Commissary added a cold storage facility, an ice making plant, and an ice cream plant. Upon opening, the cold storage plant handled nearly 1.5 million pounds of meats, vegetables, and fruits monthly, the ice plant manufactured roughly 1,950 tons of ice monthly and the ice cream plant manufactured roughly 100 gallons of ice cream per day.[30]

These additions were so popular, and demand so substantial that within a year the Commissary sought to expand the output and operating capacity of all three plants.[31]

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[29] Isthmian Canal Commission, "Annual Report of the Isthmian Canal Commission for a Portion of the Current Year to November 30, 1094.," USNA, RG 185, Collection PL 153 31, Box 507: Folder: Annual Report of the Isthmian Canal Commission Part 1 for the Year 1904, pg. 54.
[30] Panama Railroad Company Board of Directors, "Annual Report of the Panama Railroad Company to the Board of Directors for the Fiscal Year Ending June 30, 1908," pg. 21-22.
[31] *Ibid*, pg. 22.

Unfortunately for some, the acquisition of a frosty treat created more problems than it solved. Mitchell Berisford, a Barbadian working on the Canal in 1909, fell victim to dessert disaster when his wife spent ten dollars on cake and ice cream to host a party for her friends. A dejected Berisford remembered, “when I went home the evening I saw the ice cream dishes what they use and the crumbs of cake all over the table, not a crumb leave for me, pots cold, stove cold, and no dinner, and she was away, hungry killing me and nothing to eat, great experience.” Berisford deemed the sugary slight so egregious that “I had to make a divorce on her."[32]

While the number of marriages ruined by desserts on the Isthmus is difficult to track, the increase in electricity that enabled the Commissary’s expanded culinary offerings is not. The illumination of the interior and the expansion of Commissary facilities both reflected the greater emphasis placed on electrical generation in 1908. Facilities at La Boca, Cristobal, and Colon generated 984,744-kilowatt hours over the course of the year. Increasingly oil fueled the turbines that generated this power. The La Boca facility was converted to operate on oil during the year, a decision which yielded, "decided economical operation." Meanwhile the growth of the Commissary branch at Cristobal forced the electrical plant supporting the facility to more than double its output through the installation of new motors and generators. The expansion of the Commissary was so rapid that even the new machines “will be so badly overloaded that it will be impracticable to supply any current for Gatun, as was previously considered." The only way to meet the needs of the Commissary was to convert the Colon beach station to run on oil and

[32] Berisford, Mitchell, located in Ruth Stuhl, ed. *Isthmian Historical Society Competition for the Best True Stories of Life and Work on the Isthmus of Panama during the Construction of the Panama Canal* (Isthmian Historical Society: 1963), University of Florida Digital Collections, pg. 1.

integrate it with the Cristobal facility.[33] Luxury food items may have made the Canal Zone a far more alluring place to laborers, but they also stretched electrical generation to its limit.

By June of 1908, the Canal Zone was a drastically different place than it had been a year before. During his first full year on the work, Goethals made headway in excavation, particularly at the lock sites, and made drastic changes to the Canal Zone environment that made it far more alluring to prospective laborers. Illuminated night skies and luxury food items were now hallmarks of the Isthmus, a development which led to 18,000 more individuals coming to the Isthmus than leaving it over the course of the year.[34] While the ICC still made a point of recruiting laborers externally, the massive jump in immigration in 1908 suggested that the organization's labor issues could be mitigated through the modernization of the Isthmus, a process catalyzed by electricity and the amenities it provided.

Petroleum in Panama

Goethals continued to reorganize operations on the Isthmus in July of 1908, dividing the engineering force into three divisions, the Atlantic, Pacific, and Central Divisions, each of which was responsible for construction and excavation in its geographic area.[35] This change indicated the shifting work on the Isthmus. In the Central Division, excavation remained the chief concern, but in the Atlantic and Pacific Divisions work was focused on construction. This shift in the work was accompanied by the continued ascendance of oil as an efficient source of energy for construction work. Oil had played an important role in the diversification of Isthmian energy

[33] Panama Railroad Company Board of Directors, "Annual Report of the Panama Railroad Company to the Board of Directors for the Fiscal Year Ending June 30, 1908," pg. 25.
[34] Wood, "Annual Report of the Department of Labor, Quarters and Subsistence for Fiscal Year Ending June 30, 1908," July 1, 1908, USNA, RG 185, Collection PL 153 31, Box 507, pg. 1.
[35] George Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909," August 20, 1909, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer of the ICC, pg. 1.

sources for years; the summer of 1908 saw a far more concerted effort to utilize oil and its economy. Storage facilities made it more accessible, and engines across the line were converted to run on it. The energy expansion that had taken place during 1907 expanded in 1908 and 1909 as the ICC set new records in the use of coal, electricity, oil, and human labor in Panama. The single biggest testament to the expansion of oil on the Isthmus was the fact that while there was a net increase in energy over the course of the year, the bulk of that difference was made up of oil.[36] While the amount of coal consumed still dwarfed oil consumption overall, oil was growing increasingly prevalent. As the ICC established more fixed locations and was better able to transport materials around the Isthmus, oil became increasingly viable as a fuel source for static processes such as construction and power generation.

Starting in the summer of 1908, Goethals and his division leaders began constructing facilities to better handle and deploy oil. The Mechanical Division redoubled its commitment to petroleum during the year, constructing a massive 2500-barrel holding tank and a 500-barrel auxiliary tank to provide the fuel necessary for the day to day operations at Gorgona. By August 1908 the tanks and pipelines connecting them to the main facility were completed and by October Gorgona was consuming oil at a rate of 3100 barrels per month.[37] The transition immediately paid dividends, resulting in a savings of $200 per month.[38] The adoption of oil then was both an act of convenience as pipelines to fixed motors required far less labor than stoking a

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[36] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1911," August 1, 1911, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report Second Division 1909-1913, pg. 510.
[37] Brooke, "Annual Report of the Mechanical Division for the Fiscal Year Ending June 30, 1909," July 15, 1909, USNA, RG 185, Collection PL 153 31, Box 507: Folder: Annual Reports (ICC) Mechanical Division from FY 1909-1914, pg. 26.
[38] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1909," August 1, 1909, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report Second Division 1909-1913, pg. 145.

coal-fueled engine with firemen, and an act of economy as the savings received from the practice made it more cost-effective than coal as well.

The expansion of oil consumption on the Isthmus also made itself felt in electrical power generation where the ICC was conducting a piecemeal installation of new motors and engines. As was the case in the Gorgona shops, oil was rapidly becoming the dominant source of fuel in electrical generation. The Commissary continued the expansion of operations it had begun the previous year, increasing the productivity of its ice cream plant to 500 gallons per day and adding 2856 square feet of cold storage to its facility at Cristobal. These developments were enabled by the addition of three new generators.[39] Long at the vanguard of oil usage on the Isthmus, the Panama railroad also began experimenting with the use of oil for fuel in its locomotives.[40]

Electricity also expanded during the year. The Electrical Subdivision of the Mechanical Division took over administration of the Balboa plant in July of 1908, giving them control of all power plants on the Isthmus with the exception of the remaining railroad plants at Cristobal and Colon.[41] This plant consisted of direct current generators of 125 and 325 kilowatts as well as alternate current generators of 60 and 200 kilowatts.[42] The Division installed another 400-kW generator at Empire and extended their pole line all the way to Miraflores and outlying labor camps in the area. At Gorgona the additional 100 kW of capacity allowed for the expansion of lighting and a new electric crane, and even the powerplant at Gatun received an extra 50 kW of power to expand lighting in the area surrounding the lock site. All together, these new facilities

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[39] Panama Railroad Company Board of Directors, "Annual Report of the Board of Directors of the Panama Railroad to the Stockholders for the Fiscal Year Ending June 30, 1909," pg. 25-26.
[40] *Ibid*, pg. 22.
[41] Brooke, "Annual Report of the Mechanical Division for the Fiscal Year Ending June 30, 1909", pg. 30.
[42] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1909," pg. 146.

generated 3,703,407 kilowatt hours on the Isthmus, an unprecedented figure that indicated just how quickly electricity was adopted.[43]

The highest concentration of electrical expansion was at the lock sites on both the Atlantic and Pacific terminals of the Canal. By early 1909, Goethals had plans for both sets of locks and settled on 1000-foot by 110-foot lock chambers contained by miter gates at the ends of each lock.[44] The adoption of this detailed plan allowed both the Atlantic and Pacific Divisions to begin erecting the construction plants they would use to pour the concrete foundations for the locks, as well as the powerhouses at Gatun and Miraflores that provided the electricity necessary to both construct and operate the locks.

Thanks to the early identification of Gatun as a dam and lock site, the Atlantic Division, under the guidance of William Sibert, found itself ahead of its counterparts in the Pacific Division. Steam shovels and dredges removed 1,400,000 cubic yards of material from the area surrounding the locks and five dredges removed nearly 6,000,000 cubic yards of material from Colon and Mindi harbor and the approaches to the Canal.[45] Much of this material was used in the construction of the Gatun dam. The structure holding back the Chagres River, the dam was imperative to the success of the Canal by managing the water supply for Gatun Lake. As material was removed from the cut it was placed in the expanding dam structure which contained a hydraulic fill core surrounded by trestling and solid fill. By June of 1909, over 2,500,000 cubic

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[43] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1909," 146; Brooke, "Annual Report of the Mechanical Division for the Fiscal Year Ending June 30, 1909," pg. 31-34.
[44] George Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909," pg. 3.
[45] Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909," pg. 5; William Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1909," July 31, 1909, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports Atlantic Division 1909-1913, pg. 55.

yards of material were deposited in the dam and, apart from a few minor alterations, the structure seemed to be well on its way to completion.[46]

Electricity served little purpose in the excavation at Gatun, but as Sibert redirected his attention on the construction of locks themselves electricity became increasingly important. The plant at the lock site was a complex infrastructure of trains, cranes, cableways, and mixing plants that took rock and sand from quarries at Porto Bello and turned it into concrete.[47] The machines were powered by a massive power plant at Gatun consisting of Three 1500 kW turbo-generators which provided 3-phase alternate current at 2,200 volts. This energy powered the cranes, cableways, and trains. Direct current, supplied by two 500 kW and one 300 kW rotary converters, provided the energy necessary for the mixing plant itself.[48] All of this equipment was housed in a temporary power station that would be moved to the Gatun spillway upon the dam's completion.[49] While the plant had yet to be fully completed by June of 1909, the structure itself was completed and the equipment eight-five percent installed.[50]

Work on the Pacific Locks progressed more slowly. Division chief, S.B. Williamson's decision to shift the locks from La Boca to Miraflores had slowed the work, but the Division moved rapidly to catch up to their counterparts on the Atlantic. The Pacific Division outpaced the Atlantic Division in excavation during the year, removing over 10,000,000 cubic yards of

[46] Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1909," pg. 51; Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909," pg. 8.
[47] Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909", pg. 8.
[48] Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1909," pg. 44.
[49] Goethals, "Annual report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909", pg. 6.
[50] Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1909," pg. 45.

material between steam shovels and dredges.[51] Intriguingly, of the seven dredges that worked on the Pacific terminus and approach during the year, five were converted to run on oil.[52] This diversification of energy paid off and by August of 1909 the Division had nearly completed excavation at Pedro Miguel and had excavated over 80% of the upper locks at Miraflores.[53] Here too electricity was crucial. During the year, the Division began building a powerhouse at Miraflores that mirrored the one under construction at Gatun. The intent was for this station to provide the energy necessary for the construction of the Pacific Locks and to act as a redundant support for the Gatun powerplant once the Canal opened.[54] At both the Atlantic and Pacific terminals, oil and electricity were usurping the primacy that coal had enjoyed during the early years of canal construction.

Despite its utility as a source of light and power, the most valuable contribution made by electricity during the year may have been the adoption of electrical current as the firing mechanism for explosives in the Central Division. The task of carving a path through the rocky continental divide invariably required the tremendous energy contained in explosives. Of the 14,325,876 cubic yards removed by the Central Division between July 1908 and June 1909, 12,622,880 cubic yards of material were first broken apart by 3,365 gross tons of explosives.[55] The concentration of such a substantial amount of volatile energy created issues, particularly when combined with the damp conditions of Panama. Heavy rainfalls and damp conditions wreaked havoc with blasting batteries, resulting in delayed or failed explosions which could

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[51] S.B. Williamson, "Annual Report of the Pacific Division for the Fiscal Year Ending June 30, 1909," July 27, 1909, USNA, RG 185, Collection PL 153 31, Box: 509: Folder: Annual Reports of the Pacific Division for Fiscal Years 1909-1912, pg. 91.
[52] *Ibid*, pg. 102.
[53] *Ibid*, pg. 94.
[54] *Ibid,* pg. 97.
[55] D.D. Gaillard, "Annual Report of the Central Division FY 1909," July 27, 1909, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports of the Central Division FY 1909-1913, pg. 70, 72.

maim or kill unsuspecting powdermen. To counter these explosive conditions, the Mechanical Division and Central Division worked together to create a sophisticated but intuitive blasting system. The Empire plant was connected by transmission wired to the Central Division. When the current reached the Division's territory, it was directed into 45 blasting spurs, each of which was roughly 1000 feet apart and connected to a 5 kW 110-volt transformer. The fuses were connected to this spur and when a switch on the transformer was thrown the current ignited all the fuses simultaneously, ensuring that each device detonated.[56] The value of this new system was self-evident as 14,325,876 of the cubic yards of material were removed from the Central Division alone during the course of the year.[57]

The increase in energy also had the unanticipated consequence of unleashing Isthmian entropy. A frustrated George Goethals was forced to admit that, "The slides continue to be a source of annoyance."[58] Assurances from the previous year that the Cucaracha slide had been contained proved premature as it grew to cover an area of twenty-seven acres.[59] Ultimately, no fewer than ten additional slides popped up between July 1908 and June 1909, forcing Central Division chief D.D. Gaillard to oversee the removal an additional 884,530 cubic yards of material. And yet, in the face of the pervasiveness of these slides, the Gaillard remained naively optimistic, suggesting that slides would only necessitate the removal of an additional 1,000,000 cubic yards from the cut.[60] Fate soon proved this optimism misplaced, but given the amount of energy at his disposal, Gaillard felt slides could easily be dealt with.

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[56] D.D. Gaillard, "Annual Report of the Central Division FY 1909," July 27, 1909, pg. 71.
[57] *Ibid*, pg. 72.
[58] George Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1909," pg. 16.
[59] *Ibid*, pg. 16.
[60] D.D. Gaillard, "Annual Report of the Central Division FY 1909," pg. 83-84.

Landslides continued to complicate the creation of the Panama Canal, but the growth of energy made them see trivial obstacles. Oil and electricity had grown increasingly important since July of 1908, and the overall increase in energy on the Isthmus suggested that more energy could impose order on the entropic environment. It's worth mentioning that it wasn't only fossil fuels and electricity that made up this increase. By the end of April 1909, the Commission set a record with over 33,699 laborers on the work.[61] By July of 1909, a tremendous amount of progress had been made in construction, thanks in large part to the adoption of a diverse array of energy sources, each of which was suited for particular tasks. The flexibility and fluidity that this system afforded was crucial to construction and helped impose a degree of order on the Panamanian environment.

Abundant Energies

Under Goethals leadership the work reached a fever pitch by the summer of 1909. The completion of the Gatun and Miraflores power plants revolutionized lock construction while coal and oil consumption exploded in the Panamanian interior as D.D. Gaillard's Central Division continued to wage war on the entropic tendencies of the Culebra Cut. All these factors coalesced to usher in the most diverse and prolific energy regime of canal construction. While energy consumption had been increasing for the last several years, the tremendous jump that took place between July 1st, 1909 and June 30th, 1910 was the largest of Goethals' tenure. Consumption increased across all departments on the Isthmus, and across all energy sources.[62] The number of laborers on the Isthmus ballooned to nearly 39,000 during the dry season of 1910 and was so

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[61] C.A. Devol, "Annual Report of the Quartermasters Department for the Fiscal Year Ending June 30, 1909," July 30, 1909, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report of the Quartermaster's Department (ICC), pg. 207.

[62] Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1911," pg. 510.

substantial that the ICC stopped recruiting laborers for the Isthmus altogether later that year.[63] The abundance of energy even extended to pack animals. C.A. Devol, the head of the Quartermaster's Department, noted, "More animals have been available for and more have been used in construction work than at any other period on the canal work. Teams were used in the spillways at Miraflores and Gatun, on the reservoirs at Gatun and Toro Point, in the canal bottom at San Pablo, and on paving and sewer work in the city of Panama."[64] This concentration of energy was unprecedented, dwarfing the volume of energy used in years past, and continuing the trend of utilizing as broad an array of energies as possible.

One of the chief sources of excitement in the fall of 1909 was the opening of the Gatun powerplant. In August of 1909, it came online and began providing power for the construction plant building the Gatun Locks. This process was far from efficient. When the plant opened only one of its three generators was working, generators number two and three requiring replacement parts and increased insulation respectively.[65] These issues lingered through the end of the year. In March of 1910 two of the generators again burnt out, but by this point in time they were quickly replaced and put back to work. Despite these hiccups, the Gatun plant was producing roughly 850,000-kilowatt hours a month from 6400 barrels of oil by the spring of 1910.[66] Consequently the stations output grew as the year progressed. Between August and December of 1909, the station generated roughly 1,000,000 kWh. Between January 1, and June 30, 1910

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[63] C.A. Devol, "Annual Report of the Quartermasters Department for the Fiscal Year Ending June 30, 1910," July 1, 1910, USNA, RG 185, Collection PL 153 31, Box: 514: Folder: Annual Report Quartermaster's Department (ICC), pg. 306.
[64] *Ibid*, pg. 307.
[65] J.P. Jervey, "Monthly Report of the Work Done on the Gatun Locks for the Month Ended August 31, 1909," September 8, 1909, USNA, RG 185, Collection PL 153 32 Monthly Reports, Box 453: Folder: Monthly Reports of the Atlantic Division from July 1, 1909 to October 31, 1909, pg. 1
[66] J.P Jervey, "Monthly Report of Work Done at the Gatun Locks for the Month Ended March 31, 1910," April 6, 1910, USNA, RG 185, Collection PL 153 32 Monthly Reports, Box 453: Folder: Monthly Reports of the Atlantic Division from November 1, 1909 to March 31, 1910, pg. 2.

production exploded to 4,314,586 kWh.[67] Jumps like this resulted in a greater abundance of energy at a far cheaper cost, a formula for success in Panamanian construction. A few months after the opening of the Gatun plant, its twin at Miraflores followed suit. The opening of the powerplants was crucial to attempts to mitigate the flow of entropy at the lock sites. Electricity's was a consistent and reliable source of energy that could be directed to a variety of tasks. While it was relatively fixed in its distribution, the creation of an electricity-based plant at the locks allowed for regular, measured, and long-term applications of energy capable of creating and, more important, maintaining human altered landscapes in the fluid Panamanian environment.

These powerplants powered extremely complex infrastructures directed primarily towards the pouring of concrete, a material that could mitigate entropy by halting shifting soils and precluding the need for external injections of energy. As much of Panama's entropy stemmed from the hydrological conditions of the region and rain's capacity to erode and saturate soils, concrete, a fixed and impermeable structure, was essential to minimize the rate of entropy on the Isthmus and consequently minimize the amount of energy that needed to be infused into the Canal to maintain it. Concrete production took sand and gravel supplied by massive rock crushers from quarries near the lock sites and combined them with water and cement. The resulting concrete created static structures that withstood the erosive forces of Panama far more effectively than the fluid materials that naturally occurred in the region. As the lock sites were the lynchpin of the entire canal system it was imperative that they were created with a material that withstood the entropic challenges of Panama with only minimal injections of energy.

[67] William Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1910," July 31, 1910, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Report Atlantic Division: 1909-1913, pg. 118.

To this end, a massive plant was installed at the Pedro Miguel locks which mirrored that already at work in Gatun. Twelve 11.5-ton locomotives ran between storehouses and cranes at the lock. The locomotives carried two cars which held two buckets capable of carrying 64 cubic feet of concrete. Berm cranes at the storehouse loaded the buckets onto the locomotives which carried the concrete to the lock site. There, chamber cranes unloaded the full bucket and gave the locomotives an empty bucket to bring back to the storehouse to be refilled. The chamber cranes then poured the concrete where it was needed in the lock foundation.[68] This method proved remarkably efficient and made rapid headway at both the Gatun and Pedro Miguel locks. While the plant was not fully installed at Pedro Miguel until July of 1910, it paid immediate dividends. Between September of 1909 and the end of the year, the Pacific division poured 166,868 cubic yards of concrete at Pedro Miguel.[69] Gatun saw even more progress. Between July 1909 and June 1910 over 500,000 cubic yards of material were poured at the Atlantic locks.[70] This process was so efficient that starting in April of 1910, the ICC began accepting offers from contractors for the construction of the lock gates and the machines that would control them. Ultimately the contract was awarded to McClintic-Marshall Construction Company of Pittsburgh, PA at a cost of $5,374,474.82 for the entire work.[71]

Electricity powered the plant necessary to lay the foundation for the lock sites, but until they were complete entropy could still rear its ugly head. Slides and flooding grew problematic, particularly at the Gatun locks. The search for solid bedrock at the Atlantic terminus led to

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[68] S.B. Williamson, "Annual Report of the Pacific Division for the Fiscal Year Ending June 30, 1910," July 28, 1910, USNA, RG 185, Collection PL 153 31, Box 509: Folder: Annual Reports of the Pacific Division for Fiscal Years 1909-1912, pg. 162.
[69] *Ibid*, 167.
[70] George Goethals, "Annual Report for the Isthmian Canal Commission for the Fiscal Year Ended June 30th, 1910," September 1, 1910, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer of the ICC, pg. 9.
[71] *Ibid*, pg. 3.

excavation between 30-40 feet below sea-level in the lowest set of locks. The digging destabilized the surrounding banks and, after substantial flooding on November 11th and again on November 20th, the shovels at work on the locks were forced to abandon the work.[72] Pumps struggled to deal with the flooded locks and ultimately the work was delayed by these continuing hydrological issues.[73] The delay caused by these slides may have been longer were it not for the efforts of the six dredges at work on the Atlantic Division. Nearly 5,000,000 cubic yards of material was removed from the canal prism by these vessels.[74]

For S.B. Williamson's Pacific Division, dredging and pumping were crucial to the creation of the Canal, but traditional excavation played a larger role. The bulk of excavation at the Pedro Miguel Locks neared completion by June of 1910, despite two small slides.[75] As the cut approached Miraflores, however, more work remained to be done. Shovels moved 99,703 cubic yards from the trough between Pedro Miguel and Miraflores, while several more displaced 285,354 cubic yards from the upper locks of Miraflores.[76] These shovels were far less effective in the lower locks of Miraflores, where the presence of water forced engineers to use the suction dredge *Sandpiper*. As excavation shifted into the deeper water south of the Miraflores Locks, dredges again played a substantial role, removing 7,956,143 cubic yards of material.[77]

The diverse prime movers at work at the locks suggested the complexity of the task at hand. Containing and mitigating the entropy of Panama required a broad array of energies and tools, each of which fulfilled a specific function in various environments around the locks. Given

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[72] Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1910," pg. 112.
[73] *Ibid*, pg. 118.
[74] *Ibid*, pg. 112.
[75] Williamson, "Annual Report of the Pacific Division, 1910," pg. 165.
[76] *Ibid*, pg. 169.
[77] *Ibid*, pg. 172.

the breadth of the local environment, it was unsurprising that this location should be the site at which energy sources were most broadly distributed. Electricity powered the plant that was laying the concrete structures of the locks themselves while coal and oil-fueled machines removed earth on land and on the water. But as one traveled away from the locks and moved inland towards the continental divide, where the focus of the work was focused almost exclusively on excavation, the energy regime became increasingly homogenous.

In D.D. Gaillard's Central Division, the bulk of energetic growth was confined to an increase in the human labor pool the Division had at its disposal as well as a monumental jump of nearly 100,000 tons of coal.[78] While fossil fuels provided a tangible bellwether for the expansion of energy in the region, the greatest testament to the fact that the ICC had finally met its demands for energy may have been the decision to halt the importation of laborers in January of 1910 after bringing only 2,519 men to the Isthmus.[79] The cessation of labor recruitment stemmed from several factors, the chief among them the fact that immigration outpaced emigration by 21,114. This glut of human energy precluded the necessity of importing additional laborers from abroad. Thanks to the influx of laborers the Commission was able to count a record of 38,767 employees on its rolls in March of 1910.[80] The efficacy of mechanical labor had always been predicated by the availability of human labor. As such, the decision to halt the importation of laborers was an acknowledgment of the fact that the ICC had effectively met its perceived energetic needs on the Isthmus. Perhaps the most interesting part of this relationship was the way in which the growth, particularly in the gold rolls, accompanied the utilization of

[78] Panama Railroad Company Board of Directors, "Annual Report of the Board of Directors of the Panama Railroad Company to the Stockholders for the Fiscal Year Ending June 30, 1910," pg. 22.
[79] C.A. Devol, "Annual Report of the Quartermasters Department for the Fiscal Year Ending June 30, 1910," July 1, 1910, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report of the Quartermasters Department (ICC), pg. 305.
[80] *Ibid*, pg. 306.

more coal on the Isthmus. Mechanics in charge of the maintenance of machines accounted for nearly three-quarters of all hourly gold employees on the Isthmus by 1910.[81] Their increase in numbers directly correlated with the expansion of mechanical labor at work in Panama.

The muscles making their way to the interior of Panama found themselves overshadowed quite literally by the continuing influx of mechanized labor that sought to establish control over the Culebra Cut. Over the course of the year, the Central Division alone consumed 187,326 tons of coal.[82] This injection of fuel immediately paid dividends as the Central Division removed 17,558,364 cubic yards of the 19,903,000 cubic yards excavated across the Isthmus during the year.[83] This was due in large part to the continuing increase in shovels that the division had at its disposal. During 1910 the Central Division employed: two 45-ton Bucyrus, fourteen 70-ton Bucyrus, 32 95-ton Bucyrus, two Marion Model-60s, and 11 Marion Model-91s. Engineers were also becoming increasingly skilled at maximizing their efficiency, further increasing the efficiency of the machines. In 1908 shovels had averaged 121.4 cubic yards excavated per hour under steam. By 1909 that figure had jumped to 150.46, and it climbed again to 155.8 in 1910.[84]

Increases in coal consumption were in large part responsible for the growth in energy that dominated the Isthmus during the year, but oil too saw a steady increase in use. It was the dominant source of fuel at power plants and was also increasingly being used for excavation and transportation. The greatest testament to the importance of oil was the Mechanical Division's decision to create a position for a traveling engineer, who inspected all facilities on the Isthmus

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[81] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending 1910," USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report Second Division 1909-1913, pg. 208.
[82] D.D. Gaillard, "Annual Report of the Central Division FY 1910," July 26, 1910, USNA, RG 185, Collection PL 153, Box 502: Folder: Annual Narrative Reports of the Central Division FY 1909-1913, pg. 156.
[83] Gaillard, "Annual Report of the Central Division for FY 1910", 138; Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending 1910," pg. 205.
[84] Gaillard, "Annual Report of the Central Division for FY 1910," pg. 141.

to provide guidance on the efficient and economical use of oil.[85] Indeed the program proved so successful that by the end of the year a second engineer had been appointed to serve in a similar function.[86]

The 100,000-ton increase in coal consumption and the increase in employment that took place between July 1909 and June 1910 allowed the ICC to finally reach a pool of energy it was comfortable with. The increase in energy and efficiency suggested that it was possible to break through the Continental Divide and complete the excavation in the Culebra Cut. While continuing landslides indicated that Panama's entropy would remain a problem, the massive amounts of energy at work in the Isthmus were more than capable of keeping it in check.[87] As to the long-term stability of the region, the creation of power plants at Gatun and Miraflores held the promise of a steady and continuous supply of energy that could be used to mitigate entropy's long-term consequences. The ICC had reached its energy apex, now all that was left to do was divide the Isthmus and unite the world.

Plateauing Power

Given the sheer scale of the increase in energy consumption that had taken place by July 1, 1910, it was unsurprising that energy plateaued in 1911. The stabilization of energy consumption was most acute in those sources of energy that had been most important to canal construction up to this point in time: coal, and human labor. In many ways, the decline reflected the fact that Goethals had finally been able to maximize the ICC's energy consumption had an adequate volume of energy to fully realize the vision of interoceanic transit. And yet when looking at individual energy regimes, 1911 continued the incessant trend of electricity and oil

[85] Rousseau, "Annual Report of the Second Division," pg. 232.
[86] Goethals, "Annual Report of the Isthmian Canal Commission FY 1910," pg. 36.
[87] Gaillard, "Annual Report of the Central Division," pg. 139.

slowly laying claim to more of the Isthmian energy network. As excavation wound down in most areas outside of the Culebra Cut, the ICC turned to the energy sources more efficient and economic at maintaining and constructing fixed landscapes rather than excavating them. Coal still dwarfed the utilization of any other source of energy; however, electricity and oil's centrality to the work was increasingly obvious.[88]

Despite the relative stability that marked the year, the most marked distinction was the drastic increase in oil consumption which now accounted for more than a third of the energy consumed in the Isthmus. More and more Panama Railroad Locomotives used oil as their primary source of fuel, and the ICC itself saw a drastic uptick in its oil consumption thanks in large part to the rise in fixed engines and plants.[89] Ultimately, oil was simply more economical than coal. Coal still cost roughly $6 per ton thanks to its substantial shipping costs. At $1.10 a barrel, the ICC could purchase the equivalent of one ton of coal (four barrels) for only $4.40. These significant savings led Goethals to prefer oil to coal and warranted more investment in this source of energy.[90]

The plateauing of energy sources on the Isthmus also extended to human energy. Quartermaster C.A. Devol was pleased to note that, "This past year has been the first since the inception of the work that no contract laborers have been brought to the Isthmus by the Commission. The last shipment was of men received was in January 1910, over a year and a half

[88] Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1911," pg. 510.
[89] Panama Railroad Company Board of Directors, "Annual Report from the Board of Directors of the Panama Railroad Company to the Stockholders for the Fiscal Year Ending June 30, 1911," July 1911, USNA, RG 185, Collection PL 153 31, Box 510, pg. 23.
[90] Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1911," pg. 510

ago."[91] As a result, the number of laborers stayed relatively static, peaking in January of 1911 with a total of 37,271 employees, just below the total from the fiscal year 1910.[92] Here too the ICC had met their energetic needs, however, there were some signs of trouble on the horizon. Turnover remained problematic for silver and gold laborers alike, forcing the Quartermaster's Department to constantly be on the lookout for new employees. In previous years this problem had been irrelevant due to the volume of immigrants coming to the Isthmus; however, 1911 saw a significant decrease in potential laborers as immigration only outpaced emigration by 4,910 over the course of the year compared to 21,114 the previous year.[93] While this trend did not immediately endanger the work, it did point to the fact that laborers came to Panama only when there was an established need for their work.

Little had changed in D.D. Gaillard's Central Division where steam shovels and coal waged their war of attrition against the entropy of the Panamanian landscape. As the Cut grew deeper, the material which machines were excavating grew increasingly diverse and varied. Goethals suggested that this was the chief challenge in creating the Cut, arguing that, "The geological formation of the Isthmus is very irregular and the character of material encountered in the Cut is constantly changing, so that it is impossible to determine in advance where slides and breaks are liable to occur, or when they do occur, the slopes which they will ultimately assume."[94] This complexity kept engineers guessing and meant that as they altered the environment they subsequently destabilized it by breaking into materials and formations that

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[91] C.A. Devol, "Annual Report of the Quartermaster's Department for the Fiscal Year Ending June 30, 1911," July 1, 1911, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report Quartermaster's Department (ICC), pg. 354.
[92] George Goethals, "Annual Report of the Isthmian Canal Commission for FY Ending June 30, 1911," September 1, 1911, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer, pg. 52.
[93] Devol, "Annual Report of the Quartermaster's Department for FY 1911," pg. 354.
[94] Goethals, "Annual Report of the Chairman and Chief Engineer for FY 1911," pg. 22.

could not support the banks of the Cut on their own. As a result, the Bucyruses generated more work for themselves with every shovelful that they removed.

These slides regularly hindered work in the Cut, forcing Gaillard to divert resources to try to contain them. Despite the fact that the Central Division set a new record by removing 18,552,644 cubic yards between July 1910 and July 1911, they were also forced to add another 4,676,278 cubic yards to the amount of excavation that needed to be done.[95] Gaillard attributed this increase to "the unexpected development of slides beyond the limits assumed when making former estimates, especially in the two large slides at Culebra."[96] During the course of the year the Culebra slide, which was 7.3 acres at the beginning of the year, had extended to 46.6 acres, rivaling the 47.1 acres of the Cucaracha slide.[97] While slides remained a nuisance in the Cut, the utilization of 193,977 tons of coal by the Division allowed the mechanical labor force to keep pace. Indeed, the Division had managed to effectively halt the Cucaracha slide during the year.[98] Slides and coal consumption continued to grow in tandem, but the sheer volume of energy available to the Central Division meant that while slides could hinder the work, they never fundamentally threatened it.

The development of the harbor facilities that would support the Canal suggested that coal's importance would linger on well into the future. The fall of 1910 marked the first serious planning for the development of port facilities at both the Atlantic and Pacific terminals. Among the chief concerns of engineers was the ability to fuel ships that were making their way through the locks. Preliminary reports varied in the exact details of what the harbor should look like.

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[95] D.D. Gaillard, "Annual Report of the Central Division FY 1911," August 8, 1911, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports of the Central Division FY 1909-1913, pg. 134-135.
[96] *Ibid*, pg. 135.
[97] *Ibid*, pg. 149.
[98] *Ibid*, pg. 151.

However, there were several significant points of agreement, most of which revolved around the facilities' capacities to store and deploy coal and oil. This desire was expressed in the initial legislation approving the Canal which decreed "These facilities were to include the storing and furnishing of coal and other fuel for use both afloat and ashore...".[99] The ICC determined that it should construct two coaling stations, an Atlantic facility capable of holding roughly 200,000 tons and a Pacific facility capable of holding roughly 50,000 tons. In addition, both sites would each also have storage for roughly 80,000 barrels of oil.[100] The commitment to providing energy at the Canal itself directly addressed concerns that many Canal lobbyists had expressed about American energy security. Thanks to the administration of the Canal Zone, America could ensure that her military vessels in the region would always have access to reliable energy stores. Simultaneously, America could also compete with British coaling stations throughout Central and South America by allowing many ships to simply bypass them. These decisions showed that the ICC was acutely aware of the benefits offered by being the "crossroads of the world" and hoped to harness the energy windfall that could result.

While coal carved up the Culebra Cut and captured the imaginations of energy speculators, it was oil and electricity that made their presence felt in the fixed engines and power plants dotting the Canal Zone. The massive growth in oil consumption during the year was reinforced by the fact that the ICC doubled down on its previous endeavor to ensure more efficient and economical use of the fuel by hiring another traveling agent to educate employees on the proper use of fuel oil. The original two employees occupying the post had been focused on fuel consumption in locomotives before also instructing engineers and firemen on handling

[99] Goethals, "Annual Report of the Isthmian Canal Commission for FY ending June 30, 1911," pg. 36.
[100] Rousseau, "Annual Report of the Second Division for the FY ending June 30, 1911," pg. 207.

and properly firing oil. The new engineer had a far broader mandate. His duty "covered steam shovels, unloaders, spreaders, and all stationary plants, and was subsequently extended to the marine equipment."[101] The increasing oversight on fuel oil consumption yielded immediate returns. The Las Cascadas air compressor plant showed savings of 3.5 percent, the Mount Hope pumping plant 22 percent, the Gorgona pumping plant about 15 percent and the Cucaracha pumping plant about 11 percent. On average the traveling engineers generated savings of roughly 10 percent at nearly every site they visited.[102] This increased efficiency only served to reinforce the economy of oil and suggested the ICC's growing reliance on this new source of fuel was not an aberration, but rather a sign of the oil's importance on the completion of the work. Oil had more utility and was far cheaper than coal, and, as a result, it was a more practical source of consistent energy to keep entropy at bay as the Canal aged.

At the locks and at power plants located in the Panamanian interior, oil produced the electricity which illuminated towns, helped preserve food, and, at the lock sites, powered the incredibly complex machines responsible for the erection of the lock foundations. The three power plants located in the interior at Balboa, Empire, and Gorgona produced 4,911,134 kilowatt hours over the course of the year, a marked increase over their output from the preceding year.[103] Despite the increase in productivity these stations combined produced far less than the 6,797,714 kWh produced at Miraflores and the 12,962,247 kWh produced at Gatun.[104] The productivity of these sites was the result of two distinct factors. Both Miraflores and Gatun were larger than their counterparts in the interior and, as a result, had more turbines and generators. Additionally, the

[101] Goethals, "Annual Report of the Isthmian Canal Commission for FY ending June 30, 1911," pg. 44.
[102] Rousseau, "Annual Report of the Second Division for the FY ending June 30, 1911," pg. 210-211.
[103] A.L. Robinson, "Annual Report of the Mechanical Division for the Fiscal Year Ending June 30, 1911," August 1, 1911, USNA, RG 185, Collection PL 153 31, Box 507: Folder: Annual Reports (ICC) Mechanical Division from FY 1909-1914, pg. 8.
[104] Rousseau, "Annual Report of the Second Division for the FY ending June 30, 1911," pg. 209

larger size of the facilities allowed Miraflores and Gatun to generate their current from steam turbines while the powerplants at Empire and Gorgona relied on noncondensing engines and Balboa on condensing engines.[105] This was deliberate. The ICC recognized that upon the completion of construction the interior would be abandoned, and so it was unnecessary to build up large permanent plants in this region.

Miraflores and Gatun needed larger facilities to provide the power necessary to operate the massive construction plants at work on the canal locks. While minor slides continued to complicate work at both sites, excavation was ending. William Sibert was quick to point out that, at Gatun, shovel excavation was completed in the forebay, upper lock, middle lock, and lower lock during the year and by July of 1911, 2,085,000 cubic yards of concrete (68.34% of the total work) had been poured.[106] S.B. Williamson was similarly bullish on their progress at Pedro Miguel. Here excavation was also effectively complete and 665,055 cubic yards of concrete had been placed. This progress was so substantive that the Division made the decision to break up some of the plant at Pedro Miguel and move it to Miraflores In December of 1910. By June of 1911, 272,933 cubic yards of concrete had been laid at Miraflores, the bulk of it by the auxiliary plant.[107] Perhaps the best testament to the efficacy of this process lay in the fact that in the spring of 1911 the ICC made the decision to begin on-site work on the lock gates themselves. In January, contractors commenced work on the gates at Gatun, and in March they began at Pedro

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[105] Rousseau, "Annual Report of the Second Division for the FY ending June 30, 1911," pg. 209.
[106] William Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1911," July 31, 1911, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports Atlantic Division 1909-1913, pg. 113,115.
[107] S.B. Williamson, "Annual Report for the Pacific Division for the Fiscal Year Ending June 30, 1911," July 31, 1911, USNA, RG 185, Collection PL 153 31, Box 509: Folder: Annual Reports of the Pacific Division for Fiscal Years 1909-1912, pg. 159-164.

Miguel.[108] These developments suggested just how effective the plants at Gatun and Miraflores were and hinted at the impact they would have in the Canal Zone moving forward.

Miraflores and Gatun were constructed to last, and to play considerable roles in the long-term operation of the Canal. By 1911, the ICC turned its attention to the question of how the massive locks would be opened and how ships would travel through them. Recognizing the resources already at his disposal, H.F. Hodges, the head of the First Division (which oversaw lock construction), sought to use the existing power plants at Gatun and Miraflores to provide the power necessary for both these tasks. Hodges suggested that the existing power plant at Gatun should gradually be replaced by a hydro-electric station constructed on Gatun Dam.[109] While a hydro-electric plant was proposed as a means to provide power in the region as early as 1904, the tremendous progress on the Gatun Dam, made the proposal viable for the first time.[110] If it could be brought to fruition, the hydroelectric plant would turn one of the greatest obstacles to the construction of Isthmian transit, the Chagres River, into an essential source of power for the operation of both sets of locks.[111]

The ICC's emphasis on the hydroelectric plant was indicative of the organization's shifting priorities. Coal was still imperative to the completion of the work in Culebra, but the terminals were increasingly relying on oil and electricity to meet their energetic needs. Shifting energy consumption served as an indicator of the shifting nature of canal excavation itself. The plateauing of coal consumption and the substantial rise of oil and electricity suggested that the

[108] Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1911," pg. 3.
[109] H.F. Hodges, "Annual Report of the First Division for the Fiscal Year Ending June 30, 1911," July 27, 1911, USNA, RG 185, Collection PL 153 31, Box 506: Folder: Annual Reports (ICC) First Division FY 1909-1913, pg. 5.
[110] Sibert, "Annual Report of the Atlantic Division for FY Ending June 30, 1911," pg. 122.
[111] Hodges, "Annual Report of the First Division for the Fiscal Year Ending June 30, 1911," pg. 5.

era of excavation was over. As July of 1911 dawned, the Canal had been transformed from an excavation to a construction project, one with a myriad of energies at its disposal.

The Beginning of the End

Starting in July of 1911 the energy decline that began during the previous year became even more pronounced. While the ICC still possessed a considerable volume of energy, coal consumption was dwindling. Oil and electricity meanwhile were constituting a far greater percentage of Panamanian energy.[112] As excavation was completed throughout the Canal Zone, with the exception of the Culebra Cut, steam shovels and locomotives became less central to the creation of the Canal, and while dredges were still essential to the preparation of terminal facilities and lock approaches, the overall mechanical labor force of the ICC decreased over the next twelve months. Goethals' focus was increasingly placed on the preparation of harbor facilities, the locks themselves, and the power plants that would support them. The disassembling of the mechanized labor force that had been so integral to the removal of earth and rock suggested that the end of the enterprise was rapidly approaching and by the following summer oil was making up over a third of the fossil fuel energy consumed in Panama.[113]

The chief factor for the decline in coal was the tremendous progress that had been made in excavation. By July of 1912, estimates suggested that of the projected 125,735,000 cubic yards of dry material that needed to be removed to create the Canal, 108,309,364 cubic yards or roughly 86% had successfully been removed.[114] This remarkable productivity rendered steam shovels, and the energy infrastructure supporting them, increasing irrelevant beyond the bounds

[112] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1912," August 1, 1912, USNA, RG 185, Collection PL 153, Box 514: Folder: Annual Reports Second Division 1909 to 1913, pg. 215.
[113] *Ibid*, 215.
[114] *Ibid*, 215.

of the Culebra Cut. Sibert's Atlantic Division announced that they had completed its excavation near Mindi and was going to rely primarily on dredges going forward.[115] While minor slides at Pedro Miguel and Miraflores forced the Williamson's Pacific Division to use steam shovels more heavily than the Atlantic Division, here too the bulk of dry excavation had been completed.[116] In both cases, steam shovels were responsible for little more than mitigating slides and ensuring the stability of the landscape surrounding the locks. Actual work in the canal prism itself was almost exclusively the work of dredges.

Gaillard and other leaders of the Central Division also made the tactical decision to gradually diminish their mechanical force. As the central part of the Isthmus was to be flooded upon the opening of the Canal, the Central Division needed to be able to remove its material as quickly as possible when the work ended.[117] Much of this effort focused around limiting the size of their mechanical labor force. The Central Division took six shovels out of service during the fiscal year 1912 dropping the total number employed by the division from 52 to 46.[118] Simultaneously they removed 21.7 miles of auxiliary railroad tracks from the Cut.[119]

Despite its dwindling mechanical labor force, Panamanian entropy remained a fierce obstacle to Gaillard and the Central Division in the Culebra Cut. The Division removed

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[115] William Sibert, "Annual Report of the Department of Construction and Engineering: Atlantic Division FY Ending June 30, 1912," July 31, 1912, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports Atlantic Division 1909-1913, pg. 111.
[116] S.B. Williamson, "Annual Report of the Pacific Division for the Fiscal Year Ending June 30, 1907," July 31, 1912, USNA, RG 185, Collection PL 153 31, Box 509: Folder: Annual Report of the Pacific Division for the Fiscal Years 1909-1912, pg. 172,176.
[117] T.C. Dickson, "Annual Report of the Ordnance Department for the Fiscal Year Ending June 30, 1912," July 31, 1912, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Reports of the Second Division 1909 to 1913, pg. 259.
[118] Gaillard, "Annual Report of the Central Division for the Fiscal Year Ending June 30, 1911", 137; D.D. Gaillard, "Annual Report of the Central Division FY 1912," July 20, 1912, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports of the Central Division FY 1909-1913, pg. 148.
[119] *Ibid*, 152.

16,476,769 cubic yards of material between July 1911 and June 1912, but it once again had to direct a significant amount of its resources to countering slides. 35.9% of the total amount of material removed had been deposited by slides, a figure significantly higher than the 30.07% that had been removed due to slides during the previous year.[120] Entropy remained far from contained in the Culebra Cut.

It was unsurprising that slides became more prevalent as the Cut deepened. Gaillard noted that this outcome "was anticipated", but that it nonetheless proved extremely detrimental to the work as, "No plan of treatment for slides has proven thoroughly effective once they have developed, except that of excavating and hauling away the material composing the moving mass until the slide comes to rest upon reaching the angle of repose for the particular material in motion."[121] In principle, this approach seemed easy, but the inconsistent formations underlying the Cut meant that angles of repose could vary radically from one area of the Cut to the next.[122] The only way of adequately dealing with slides was an incessant process of trial and error as shovels simply removed material until banks stopped moving. While not an elegant solution, the tremendous amounts of coal still at work in Culebra afforded Gaillard an abundance of energy capable of mitigating the impact of these slides. While they were troubling, Gaillard suggested that slides were given "sensational importance" whenever they occurred and that, in reality, they were little more than inconveniences to the work.[123]

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[120] George Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending 1912," September 10, 1912, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Reports of the Chairman and Chief Engineer of the ICC, pg. 32.
[121] Gaillard, "Annual Report of the Central Division for the Fiscal Year Ending June 30, 1912," pg. 161.
[122] Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending 1912," pg. 33.
[123] Gaillard, "Annual Report of the Central Division for the Fiscal Year Ending June 30, 1912," pg. 34.

Goethals seemed equally confident in the progress of the work at the Canal's terminals. The Commission refined its plan for the creation of terminal facilities for fueling of ships and began constructing the coal pits and fuel tanks that would store energy for ships transiting the Canal. Cristobal, near the Atlantic terminus of the Canal, was dredged to hold a 200,000-ton coaling station. Two 40,000-barrel storage tanks were under construction on the mainland and pipes were created to transport the oil from the tanks to waiting ships. The plan for the Pacific terminus was slightly changed as the capacity of the facility at Balboa doubled from 50,000 tons to 100,000 tons to deal with the increased traffic expected from the West Coast. Here too, two 40,000-barrel storage tanks were under construction to deal with ships relying on oil.[124]

Miraflores and Gatun continued to provide the energy necessary for construction at the lock sites. The Gatun steam plant saw another massive jump in its energy output as it produced 16,263,510 kWh, a jump of nearly 4,000,000 kWh over the previous year. The Miraflores plant also saw a modest increase in output as it generated 9,552,400 kWh for construction at the Pacific locks.[125] At Gatun, construction on the locks was largely done and progress focused on the flare walls along the canal approach.[126] Construction at Pedro Miguel met with similar success and more of the auxiliary plant was transferred to Miraflores to focus on the construction of the lock foundations there. The result was the most productive year of construction yet as 751,540 cubic yards of concrete were poured at Miraflores.[127] While there was still work to be

[124] Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1912," pg. 216.
[125] A.D. Faure, "Annual Report of Cost Keeping Accountant FY 1912," August 31, 1912, USNA, RG 185, Collection PL 153 31, Box 504: Folder: Annual Report of the Cost Keeping Accountant, Office of the Chief Engineer, 1910-1913, pg. 305.
[126] Sibert, "Annual Report of the Atlantic Division for the Fiscal Year Ending June 30, 1912," pg. 122.
[127] Robinson, "Annual Report of the Pacific Division for the Fiscal Year Ending June 30, 1912," pg. 177.

done, the rapid progress at the locks redirected the attention of Sibert and the Atlantic Division to developing the Gatun Hydro-electric plant that would power the locks themselves.

The key to constructing the Gatun hydro-electric plant was completing the Gatun Dam. Material removed from the lock sites was used as fill for the massive structure, and by the end of the year nearly 20,000,000 cubic yards of material had been pumped and carried to the structure.[128] Largely this work progressed without incident. The lone challenge facing the dam's completion was increasing concern that the angle of repose for the dam was too steep and could shift if the Chagres ran particularly strongly. In response, Sibert and his engineers lowered the dam's height while simultaneously making the slopes supporting it more gradual.[129] These decisions provided a degree of stability for the dam and made it far more conducive to the creation of the power plant and by May of 1912, a steam shovel began working on gouging out the spillway where the hydroelectric plant would be located.[130]

While undoubtedly important, selecting and preparing the site for the dam was only one part of the equation. In September of 1911, H.F. Hodges, head of the Engineering Division, shared the specifications for the electric equipment and explained how it would be connected to the dam. The main generator consisted of three 2,000 kW units powered by three 2250 kW turbines located along the spillway.[131] The current would be conveyed by transmission lines to the locks themselves where a total of 36 transformers (sixteen at Gatun, eight at Pedro Miguel, and twelve at Miraflores) converted the 2,200 volts received from the power plant to 220

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[128] Sibert, "Annual Report of the Atlantic Division for the Fiscal Year Ending June 30, 1912," pg. 129.
[129] Goethals, "Annual Report of the ICC for the Fiscal Year Ending June 30, 1912," pg. 24.
[130] Sibert, "Annual Report of the Atlantic Division for the Fiscal Year Ending June 30, 1912," pg. 129, 133.
[131] H.F. Hodges, "Annual Report of the First Division for the Fiscal Year Ending June 30, 1912," July 1912, USNA, RG 185, Collection PL 153 31, Box 506: Folder: Annual Reports (ICC) First Division FY 1909-1913, pg. 2.

volts.[132] This voltage powered 966 motors spread across the three locks that handled tasks ranging from opening and closing the lock gates to powering the electric locomotives that carried ships through the Canal. This complex network of wires, motors, and transformers ran throughout the foundations of the locks, forming copper arteries that would allow ships to transit the locks.[133] While construction on these systems didn't begin in earnest until the summer of 1912, the ICC awarded contracts for the hydraulic equipment to the Pelton Waterwheel Company, and the electrical equipment to General Electric in November of 1911. Delays in the delivery of the equipment prevented the ICC from beginning electrical work in earnest, but the decision to rely on electricity as the dominant source of power for the operation of the locks marked yet another example of the declining utility of coal. The electricity produced by the Chagres River was more efficient, economical, and theoretically reliable than what coal could produce.

As the summer of 1912 arrived, dry excavation was complete nearly everywhere except for the Culebra Cut. Coal remained the chief source of fuel in the Cut where steam shovels continued to deal with the entropy of the Panamanian environment, but as the Canal approached completion, oil and electricity were increasingly dominating energy production and consumption throughout the Isthmus. The low cost of these energies and their capacity to provide consistent, economical sources of energy rendered them far more practical for long-term utilization. The chief development of the year, the acquisition of the materials for the Gatun hydroelectric plant, suggested that Panama would become an electrical Isthmus rather than a canal of coal.

[132] Goethals, "Annual Report of the ICC for the Fiscal Year Ending June 30, 1912," pg. 11.
[133] Hodges, "Annual Report of the First Division for the Fiscal Year Ending June 30, 1912," pg. 8.

Marshaling Maintenance

The summer of 1912 brought with it a tangible decline in the overall consumption of energy. While human labor and animal labor both increased over the next year, thanks in large part to efforts to install the lock gates, coal consumption dropped significantly as the Gaillard's Central Division approached the end of their work. These developments reflected the changing objectives of the ICC The Commission had largely completed the extensive landscape alteration necessary to create an aquatic passage across the Isthmus. The focus now was on adopting an energy infrastructure that could hold the entropy of the Isthmus at bay and maintain the consistent operation of the Canal itself. To this end, work focused on the construction of the Gatun hydroelectric station and the transmission line that would carry current between the Atlantic and Pacific terminals. This transition was also defined by an aggressive attempt to remove resources and laborers from the interior of the Canal Zone which would soon be the site of Gatun Lake. The emphasis placed on the creation of an electrical landscape and the attempts to eradicate the excavation infrastructure that had helped carve out the canal prism defined the final era of canal construction and paved the way for the opening of the Canal itself.

The single greatest testament to the changing nature of work in the summer of 1912 was the first decline in the overall consumption of energy since the commencement of the work.[134] The overall decline in energy was fairly modest at only a little over 20,000 tons over the previous year, and yet the fact that energy consumption declined at all was a substantial but inevitable change. There were a variety of factors that contributed to this trend but particularly important was the fact that many of the machines that remained in service were relying on oil as their chief

[134] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1913," August 15, 1913, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report of the Second Division 1909-1913, pg. 249.

source of fuel. By July of 1913, fifteen of the sixteen Panama Railroad Locomotives in mainline service had been converted to run on oil rather than coal.[135] This, in conjunction with the declining importance of steam shovels, substantially cut into coal usage.

Ironically, the decline in coal was accompanied by a slight resurgence in the value of human and animal labor. In March of 1913, as work on the lock gates reached its peak, 44,733 human laborers were at work on the Isthmus.[136] This influx of labor pointed to one of the complications faced by the ICC during the final phase of construction. The installation of locks required a tremendous number of skilled craftsman capable of driving rivets and installing electrical equipment that required a level of prevision beyond the scope of mechanical labor.

Intriguingly, it wasn't just on the Canal that human labor increased. The Public Works Department on the Isthmus constructed roads to connect isolated townsites on the Isthmus with significant locations like Empire. Animal labor proved valuable to this task and, for the first time in five years, the ICC found itself purchasing pack animals to help pave roads and transport people and items.[137] More difficult to obtain were human laborers willing to lay roads through swampy jungles. In response the Public Works department relied on a novel source of labor: convicts. While convict labor never became prevalent in Panama, the fact that it was used at all suggested that the ICC certainly still needed human energy even though construction was rapidly approaching its conclusion.[138]

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[135] H.H. Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1913," pg. 247.
[136] R.E. Wood, "Annual Report of the Quartermaster's Department for the Fiscal Year Ending June 30, 1013," July 1, 1913, USNA, RG 185, Collection PL 153 31, Box 514: Folder: Annual Report of the Quartermaster's Department (ICC), pg. 372.
[137] *Ibid*, 374
[138] ICC, "Annual Report of the Division of Public Works for the Fiscal Year Ending June 30, 1913," July 12, 1913, USNA, RG 185, Collection PL 153 31, Box 512: Folder: Annual Reports of the Division of Public Works for Fiscal Years 1907-1914, pg. 7.

The number of laborers may have been growing at terminal facilities, but it was dwindling just about everywhere else. Even Gaillard's Central Division saw a substantial decline in its energy consumption, labor force (both human and mechanical), and progress during the year. The Central Division managed to remove 12,828,086 cubic yards during the year, a figure considerably lower than that removed the preceding year. This decline in productivity was partially intentional as the Division shrank its mechanized labor force down to only 42 steam shovels.[139]

And yet this optimism may have been somewhat premature. Slides continued to increase projections for the amount material to be removed. By July of 1913 engineers estimated that they needed to excavate an additional 9,280,237 cubic yards of material. Gaillard suggested that this substantial increase was "due to the development of new slides as the depth increased and to increased activity of slides already existing at the beginning of the fiscal year."[140] Perhaps the most compelling argument for the lingering impact of the slides was the fact that of the 12,828,086 cubic yards removed during the year, 5,899,200 cubic yards or 46.67 percent of the material removed was the result of slides.[141] At the end of the previous fiscal year, the division had been confident that many of the slides, particularly the incessant Cucaracha slide had reached a stable angle of repose, but an increasingly perturbed Chief Engineer Goethals concluded simply that this, "had not been realized."[142]

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[139] D.D. Gaillard, "Annual Report of the Central Division FY 1913," July 21, 1913, USNA, RG 185, Collection PL 153 31, Box 502: Folder: Annual Reports of the Central Division FY 1909-1913, pg. 140, 143.
[140] *Ibid*, pg. 141.
[141] George Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1913," September 15, 1913, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Report of the Chairman and Chief Engineer of the ICC, pg. 26-27.
[142] *Ibid*, pg. 27.

The continuing slides were little more than a nagging thorn in the side of construction until January 20th, 1913. On that day, "the basalt rocks broke and there slid into the Cut approximately 2,000,000 cubic yards of material extending completely across the Cut, topping the tracks on the 67-foot level and completely stopping the passage of trains from the north."[143] Gaillard attempted to deal with this issue by installing pipes to remove hydraulic material, but heavy rains in the days following saturated the soil, shifting it further, and snapped many of the pipes. To finally deal with the slide and remove the material the Division developed a split shift policy in which shovels worked in both the Cut and on slides for twelve-hour days. This approach allowed them to make headway but by the end of the year, they still anticipated the removal of nearly 6,000,000 cubic yards of material from the Culebra and Cucaracha slides alone.[144]

These developments indicated that a new course of action was needed. Frustrated with the challenges presented by the continued reliance on dry excavation, in February of 1913, Goethals and his engineers proposed flooding the Cut the following October in hopes that slides would be easier to manage. Some viewed this plan with apprehension. Goethals noted that, "It has been the general belief that the effect of the water in the Cut would tend to retard slides and the experience below the Gatun locks in the sustaining power of water against slides fully justifies this belief; on the other hand the geologist is of the opinion that the water may to some extent develop new slides."[145] Despite the risks, the incessant slides had substantially delayed the work in the Cut and suggested that a new tactic was needed to deal with Isthmian entropy.

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[143] Goethals, "Annual Report of the Chairman and Chief Engineer for the Fiscal Year Ending June 30, 1913," pg. 27.
[144] *Ibid*, pg. 27-29.
[145] *Ibid*, pg. 82.

Considerable work remained to be done before this ambitious plan could be put into action. Both the Pacific and Atlantic Locks were far from complete and the terminal facilities, which were now under construction, raised new questions about how the United States would determine who would have access to these potentially lucrative energy markets. Before the Commission could consider the completion of the work and the passage of ships through the locks they had to deal with these issues.

The first issue that the ICC dealt with wasn't physical, but instead political. The construction of the fueling facilities at the canal terminals had garnered the interest of energy speculators looking to capitalize on the opportunity to distribute their fuel.[146] The ICC was bombarded by requests from coal dealers who wanted to lease space to supply their coal to ships refueling at either facility. And yet there was no legislation that gave the United States authority to lease land apart from a 1909 ordinance allowing land to be used for agricultural purposes. The government was careful to note however that it did not intend to "exercise a monopoly of the coal business on the Isthmus."[147] To this end, they decided to allow companies and individuals to rent out space at the two handling facilities for a reasonable rental fee and a merchandise tax of five cents for each ton of coal sold.[148] This policy mitigated their issue, but also pointed to the substantial energy markets created by the Canal's opening.

In addition to questions over the energy trade, the ICC also faced the task of completing the construction of its terminal facilities. Electricity still provided the dominant source of energy for the construction and maintenance of these facilities. The Miraflores powerplant remained productive, generating over 9,000,000 kilowatt hours between July of 1912 and June of 1913, but

[146] Rousseau, "Annual Report of the Second Division for the Fiscal Year Ending June 30, 1913," pg. 217-218.
[147] Goethals, "Annual Report of the ICC for the Fiscal Year Ending June 30, 1913," pg. 53.
[148] *Ibid*, pg. 53.

the Gatun plant only produced 10,315,790 kilowatt hours during that same period.[149] While this was a substantial decline in productivity, it pointed to the fact that much of the work being done by the construction plant at Gatun was effectively done. Simultaneously, the Gatun hydro-electric plant was close to coming on line and the Atlantic division began transferring equipment to that facility.

The major challenge facing the Pacific Division was the fact that it no longer existed. S.B. Williamson resigned in December of 1912 claiming that he had completed enough of the work to render a full division unnecessary. Goethals disagreed. The Chief engineer was incensed by what he saw as Williamson's betrayal and reluctantly created the Fifth Division to finish the remaining construction.[150] In some ways, Williamson may have been correct. During the remainder of the year, the Fifth Division poured an additional 58,262 cubic yards of concrete at Pedro Miguel, bringing the total to 906,187 cubic yards and leaving only specialized structures such as lighting towers and control sheds left to build.[151] Miraflores faced some challenges with slides, particularly along the western wall, but here too construction progressed rapidly and by July 1913 the Fifth Division had nearly completed concrete work at Miraflores.[152]

Sibert's Atlantic Division operated far more smoothly than the Pacific Division. The advanced state of work on the locks meant that, except for cleaning up some slides and finishing a bit of the foundation, the Atlantic division focused on the completion of the Gatun Dam and the construction of the hydroelectric power plant that would provide the energy necessary to operate

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[149] AD Faure, "Annual Report of Cost Keeping Accountant for the Fiscal Year Ending 1913," August 31, 1913, USNA, RG 185, Collection PL 153 31, Box 504: Folder: Annual Report Cost Keeping Accountant, Office of the Chief Engineer 1910 to 1913, pg. 282.
[150] H.O. Cole, "Annual Report of the Fifth Division for Fiscal Year Ending June 30, 1913," July 31, 1913, USNA, RG 185, Collection PL 153, Box 506: Folders: Annual Reports (ICC) Fifth Division for FY 1913, pg. 161.
[151] *Ibid*, pg. 163.
[152] *Ibid*, pg. 166.

both sets of locks. By July of 1913, the dam had been entirely filled and the concrete at the spillway was 98% completed.[153] The quick work on the dam and the spillway opened the door for the creation of the power station itself. Sibert initially focused on creating the superstructure in which the equipment would be housed. Work on this front moved swiftly and on May 16th, 1913 erection of the superstructure began at the site. Over the course of the month, the Division installed 65% of the steel, cased the penstocks in concrete and completed much of the structural work for the generators.[154]

Delays in the delivery of steel meant that electrical equipment was not installed until the summer of 1913. In the meantime, the ICC focused its attention on preparing the infrastructure that would carry the current from the hydroelectric station to the locks at both the Pacific and Atlantic terminals.[155] At the Atlantic Locks, the Electrical Division began installation of the motors, switchboards, and breakers that distributed the power coming from the hydroelectric plant. By the end of the year, all electrical equipment necessary for the operation of the gates was delivered and nearly 25% of it was installed.[156] This work was supplemented by a tremendous amount of ductwork at both facilities. The ICC placed orders for 2,372,110 feet of insulated wires to convey electricity through the facilities. By the end of the year, the order had been filled and the Division had already run over 400,000 feet through ducts at the lock sites and hydroelectric station.[157] The massive amount of electrical work done suggested just how close

[153] Sibert, "Annual Report of the Atlantic Division for the FY Ending June 30, 1913," pg. 129.
[154] *Ibid*, pg. 130.
[155] H.F. Hodges, "Monthly Report of the First Division for the Month Ended June 30, 1913," July 10, 1913, USNA, RG 185, Collection PL 153 32, Box 468: Folder: Monthly Reports of the First Division Between May 1, 1913, and June 30, 1913, pg. 6.
[156] *Ibid*, pg. 6.
[157] *Ibid*, pg. A-3.

construction was to concluding and also reinforced the central role the hydroelectric station and Miraflores plant would play in the operation of the Canal.

All the duct work and cabling in the world was useless however without access to the electricity being generated at the hydroelectric plant. Arguably the most important development during the spring of 1913 was the decision to construct a 44,000-volt transmission line between Balboa and Cristobal, connecting the Gatun and Miraflores plants.[158] This transmission line was crucial to the successful operation of the Canal as it provided redundancy should either of the power plants go offline. The line consisted of duplicate 3-phase lines draped atop 40-foot steel towers spaced in 300-foot intervals (200 feet along curves) alongside the Panama railroad. This line connected four substations located at Cristobal, Gatun, Miraflores, and Balboa, allowing the ICC to distribute power to each of those sites.[159] Once this transmission line and the hydroelectric power plant were connected, the Canal Zone would have a steady reliable source of power that could both ensure the continued operation of the Canal itself and provide power and light throughout the Canal Zone.

The creation of the transmission marked the energetic shift taking place in Panama. As energy consumption on the Isthmus decreased, the dream of connecting the oceans neared realization. Slides remained problematic, but the decision to flood the Culebra Cut in October of 1913 suggested that the era of dry excavation was coming to an end. Meanwhile, a massive human labor force directed its substantial, and specialized energy at the tasks of erecting the locks gates and the electrical subsystems that controlled them. Perhaps most importantly the ICC made considerable progress on the installation of the Gatun hydroelectric station, and the

[158] Goethals, "Annual Report of the ICC for the Fiscal Year Ending June 30, 1913," pg. 12.
[159] *Ibid*, pg. 12.

network of poles and wires that would carry its current throughout the Canal Zone. In this sense, 1913 marked a passing of the torch. Coal still provided valuable energy to ships looking to refuel on their way through Panama, and still was essential to the operation of dredges and a few remaining steam shovels, but electricity and oil had established themselves as equally important in the energy network that powered the Canal Zone.

The End of an Era

Woodrow Wilson's electrifying detonation of the Gamboa Dam and the subsequent flooding of the Culebra Cut may have been the most dramatic moment of the fall of 1913, but the most important development was the completion of the locks and the creation of the electrical infrastructure that operated them. Completing the Gatun hydroelectric station, and the transisthmian transmission line, as well as installing electrical equipment at the locks themselves soon became the primary focus of the work. In addition, the Commission expanded efforts begun during the previous fiscal year to remove material and manpower from the Isthmian interior in anticipation of the Canal's opening. For arguably the first time the ICC had to reckon with an overabundance of energy rather than a shortage of it.

The dwindling nature of the work on the Isthmus was reflected in the sharp decline in energy consumption that started in July of 1913. This trend impacted nearly all facets of the Isthmian energy regime but was most prevalent in the coal and human energy that had been so crucial to excavation. The ICC made the decision to abolish Gaillard's Central Division on October 10th, 1913, the same day the Gamboa Dam was blown.[160] The closure of the Commission's last major dry excavation force coincided with a stark decline in coal usage during

[160] George Goethals, "Annual Report of the Isthmian Canal Commission and the Panama Canal for the Fiscal Year Ending June 30, 1914," September 20, 1914, USNA, RG 185, Collection PL 153 31, Box 503: Folder: Annual Reports of the Chairman and Chief Engineer, pg. 2.

the next twelve months as coal consumption dipped by over 130,000 tons.[161] The end of excavation and the near completion of the locks also catalyzed a decline in human labor on the Isthmus as well. At the beginning of July 1913, the labor force stood at 43,350 men; a year later, in July of 1914, it had dropped by nearly a third, down to 29,673, the lowest total since December of 1907.[162] Whether tracked in manpower or machinery the trend during the fiscal year 1914 was the same, energy was leaving the Isthmus.

Disassembling the massive network of muscle and machine that had driven Isthmian excavation for the last decade was a formidable task. The Supply Division noted that "To meet these changes, it has been necessary to transfer thousands of employees and millions of dollars' worth of material."[163] The Division had to transport these men and material from the interior to port facilities and from there either back to America or other ports where they were in demand. The Mechanical Division and its primary repair facility at Gorgona were gradually taken out of service. Meanwhile the Division retired nearly 80 locomotives and 800 cars while losing manpower and closing facilities.[164] Where it could, the ICC sought to get a return for its equipment. During the year they managed to sell eighteen of their steam shovels and 24 of their locomotives.[165] The era of the steam fueled behemoths was ending.

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[161] Panama Railroad Company Board of Directors, "Annual Report of the Board of Directors of the Panama Canal Company to the Stockholders for the Fiscal Year Ending 1914," July 1914, USNA, RG 185, Collection PL 153 31, Box 510, pg. 33.
[162] ICC, "Annual Report of the Supply Division for the Fiscal Year Ending June 30, 1914," July 1, 1914, USNA, RG 185, Collection PL 153 31, Box 512: Folder: Annual Reports of the Quartermaster's Department for the Fiscal Years 1909-1914, pg. 3.
[163] *Ibid*, 1.
[164] ICC "Annual Report of the Mechanical Division for the Fiscal Year Ending June 30, 1914," July 31, 1914, USNA, RG 185, Collection PL 153 31, Box 507: Folder: Annual Reports (ICC) Mechanical Division from F.Y. 1909-1914, pg. 14.
[165] ICC, "Annual Report of the Supply Division for the Fiscal Year Ending June 30, 1914," pg. 25.

Managing excess human energy also proved troubling. The sharp decline in employment on the Isthmus garnered a substantial emigration from Panama. For Americans, this was simple, as the ICC furnished them with tickets back to the States, but many West Indian laborers were either loath to return to the poverty-stricken islands they had left behind or simply couldn't afford passage back home. Seeing an opportunity to acquire cheap labor, the United Fruit Company set up a labor agent in the Canal Zone to recruit from the ranks of silver laborers. Roughly 2,000 others made their way to Honduras in search of opportunity and thousands of others ventured to Costa Rica. Thousands more attempted to stay in Panama in hopes of obtaining long-term employment on the operation of the Canal.[166] This created a challenge for the ICC which lacked adequate housing at the canal terminals. In response, the Commission created the village of La Boca. To keep the costs of construction down, the ICC simply removed buildings and homes from retired silver townsites and reassembled them at La Boca.[167] The speed with which this allowed the ICC to construct the townsite was imperative given the brief timetable in which La Boca had to be ready to accommodate laborers.

Despite the considerable resources invested in removing unnecessary components of the energy network in Panama, the chief focus during the year was the erection of the gates and locks, and the hydroelectric station and transmission line that supported them. Excavation continued after the Culebra Cut was filled in October, but dry excavation was conducted by only a small force of five shovels which worked mitigating the Culebra and Cucaracha slides.[168] The heavy lifting fell mostly under the purview of the dredges, which now worked not only in the locks and approaches but also the Culebra Cut. The fleet had grown from a handful of ships to

[166] ICC, "Annual Report of the Supply Division for the Fiscal Year Ending June 30, 1914," pg. 4.
[167] Goethals, "Annual Report of the Chairman and Chief Engineer of the Panama Canal Company," pg. 62.
[168] *Ibid*, pg. 37.

upwards of twenty dredges of various makes and models. During the year they became the chief source of earthmoving for the ICC and removed 15,341,371 cubic yards of material.[169] This substantial contribution effectively cleared the Canal. The only obstacle remaining in the way of the opening of the Isthmus was now the work being done at the locks and the hydroelectric station that supported it.

Work on the electrical energy network continued to progress. Slow deliveries of steel and challenges in erecting the powerhouse on the Gatun spillway prevented the installation of electrical equipment at the hydroelectric station, but H.F. Hodges, the head of the First Division, was confident that as soon as these logistical obstacles were overcome things would progress rapidly.[170] In the meantime, the Division directed its attention to constructing the transmission line and installing electrical equipment at the locks. In August of 1913, a group of 16 gold laborers and 305 silver laborers began drilling holes for the transmission towers and laying the concrete foundations. Simultaneously they distributed materials across the interior so that once these foundations were laid, they could be easily completed. By the end of the month they had finished 92 of the foundations and within just two months that number ballooned to 379.[171] The rapid pace of the transmission line construction was cause for optimism and pointed to how far construction work in Panama had progressed.

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[169] Goethals, "Annual Report of the Chairman and Chief Engineer of the Panama Canal Company," pg. 43.

[170] H.F. Hodges, "Monthly Report of the First Division for the Month of October 1913," USNA, RG 185, Collection PL 153 32, Box 468: Folder: Monthly Reports of the First Division from September 1, 1913, to November 30, 1913, pg. 6.

[171] Ira Dye, "Monthly Report on the Construction Work on the Cristobal-Balboa Transmission Line for the Month of August 1913," September 3, 1913, USNA, RG 185, Collection PL 153 32, Box 468: Folder: Monthly Reports, first Division from July 1, 1913 to August 31, 1913, pg. 1,3; Hodges, "Monthly Report of the First Division for the Month of October 1913," pg. 7.

The ICC had another reason to celebrate at the locks themselves. In January of 1914, the lock gates were fully installed at each of the three sets of locks. The Pedro Miguel gates were completed on the 8th, Miraflores on the 19th and Gatun on the 26th. The installation of the electrical equipment at the locks also progressed nicely. At Gatun, 88% of the equipment was installed and both Miraflores and Pedro Miguel sat at 86%.[172] The concrete work was completed at all three locations during the course of the year with the exception of minor structures and finishing work necessary for lighting fixtures.[173] Finally, the installation of the machinery and electrical system necessary for the operation of the miter gates also progressed well. All required equipment had been installed at Gatun in February of 1914, at Pedro Miguel in March of 1914, and at Miraflores in May of 1914. The locks were ready, the only question was when the electricity necessary to power them would be available.

By March of 1914, the hydroelectric station was taking shape. The Hodges believed that the First Division had completed roughly 85% of the work on the station and was so optimistic that they could begin small-scale tests in April or May.[174] This development accompanied by news that the transmission line was being constructed at a rapid pace. By the end of March, laborers had laid the foundations for 793 transmission towers and only 16 remained to be completed. Additionally, they had strung over 33 miles worth of transmission lines. Hodges was so enthused by this progress that he noted, "At the present rate of progress, the indications are

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[172] H.F. Hodges, "Monthly Report of the First Division for the Month of January 1914," February 10, 1914, USNA, RG 185, Collection PL 153 32, Box 468: Folder: Monthly Reports of the First Division from December 1, 1913, to January 30, 1914, pg. 1.
[173] Goethals, “Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1914”, pg. 9-11.
[174] H.F. Hodges, "Monthly Report of the First Division for the Month of March 1914," March 31, 1914, USNA, RG 185, Collection PL 153 32, Box 468: Folder: Monthly Reports of the Firth Division from February 1, 1914, to March 31, 1914, pg. 2.

that the construction work on the transmission line will be nearly completed before the end of the month in April."[175]

Despite a few hiccups, by June of 1914, the hydroelectric plant and the transmission line connecting it with the Miraflores plant were completed. The Transmission line ran 44.46 miles and consisted of 266 miles of 2/0 copper stranded wire and 88 miles of copper grounded wire.[176] The Gatun hydroelectric plant was completed. In anticipation of the plant's opening, the ICC transferred one 1,500 kW turbo-generator sets and two water boilers from the Gatun steam power plant to the Miraflores power plant and finished installing them on June 1st. As a result, the Miraflores plant outproduced the Gatun plant for the first time, generating 16,352,732 kilowatt hours compared to the Gatun plant's 6,824,556 kilowatt hours.[177] While this arrangement was temporary and the hydroelectric plant was expected to begin supporting canal operations in July of 1914, the month of June suggested that both the transmission line and the Miraflores powerplant were up to the task of powering the Canal if necessary. The energy to power the gates was in order and the Panama Canal was ready to be unveiled to the world.

The first vessel to make the voyage across the Panama Canal got little press. The *Cristobal* made the journey back and forth across the Isthmus on August 3, 1914, without any pageantry or prestige. This was intentional. The *Cristobal* was the sister ship to the *Ancon*, the War Department steamship set to make the official inaugural trip across the Isthmus two weeks later. Yet if the enthusiasm which greeted the *Ancon* as it set off on August 15th was any greater it was difficult to tell. While the *Ancon* held numerous dignitaries, it generated little press

175 H.F. Hodges, "Monthly Report of the First Division for the Month of March 1914," pg. 5.
176 H.F. Hodges, "Annual Report of the First Division for the Fiscal Year Ending June 30, 1914," July 1914, USNA, RG 185, Collection PL 153 31, Box 506: Folder: Annual Report of the First Division FY 1914, pg. 9.
177 Goethals, "Annual Report of the Isthmian Canal Commission for the Fiscal Year Ending June 30, 1914," pg. 29.

internationally. In many newspapers, the *Ancon's* voyage fell to the bottom of the front page, or off it entirely. By August of 1914 papers in America looked east rather than south as the most powerful nations in the world prepared to fight and die on the fields of Europe. The opening of the Panama Canal, heralded by some as the greatest man-made structure ever, was relegated to little more than an afterthought.[178]

Locked into Energy

World War One may have drawn the public gaze away from the Canal, but the path between the seas still occupied a place of prominence on the global stage. Ships laden with coal, oil, food, metals and countless other materials soon flowed en masse through the towering locks of Gatun, Pedro Miguel, and Miraflores. The dream of interoceanic transportation had finally been realized. Over the course of a decade, the energy regime of the Canal had diversified, shifting from a reliance almost exclusively on human energy and coal to also include oil and electricity, sources of energy that were far more economical and efficient for fixed landscapes and power plants. The addition of these new energies also contributed to the massive proliferation of energy in which the sheer concentration of a broad array of energy sources provided enough power to finally mitigate the entropic tendencies that had defined the Isthmus for decades. As excavation wound down and the ICC focused its attention on the process of construction, oil and electricity became particularly significant as their steady, reliable, and economic energies proved perfect for the construction and operation of the locks. The flexibility afforded by the variety of energy sources employed by the ICC allowed the Commission to wield

[178] Isthmian Canal Commission, *The Panama Canal Record*, Vol. 7 No. 50, August 5th, 1914, pg. 493; Isthmian Canal Commission, *The Panama Canal Record*, Vol. 7 No. 52, August 19th, 1914, pg. 521; "War Department Steamship Officially Opens Canal", *The Evening News*, San Jose, California, August 15, 1914, pg. 1.

whatever source of energy was best suited to tasks ranging from dredging harbors, to detonating rock formations, to constructing roads, housing, and power lines.

And yet, while the entropic tendencies of Panama's climate were mitigated, the fixed landscape of concrete and steel that was left behind faced its own limitations. The tension between energy's capacity to impose order over the Panamanian landscape and the fixed nature of the order it imposed created challenges for the long-term viability of the Canal. Ironically, the limits of the Canal's efficacy were foreshadowed by the events surrounding its opening. While World War One didn't fundamentally challenge the role that the Canal played in international commerce, it did fundamentally change the nature of war. The growing importance of aerial combat created a new set of concerns for Canal security and suggested that as war became more complex so did threats to the Canal.

Additionally, the energy proliferation that helped construct the Canal also hinted at its limitations. The growing importance of oil as a source of fuel was not isolated to the Canal. As the 20th century progressed oil was found to be increasingly abundant and efficient as a source of fuel for a variety of machines. The technological explosion that took place during WWI and the rise of the automobile in the first decades of the 20th century helped reinforce the growing primacy of oil and dictated that the transportation of substantial amounts of oil was imperative to international commerce. To most efficiently transport this new commodity, merchants recognized that it was far more economical to maximize the size of their vessels to carry as much petroleum as they could. The massive locks were by no means in danger of imminent obsolescence, but the increasing size of ships progressed far more rapidly than canal lobbyists had ever imagined.

In this sense energy proliferation took place far more rapidly than the landscape it created could hope to keep pace with. The creation of the Canal required a monumental marshaling of energies of all sorts, at no small cost to the United States government. And yet as ships became bigger and threats to the Canal began to come not only from the sea but also from the air, questions of the Canal's longevity soon emerged. The lack of available energy following the completion of the Canal, a product of entropy and an unwillingness on the part of the US government to continue their considerable investments in Panama, made alterations of the waterway impractical both energetically and economically. As war once again loomed on the horizon, new energy sources, security, and ship size combined to present a unique challenge to the Canal's operation. These factors suggested the U.S. needed to explore expansions to the Canal or even the possibility of constructing a new canal. As scientists, engineers, and politicians grappled with these problems they found that energy once again shaped the Canal and its future.

Chapter IV: The Canal, Fixed: The Limits of the Panama Canal: 1914-1947

Roughly eight inches separated the hull of the USS *Missouri* from the concrete sides of the Miraflores Locks. On October 13, 1945, the battleship transited the Panama Canal, traveling from the Pacific en route to New York City where it was to take part in Navy Day celebrations. Commissioned in June of 1944, the Missouri became a symbol of American victory in WWII when Japanese officials signed the Japanese Instrument of Surrender on board the vessel on September 2, 1945. And yet the battleship was also a symbol of the challenge faced by the Panama Canal. The 887 by 108 foot battleship was one of the last US naval vessels specifically designed with the utilization of the Panama Canal in mind and reflected just how dramatically World War II had altered warfare.[1] The Canal proved itself an invaluable asset to the American war effort. In 1945 alone, over 6000 American military vessels transited the Canal, constituting nearly 62% of total traffic for the year.[2] And yet Canal Zone Governor Joseph Mehaffey was careful to point out that, "The services rendered by the Panama Canal in support of military operations were possible only because the Canal was never attacked or damaged."[3] The emergence of aircraft carriers, saturation bombing, and atomic weaponry constituted an

[1] 80-G-701369: USS Missouri (BB-63). In the Miraflores Locks, Panama Canal, 13 October 1945, author unknown, US Navy, retrieved from the Truman Presidential Library, https://www.trumanlibrary.org/photographs/view.php?id=58517 , 12/26/18.

[2] O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947: Annex E: Traffic Requirements and Capacity of Canals." Department of Operations and Maintenance: Special Engineering Division, March 13, 1947. USNA, RG 185, Collection: A1 120-A Isthmian Canal Studies and Memorandums 1946-1947, Box 4, Declassification NND 008022, pg. E-91.

[3] Mehaffey, Joseph. "Digest Report of the Governor of the Panama Canal Rendered in Accordance with Public Law 280 79th Congress, 1st Session." Isthmian Canal Studies, 1947. USNA, RG 185, Collection A1 152: Reports, Papers, and Proceedings Related to the Improvement of the Canal, Box 7, pg. 1.

existential threat to the Canal and pointed to a growing perception of obsolescence surrounding the only three-decade-old waterway.

These developments were a result of the steps Canal engineers had taken to establish permanence and stability over the unstable environment of the Canal. If entropy worked to disrupt that which energy had made possible, permanent structures made from concrete could mitigate landslides and siltation that would require considerable injections of energy to counter. Ironically, their success presented a fundamental challenge to the long-term utility of the Canal. The fixed Canal proved difficult to adapt and required an unprecedented investment of capital and energy to modernize. As ships grew larger, traffic more voluminous, and weapons more destructive, the rigidity of the Canal complicated both interoceanic commerce and American national security.

These limitations did not arrive without warning. From its very opening, the Canal faced difficulties. Landslides remained problematic in the years following its opening, halting traffic for considerable periods. Perhaps more significantly, the first few decades of the Canal's life were defined by global upheavals and economic instability. The Canal had the misfortune of opening alongside the outbreak of World War I. As chaos and conflict tore through Europe, international shipping waned, and the Canal failed to attract as much traffic as lobbyists had anticipated. The 1920s presented a golden age of sorts for the Canal. Booming markets in the United States led to growth in intercoastal shipping and Americans relied on the Canal to expedite this process. Globally, recovering European markets and expanding Asian markets also found the Canal an asset. This increase in traffic outpaced predictions of canal usage and raised uncomfortable questions about the Canal's capacity.

The global depression of the 1930s mitigated these concerns somewhat but came with its own difficulties for the Canal as traffic again dropped.[4] Global instability in the 1910s, '20s, and '30s made predictions of the Canal's viability imprecise and generated more questions than answers. While they never presented an existential threat to the Canal in the same way that WWII did, WWI, the '20s, and the Depression emphasized that the Canal didn't exist in isolation, but instead was intimately interconnected with global markets and politics. As these forces collided in 1939 and the world found itself again drawn into an unprecedented conflict, the Canal's fate seemingly hung in the balance.

Emphasizing the shifting place the Canal had in the minds of Americans complicates the notion that the Canal was completed in 1914 and had a static existence from that point onwards.[5] Nothing could be further from the truth. Little over a decade after its completion, economists, engineers, administrators began to wonder about the lifespan of the path between the seas. As a result, the Canal was constantly being both ideologically and physically altered. Studies suggested fixes to the Canal's long-term viability issues, and the Panama Canal Company conducted repairs and maintenance to keep its waterway in working order.[6] These attempts at

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[4] For the best account of traffic volumes during the thirty years following the Canal's opening see Noel Mauer and Carlos Yu, *The Big Ditch: How America Took, Built, Ran, and Ultimately Gave Away the Panama Cana,*. (Princeton, N.J: Princeton University Press, 2011), Maurer and Yu's economic analysis provides excellent insight into the pressures that global developments exerted on the Canal's operation.

[5] Many more popular histories have embraced this frame of reference. Likely the most well-known work in this mold is David McCullough, *The Path between the Seas: The Creation of the Panama Canal, 1870-1914*, (New York: Simon and Schuster, 1977).

[6] Historians have increasingly been paying attention to the question of maintenance as it relates to the Panama Canal. In most cases, attempts at maintaining the stability of the landscape manifested themselves in the lock overhauls that were scheduled every four years. Some projects, however, were considerably bigger. One of the chief issues facing the Canal in the 1920s and 1930s was the maintenance of a suitable amount of water to operate the locks. The creation of Madden Dam in the 1930s was a direct response to this and suggested the sort of renovations necessary to maintain the Canal's efficacy in a rapidly changing world. For the most complete account of this process see Ashley

imposing order and realizing the Canal's promise of restructuring global trade were reflective of the ongoing issues that pestered the waterway during its first few decades of operations and pointed to the need for continual maintenance and injections of energy to keep it running smoothly.

At their core, these issues all stemmed from the same reality. The Canal's builders had met their task of imposing order on an entropic environment far too effectively. In hopes of keeping the shifting soils and mucks of Panama at bay, they relied on the stability afforded by concrete and steel. These materials fixed the Canal against the unwanted entropy of the Isthmus, but also fixed it against desired changes. It was impossible to increase the capacity of the entire canal without first overcoming the limitations placed on ship size and transit time imposed by the locks. This reality was troubling in the 1910s, '20s, and '30s when war and global upheaval suggested that the demands of global commerce may be just as fickle, if not more so, than the Panamanian environment. Changes in technology, ship size, and global trade occurred more rapidly than the canal locks could accommodate and foreshadowed the threats looming in the Canal's future. World War II manifested these threats as the dramatic implications of mechanized warfare and atomic technology were laid bare. These technologies presented an existential threat, both physically and ideologically, to the Canal. The waterway needed to adapt to remain relevant. The only question was whether the Panama Canal Company and the US government could overcome the fixed nature of the Canal itself.

Carse, *Beyond the Big Ditch: Politics, Ecology, and Infrastructure at the Panama Canal*, (Cambridge, US: The MIT Press, 2014).

Sliding out of the Gate: 1914-1930

When the Canal opened in August of 1914, it was heralded as the arrival of a new epoch. Canal advocates believed that the interoceanic passageway would usher in a new era of wealth and opportunity the world around. William MacCorkle, ex-governor of the state of West Virginia, expressed the enthusiasm of many, arguing that, thanks to the Canal, peoples "yellow, brown, and white- filled with the desires of new commerce, fired with new hope by the touch of the West, thrilled with new ideas of government and religion are all mingled in one tremendous combat for the mightiest markets vouchsafed to man since the stars sung together."[7] The implications were clear. Bridging the Isthmus had reorganized the world. Now it was time to capitalize on the opportunities the waterway offered.

And yet the Canal's promise of wealth proved elusive. It was an old adversary that initially laid low the hopes of speculators. The incessant entropy of Panama once again caused slides in the Culebra (or as it came to be known "Gaillard") Cut. Throughout 1914 and early 1915 the slides, while problematic, never halted traffic for more than a week. While this was frustrating, it didn't undermine the utility of the Canal. That changed on September 15, 1915, however. A massive slide in the Cut sent tons of material crashing into the Canal itself. Ultimately the Canal was practically inoperable until April of 1916, over six months after the slide had initially taken place.[8] The slide served as a sobering reminder that while the Panamanian environment could be altered, it could never truly be controlled. This point was

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[7] MacCorkle, "'Relation of West Virginia Coals to the Panama Canal' Address Before the West Virginia Coal Mining Institute on the Relation of West Virginia Coals to the Panama Canal Delivered at Charleston, W. VA. on December 8, 1913" (Government Printing Office, 1914), pg. 4.

[8] E.H. Bourquard, *Memo 124: Review of Past Panama Canal Traffic* from "Papers Presented at the Meeting of the Board of Consulting Engineers of the Panama Canal at Diablo Heights, Canal Zone, February 11-18, 1947: Studies Under Public Law 280 79th Congress," March 1947. USNA, RG 185, Collection A1 120-A Isthmian Canal Studies and Memorandums 1946-1947, Box 5, Declassification NND 008022, pg. 9.

reinforced by the continued occurrence of small slides over the coming years. Fortunately for the Panama Canal Company, future slides never halted traffic for more than a few days. This was not the end of the Canal's challenges, however. Warfare proved a far more difficult obstacle to overcome.

World War I’s capacity to overshadow the Canal went unmitigated in the years following the Canal’s opening. The spread of warfare dramatically impacted international commerce and prevented the Canal from asserting itself as dramatically as MacCorkle and others anticipated. Between 1914 and 1918, traffic through the Canal averaged between 1000 to 2000 vessels annually, peaking in 1918 when 2,460 ships transited the Canal carrying 7,526,000 tons of material.[9] These modest numbers reflected the dramatic consequences that global instability could have on canal traffic. The fact that conflict was focused in Europe and that American manufacturing was primarily rooted on the East Coast at the time meant that interoceanic travel waned next to the centrality of Atlantic shipping. The Panama Canal had been built on the hope that global trade routes were dynamic and would evolve to meet demand, its architects hadn't assumed that those forces could route traffic away from the Canal as well. The silver lining, however, was that, apart from the slides, the fault lay not with the Canal itself, but rather with the powers utilizing it. Global conflict focused traffic elsewhere, but in the recovery that followed World War I, the Canal stood poised to be a crucial part of the global economy.

The 1920s saw the value of the Canal asserted with remarkable efficacy. Americans accounted for over 30% of the traffic flowing through the Canal during the decade, and as the American economy ballooned in the 1920s so too did Canal traffic.[10] But it wasn’t the United

[9] Bourquard, *Memo 124: Review of Past Panama Canal Traffic,* pg. 9.
[10] *Ibid*, pg. 4.

States alone that was responsible for the glut of vessels pouring through the Isthmus. The postwar recovery saw Europe using the Canal extensively to access raw materials in the Pacific. Meanwhile, Japan's emergence on the world stage was accompanied by an increase in vessels seeking Asian markets.[11] All of these forces coalesced to consistently increase traffic during the postwar years. Between 1920 and 1930 net vessel tonnage increased by nearly 20,000,000 tons and traffic increased threefold, peaking in 1929 when 7,800 ships used the Canal. Growth was so dramatic that, only 15 years after the opening of the Canal, many began to wonder when additional facilities would be required to handle the increase in traffic.[12]

The emergence of the Panama Canal was tied as much to energy as it was to postwar economic booms. While many commodities made their way between Atlantic and Pacific during the decade, petroleum dominated international shipping throughout the decade. Rich oil fields in California catalyzed an economic boom in which tens of millions of tons of oil were shipped from the Pacific to the Atlantic.[13] 11,000,000 tons of petroleum crossed the Isthmus in 1924 alone. While it dwindled as the decade progressed, petroleum remained the single biggest commodity in Panama Canal traffic.[14] Indeed, oil was so central to the Panama route that when studies were made to predict future traffic trends, most projections analyzed oil independently as they were concerned that integrating it with other commodities would skew their projections.[15]

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[11] Mehaffey, Joseph. *Annex 1: Panama Canal Traffic Survey*, "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Annex 1 & 2," November 21, 1947. USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to Improvement of the Canal, Box 8, pg. 53.
[12] Bourquard, *Review of Past Panama Canal Traffic,* 9-10.
[13] *Ibid*, *Traffic,* 9.
[14] Mehaffey, *Panama Canal Traffic Survey,* 16.
[15] Mehaffey, Joseph. *Annex II: Future Capacity Needs,* from "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Annex 1 & 2," November 21, 1947. Record Group 185. USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to the Improvement of the Canal, Box 8, pg. 1-3.

Oil provided the energy to fuel these booming economies and helped the Canal attain a central place among the trade routes of the world.

As the 1920s gave way to the 1930s and the global economy collapsed, the Canal found itself once again at the mercy of forces beyond its control. Traffic through the Canal declined, and those ships that did make their way through the locks seldom carried a full load of cargo. Traffic fell precipitously during the first few years of the 1930s, bottoming out at 5,490 transits in 1933.[16] At no point during the Depression did traffic drop to the anemic levels it had been at during World War I but the substantial drop in utilization did shake faith in the Canal's economic stability. As the 1930s went on, traffic recovered, nearly reaching the levels it had been at in the late 1920s by 1939.[17] The Canal had once again managed to weather the storm.

And yet instability was the defining characteristic of the Canal's first two decades of existence. The slides that had halted traffic in 1915 and 1916 pointed to the need for continual maintenance of the waterway to retain its utility. Diplomatic and economic entropy in the form of warfare, economic booms, and relapses all pointed to the tenuousness of the Canal's position on the global stage. Thanks to this chaos, it was difficult for administrators to determine how effective the Canal truly was. If the Canal were going to see the rapid expansions in traffic that had characterized the 1920's, then it was imperative that studies be made into potential expansions and additions immediately. If, on the other hand, the 1920s were an aberration and the 1930s were indicative of the future the Canal could handle traffic for the foreseeable future. Starting in the 1920s, economists, military officials, and policymakers sought to unravel the enigma that was the Canal's place in the world. In the process, they restructured the Canal,

[16] Bourquard, *Review of Past Panama Canal Traffic,* pg. 10.
[17] *Ibid*, pg. 10.

generally ideologically as the Canal's concrete structure resisted change, but at times even the waterway itself was altered in the name of increasing capacity.

Damming Studies and New Locks

Thanks in large part to the unpredictability of the interwar years, the Panama Canal Company and the US Government spent a considerable amount of resources trying to understand the role the Canal was destined to play in international commerce. Starting in 1924, the Canal was the subject of regular studies to determine its capacity and develop plans for its expansion. Thanks to the volatility of the data academics had at their disposal, the bulk of these studies failed to accurately predict traffic trends and, as a result, few tangible steps were actually taken to expand the Canal. More often than not, the only alterations made to the Canal were regularly scheduled lock overhauls conducted every four years. As the 1930s emerged, however, the government became more proactive in restructuring the Canal, providing the funds and resources to carry out two substantial Canal alteration projects: the Madden Dam, and the Third Locks projects. These two projects sought to expand the capacity of the Panama Canal in anticipation of the larger ships, and greater volume of traffic that loomed on the horizon. The world was changing, and the Canal struggled to change with it.

Long-term traffic projections were initiated as early as the construction of the Canal. Emory Johnson, an economist contracted by the Isthmian Canal Commission was the first to compile a projection for future canal traffic in 1904. Johnson revised his estimates in 1912, closer to the Canal's opening to account for the adoption of a lock-style level canal. A decade later Major Clarence Ridley, an engineer working on the Canal, applied the rate of growth in traffic from the Suez Canal to the Panama Canal. Finally, a paper by Lieutenant Hans Kramer was published in the Proceedings of the American Society of Civil Engineers in August of

1928.[18] While important, these initial estimates tended to shy away from the topic of when the Canal would reach its capacity. They suggested the Canal would not approach this problem until some amorphous date in the 1960s or later. As a result, while they were valuable, they didn't constitute a call to action, but rather a more detached analysis of the Canal's value.

As the true scope of the expansion of interoceanic commerce made itself felt during the 1920s however, studies into traffic became far more concerned with the need to expand Canal facilities. In 1929 Congress passed a Joint resolution to conduct a study into the capacity of the Canal and the potential development of Canal facilities to accommodate growths in traffic.[19] The studies explored a variety of topics surrounding the Canal's utility, including the most substantial projection of future canal traffic yet undertaken. Sydney Williamson's 1931 study was the first written with a stated objective of assessing the potential need for expanded facilities. Williamson combined the relationships of Panama shipping to world trade, the past growth of Panama traffic, and the relation of Panama traffic to Suez traffic to determine the potential growth of Canal traffic. Using these three measurements Williamson concluded that the Canal would see 74,145,000 net tons of traffic over 16,757 transits by the late 1960s, a level of traffic that

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[18] Most of the studies focused not necessarily on the traffic itself, but rather on the volume of Cargo. Johnson's study ran projections from 1915-1935 and suggested traffic would peak at 30,200,000 tons by 1935. Ridley's algorithm projected annual growth of 687,500 net vessel tons per year, a figure that would result in 46,400,000 tons of cargo annually by 1960. Kramer actually undertook two projections. The first was based on the growth in Canal traffic during the 1920's and assumed an annual growth of 3,385,000 tons per year. Kramer's second projection was a modified projection of Suez Canal traffic which assumed an annual growth of 1,230,000 tons per year. Kramer's study was focused on the date at which Canal traffic would hit 74,000,000 tons, a figure he deemed as the absolute maximum for Canal traffic. The first projection led to Kramer to suggest that figure would arrive around 1940 and the second projection led him to determine the figure would be hit around 1970. Bourquard, *Memo 125: Summary of Panama Canal Traffic Predictions,* from: "Papers Presented at the Meeting of the Board of Consulting Engineers of the Panama Canal at Diablo Heights, Canal Zone, February 11-18, 1947: Studies Under Public Law 280 79th Congress," March 1947. USNA, RG 185, Collection A1 120-A: Isthmian Canal Studies and Memorandums 1946-1947, Box 5, Declassification NND 008022, pg. 2-3.

[19] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session," November 21, 1947. Record Group 185. USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to Improvements of the Canal, Box 8, pg. iii.

exceeded the Canal's capacity.[20] The implication was clear. If action was not taken, the Canal would effectively be obsolete in a few decades time. This study helped catalyze the first major canal alteration since the waterway's construction: the creation of Madden Dam.

By the 1930s, ship size was not a pressing concern. Instead, the major limitation faced by the waterway was maintaining an adequate water supply. The genius of the lock canal was that it was operated by gravity. Gatun Lake, created by the damming of the Chagres River, provided the water to fill the locks. Culverts running through the concrete substructure of the locks themselves were opened to allow water to flow from the lake into the locks. This process was repeated for each set of locks, allowing ships to rise to the height of Gatun Lake as they entered the Canal, and gradually return to sea-level as they exited it.[21] Panama's rainy climate allowed this system to work, generally, but in years of light rainfall traffic occasionally needed to be slowed or halted due to a lack of water.[22] As traffic increased in the 1920s, the water level of Gatun Lake came under increased scrutiny as the biggest threat to canal operation. The building of Madden Dam in 1935 created Madden Lake (known as Alajuela Lake after control of the Canal reverted back to Panama), a reservoir that provided an emergency supply of water in case of a drought, and also served as the perfect site for an additional hydroelectric station.[23] For the first time, Canal administrators dealt with the limitations of the Canal with substantial alterations to the physical canal, setting a precedent that spanned decades.

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[20] Bourquard, *Summary of Panama Canal Traffic Projections*, pg. 3.
[21] Carse, *The Big Ditch,* pg. 4.
[22] Carse's *The Big Ditch* provides a far more thorough account of the unique challenges presented by the Canal's demand for water and is essential reading on the topic. Carse doesn't focus extensively on Madden Dam but instead examines how the Dam was just one of many projects which attempted to deal with the hydrological needs of the Canal as a viable waterway.
[23] Bush, Richard (Mechanical-Electrical Section). "Isthmian Canal Studies (I.C.S.) Memo No. 64 Existing Power System of the Panama Canal," October 14, 1946. USNA, RG 185, Collection A1 124 Isthmian Canal Studies Memorandums and Meeting Minutes 1946-1948, Box 2: Folder: ICSM 64-69, pg. 11.

Spurred on by the success of the Madden Dam, Canal administrators showed an interest in undertaking additional concrete changes to the Canal's capacity by tackling the limitations of the locks themselves. Lock dimensions were an increasing topic of conversation during the 1930s as ship size steadily increased. The Navy had long held the view that the locks afforded a reasonable cap on ship size. But in 1930 and 1931 military officials began advocating for larger locks. In 1930 and 1931 the Navy Department and U.S. Army Interoceanic Canal Board submitted reports recommending expanded lock dimensions of 1300 feet by 145 feet and 1200 feet by 125 feet respectively.[24] These security concerns soon spilled over into commercial shipping as well. While Madden Dam was approaching completion in 1935, the *Normandie* was constructed. At 1029 feet long and possessing a beam of 117.9 feet, the *Normandie* was the first commercial vessel incapable of navigating the locks. Within five years it was joined by the *Queen Mary* (1936) and *Queen Elizabeth* (1940).[25] The once gargantuan locks seemed to be shrinking next to the huge new vessels making their way around the world's oceans.

There were only a small number of vessels too large to fit in the concrete locks, but the rigidity of the Canal was becoming increasingly problematic thanks to the fact that ship size was impacting the Canal’s capacity to undertake double lockages. Ultimately, the Canal's capacity was controlled by the speed at which ships could pass through the locks.[26] An obvious way to increase the efficiency with which ships could traverse the Isthmus was to have two ships journey through the locks in tandem. In the late 1930s, the Canal averaged roughly 1.08 ships per

[24] Stratton, James, *Memo 126: Data on Future Size of Large Ships Influencing Lock Dimensions* from: “Papers Presented at the Meeting of the Board of Consulting Engineers of the Panama Canal at Diablo Heights, Canal Zone, February 11-18, 1947: Studies Under Public Law 280 79th Congress,” pg. 7-8.
[25] *Ibid,* pg. 6.
[26] O’Shaughnessy, P.S. “United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947,” pg. E- 101

lockage, meaning that the vast majority of ships transiting the Canal were locked individually. It was suggested that in order to meet the capacity for expanding traffic it might be necessary to accommodate 1.77 ships per lockage.[27] Consequently, it wasn't necessarily massive vessels of over 1000 feet that concerned engineers as much as the growing percentage of vessels between 500-600 feet which were unable to pass through the existing locks in tandem.[28] The combined pressure presented by the expansion of naval and commercial vessels too wide to transit the locks, and an increasing number of ships which were too long to make tandem lockages highlighted the need for larger locks themselves.

The challenge of expanding the locks was obvious. The concrete locks at Gatun, Miraflores, and Pedro Miguel had been constructed to last. As a result, it was prohibitively expensive to expand them. The mechanical infrastructure behind the Canal's operation needed to be entirely removed and rebuilt to accomplish such a task, a proposal which necessitated sharp restrictions in traffic in the Canal. While the concrete locks mitigated problems stemming from entropy, their utility was undermined and constricted by the expansion of ship dimensions. Congress acted quickly in hopes of heading this problem off at the pass. In 1929, early in the discussions for Canal expansion, Congress passed Public Resolution 99, which charged the President to determine the practicality and potential cost of, "such additional locks and other facilities in the Panama Canal as may be necessary to provide for the future needs of interoceanic shipping."[29] The study lasted several years and while it did suggest that the government consider the creation of a new set of locks 1200 feet long by 125 feet wide and 42.5 feet deep, when

[27] Bourquard, E.H., *Memo 128: Capacity of the Present Panama Canal*, from: "Papers Presented at the Meeting of the Board of Consulting Engineers of the Panama Canal at Diablo Heights, Canal Zone, February 11-18, 1947: Studies Under Public Law 280 79th Congress," pg. 11.
[28] Bourquard, *Memo 124: Review of Past Panama Canal Traffic*, pg. 5.
[29] Edgerton, Glen. "The Third Locks Project." Panama Canal Company, June 1, 1941. University of Florida Latin American Collections. University of Florida Digital Collections. http://ufdc.ufl.edu/AA00019286/00001/1x, pg. 1.

Governor Julian Schlay submitted his final report in 1934, he determined that the creation of the Madden Dam had rendered a third set of locks unnecessary until at least 1970.[30]

The Governor's optimism proved less than contagious. Less than two years after Schlay submitted his report Congress passed Public Resolution 85 which authorized the Panama Canal Governor to investigate a means of expanding the capacity of the Canal for international shipping. The report, submitted in February of 1939, argued that the United States should begin construction on a third set of larger locks within the next ten to twelve years at a cost of $277,000,000. Not content to delay any longer, Congress passed Public Resolution No. 391 in August of 1939 which granted the Third Locks project an initial budget of $15,000,000 dollars to begin surveys and excavation. Less than a year later, on July 1, 1940, the dredge *Cascadas* began subaqueous dredging on the Atlantic approach.[31] The expansion of the Panama Canal was underway and the potential of overcoming the limitations of the locks was the closest it would be for half a century.

Construction progressed rapidly in 1940 and 1941. The Special Engineering Division, created in 1939 to oversee the construction of the Third Locks Project, settled on lock dimensions of 1200 feet by 140 feet by 45 feet and began excavation at the lock sites.[32] The locks were positioned adjacent to the existing locks and were expected to use similar machinery. The planning completed, excavation was carried out at a rapid pace in hopes of meeting a condensed construction timetable of five years.[33] By 1942 excavation and dredging at the

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[30] Edgerton, "The Third Locks Project," pg. 2.
[31] *Ibid*, pg. 3-4.
[32] *Ibid*, pg. 8.
[33] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Appendix 3: The Third Locks Project," November 21, 1947, USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to the Improvement of the Canal, Box 9, pg. 9, 20.

Atlantic Locks and approach were complete and the Pacific Locks had only 1,345,000 cubic yards left to excavate. What the Third Locks Project could not have anticipated however was the speed with which WWII would spread. Pulled into the war by the Japanese attack at Pearl Harbor, the United States militarization necessitated cuts to the Third Locks Project.[34] On May 25, 1942, the Secretary of War effectively halted the project, allowing excavation of the Lock sites to continue, but preventing the construction of the lock facilities themselves.[35]

Initially, the intention was to continue the work upon the cessation of hostilities, and yet WWII resulted in such drastic developments in warfare that the Third Locks Project was itself deemed an imperfect solution to the long-term viability of the Canal. The Third Locks Project then was the last gasp of a dying world, one in which vessels with beams of 110 feet were a rarity and threats to the Canal resided primarily in naval vessels and invading armies. While there were whispers of the Canal's obsolescence in the 1920s and 1930s, there were no existential threats to its existence. World War II ushered in a dangerous new world in which aerial combat became a crucial component of warfare. This development presented new challenges to the lock canal. The concrete locks and dams that had mitigated the entropy of Panamanian environment and made the interoceanic highway possible were incredibly susceptible to a new form of energy, one which could shatter concrete, bend steel, and render the Canal impassible for years at a time.

[34] Miles Duval, "Presentation before the General Board of Consultants of the Panama Canal at the Request of the Governor on the Marine Operating Problems Involved in the Proposed Modernization Studies of the Panama Canal Authorized by Public Law 280, 79th Congress." Navy Department, May 13, 1947. USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to the Improvement of the Canal, pg. 5.

[35] Mehaffey, "Appendix 3: The Third Locks Project," pg. 25-26.

Aircraft Carriers and Atoms

As oil-fueled war machines spread around the world in the early 1940s, it became increasingly apparent that warfare had fundamentally changed. The prevalence of mechanized warfare ushered in a faster, more mobile, and increasingly aggressive style of conflict that seemed alien to the static fortifications and trench lines of World War I. A fixed concrete and steel structure dotted with immobile fortifications; the Panama Canal found itself woefully unprepared for this development. The locks of the Canal had been constructed to withstand attack from naval shellings and invading armies. It was completely unequipped to deal with the prevalence of aerial combat and the aircraft carriers and atomic bombs that accompanied it. The complexity and the rigidity of the locks, once the source of the Canal's salvation, had become its single greatest vulnerability. James Stratton, the Chief Engineer of the Special Engineering Division of the Panama Canal, admitted that, in light of advances in aerial warfare, "no reasonable amount of structural alteration would greatly decrease the vulnerability of the present locks."[36] The efficacy of the Panama Canal was once again under siege, this time however obsolescence didn't reside in a vague future date; it had arrived.

The first challenge to the Canal's utility was one that had been foreseen but had arrived far earlier than anticipated: the arrival of military vessels that could not transit the Canal. In a report to Congress, Governor Mehaffey noted that "Until World War II, the present lock chamber width of 110 feet and length of 1000 feet were accepted as a rigid limitation on the design of U.S. Navy ships. However, several U.S. warships constructed during the war exceed

[36] James Stratton, *Selection of Route in Panama and Vicinity and Determination of Type of* Canal, located in, O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947," pg. E-312.

the dimensions of the present locks and are therefore unable to utilize the Canal."[37] The warships guilty of ignoring the confines of the Canal were the aircraft carriers that proved so crucial to combat in the Pacific. The unique demands of island hopping, namely the need to deploy short-ranged aircraft with radical mobility in a theater where land was sparse and airfields practically nonexistent, catalyzed the shift towards aircraft carrier battlegroups. The US quickly recognized the utility of these vessels and *Essex*- and, towards the end of the war, *Midway*- class carriers became the backbone of the American Navy.[38]

While older *Yorktown* class carriers could transit the locks, the newer carriers dwarfed the locks. The massive CVB class had a length of 1190 feet and a beam of 130 feet, and its flight deck and gun emplacements led to an actual width of over 150 feet. While smaller, with a length of only 962 feet and a beam of 106 feet, the C-2 couldn't transit the locks thanks to the 160 foot width of its flight deck.[39] These carriers were among the first ships incapable of utilizing the locks, but the Navy acknowledged that larger ships would likely become increasingly prevalent. A 1946 Navy Department report stated that "The size of future naval vessels is of necessity a matter of conjecture. The trend in design may well develop towards holding to present sizes or even to smaller vessels and lead away from mammoth ship construction, but at the present time, a tendency towards smaller vessels has not actually developed. In fact, the trend towards increased dimensions still continues."[40] In this context, the limited size of the locks grew increasingly problematic.

[37] Mehaffey, Joseph. "Digest Report of the Governor of the Panama Canal Rendered in Accordance with Public Law 280 79th Congress, 1st Session," pg. 3.
[38] For an overview of the development of aircraft carriers and their role in WWII, a good overview is Macdonald, Scot. *Evolution of Aircraft Carriers*. Washington: Government Printing Office, 1996.
[39] Stratton, *Data on Future Size of Large Ships Influencing Lock Dimensions,* pg. 3.
[40] *Ibid*, pg. 3.

The concrete foundation of the locks and the proximity of the lock lanes meant that it was impossible to accommodate aircraft carriers and other large vessels without completely rebuilding the locks themselves. But military officials felt that maintaining the status quo was equally unacceptable. WWII had both laid bare the Canal's limitations and reinforced the need for expedited transit between the seas. Governor Mehaffey expressed this tension explicitly, writing, "Transportation facilities were a limiting factor during World War II, and the loss of the Canal might well have resulted in grave consequences. It probably would have restricted military activities and no doubt would have prolonged the war."[41] Ultimately the Canal presented the American military with a sort of catch-22. The Canal had proven itself invaluable to the war effort, so much so that during the war years the bulk of traffic utilizing Canal facilities was military in origin. And yet simultaneously, the Canal seemed incapable of dealing with the changing nature of military combat.

Aircraft carriers may have pointed to the practical limitations of the existing Canal, but the rise of unprecedented bombing campaigns, both conventional and atomic, could eradicate the Canal altogether. Mehaffey cautioned that "The vulnerability of the present Canal to any modern weapons is so marked that dependence cannot be placed on its use in war, and for this reason, the Canal as it exists today cannot be considered as meeting the future needs of national defense."[42] The Canal's susceptibility to aerial attacks came from the vulnerability of two crucial features, the locks and dams. While these structures contained the entropy of the Panamanian environment, they were fragile in the face of the explosive power of bombs. Mehaffey didn't mince words when expressing his concerns, writing, "Irreparable damage to a lock canal could

[41] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session," pg. 20.
[42] *Ibid*, pg. 16.

be inflicted by the hit of a single atomic bomb. Multiple attacks with this weapon, or with conventional weapons in combination, would mean the loss of use of the Canal for four years."[43] Both the locks or the dam could be damaged beyond repair, taking years to rebuild. In the case of an attack on the dam, it would also drain the artificially constructed summit lake, meaning that before the Canal could be used again the dam needed to be rebuilt and the lake refilled. The result would be years without an interoceanic passage, an unacceptable reality.

While atomic bombs constituted the chief threat to the Canal, conventional bombs still held the potential to destroy the Canal. Conventional explosives expanded in destructive capacity during the war. New explosives like the ten-ton "blockbuster" were more than capable of shattering concrete and shredding steel.[44] Additionally, aircraft carriers allowed hostile forces to mobilize considerable numbers of aircraft in areas previously thought isolated and inaccessible. This meant that a hostile force could theoretically carry out sustained bombing in nearly any location including the Canal Zone.[45] The Canal, while it was equipped with fortifications and defensive structures, could not withstand such a substantial attack. Conventional explosives could create craters hundreds of feet wide, more than wide enough to encompass both lanes of locks.[46] While these conventional bombs were dangerous, however, they paled in comparison next to the destructive capability of nuclear weaponry.

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[43] Mehaffey, Joseph. "Digest Report of the Governor of the Panama Canal Rendered in Accordance with Public Law 280 79th Congress, 1st Session." pg. 6.

[44] James Stratton, *Introductory Statement* from, "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Discussion Presented at the Meeting of the Board of Consulting Engineers July 28 to 31, 1946." Department of Operations and Maintenance: Special Engineering Division, August 1946, USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related the Improvement of the Canal, Box 4, pg. 4.

[45] *Ibid*, pg. 4.

[46] Darling, James, *Appendix C: Characteristics and Effects of Conventional Explosives*, from "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Harvard Conference At Cambridge Massachusetts September 10, 11, 12, 13 and 21, 1946." Department of Operations and Maintenance: Special Engineering Division, March 6, 1947. USNA, RG 185, Collection A1 120-A Isthmian Canal Studies and Memorandums 1946-1947, Box 1, Declassification NND 008022, pg. p-1 32.

The dropping of the atomic bombs at Hiroshima and Nagasaki pulled the world into a frightening new era. Fission energy was radically more powerful than any source of energy humanity had previously harnessed and when applied to the task of destruction it became, in the words of Dr. J. Robert Oppenheimer, "the destroyer of worlds." Oppenheimer's description proved prophetic, if perhaps a bit too sophisticated to describe the brutal efficiency of nuclear explosions. Conventional explosions could crack concrete and bend steel, atomic explosions could shatter or vaporize concrete and melt steel, leaving thousand-foot craters in their wake.[47] What chance did the Canal have in the face of the destroyer of worlds?

The short answer was none. While it was possible that the Canal could recover from the damage rendered by a conventional bomb, engineers were resigned to the fact that, "the damage caused by the atomic bomb crater would be so extensive that it would be improbable that any attempt would be made to repair the lock for further use during the time of war."[48] Advances in the offensive capacity of warfare had advanced more rapidly than the fixed Canal and its increasingly modest locks could accommodate. This pointed to the tension that stalked the Canal throughout the decades following its development. Restructuring the Panamanian landscape to create a canal had taken a decade, millions of dollars, and unprecedented volumes of energy, yet left in its wake a fixed and static waterway. This meant that alterations to the Canal were impractical to the point of requiring an equally, if not more extensive investment of energy than had been required to construct the Canal in the first placed. As a result, the Canal that faced the

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[47] Westergaard, H.M. "Letter from H.M. Westergaard to James H. Stratton, June 30, 1947," June 30, 1947. USNA, RG 185, Collection: A1 152 Reports, Papers, and Proceedings Related to Improvement of the Canal, Box 3, pg. 5.
[48] Darling, James. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Dr. H.M. Westergaard at Diablo Heights, Canal Zone, October 14-19, 1946." Department of Operations and Maintenance: Special Engineering Division, December 31, 1946, USNA, RG 185, Collection A1 120-A Isthmian Canal Studies and Memorandums 1946-1947, Box 1, Declassification NND 008022, pg. P1-18.

prospect of nuclear annihilation in the aftermath of WWII remained a structure created for an era in which, "critical forms of attack were envisioned as naval gunfire directed against the locks and enemy forces moving overland to capture the Canal intact."[49] The Canal needed to be modernized, and the unique challenges presented by WWII laid the defects of the waterway bare. In response, the government mobilized its resources to try to conclusively deal with these limitations and overcome the fixed limitations of the Canal that had hindered it over the past three decades.

Reimagining the Canal

The passage of Public Law 280 on December 28, 1945 was the culmination of the studies initiated in the 1920s and 1930s. Building on those studies, particularly the 1929 and 1939 studies that paved the way to the Madden Dam and Third Locks projects, Public Law 280 sought to modernize the Canal. The role that WWII played in impacting this process was undeniable. When construction on the Third Locks was halted in 1942, it was assumed that work would resume at the end of the war. And yet due to the development of aircraft carriers, saturation bombing, and atomic weaponry, it was decided that "The requirements of capacity and security have changed radically since 1939 when the Third Locks project was conceived."[50] The new studies would need to completely reimagine the Canal in order to ensure its relevance and utility in the coming decades. To this end Congress charged Governor Joseph Mehaffey, under the guidance of the Secretary of War, with examining plans to improve passage between the oceans

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[49] Stratton, James, *The Future and the Panama Canal*, from "Proceedings of the American Society of Civil Engineers: Vol. 74, No. 4: Panama Canal: The Sea-level Project." American Society of Civil Engineers, April 1948. USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to Improvement of the Canal, Box 1, pg. 445.

[50] Mehaffey, Joseph, *Annex 6: Panama Lock Canals,* "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Annex 6," November 21, 1947. USNA, RG 185, Collection A1 152 Reports, Papers and Proceedings Related to the Improvement of the Canal, Box 8, pg. 8.

either by renovating the existing Canal, constructing a new canal in Panama, or finding another route that could be used to facilitate interoceanic shipping.[51] The quest for a new canal had commenced.

Mehaffey was well suited to this task. Born in Ohio in 1889, Mehaffey attended West Point before continuing his education at the Army's Engineering School. After completing his degree in 1913, Mehaffey was posted around the world, overseeing engineering projects in Alaska, France, and Panama over the decades before being promoted Brigadier General in 1942. Mehaffey's broad-ranging experience and history with Panama made him well suited to serve as Governor of the Canal Zone, a post to which he was appointed in 1944.[52] While talented, Mehaffey, busy with the administration of the Canal, couldn't dedicate all his time to the Canal Study. To this post was appointed a talented Army Officer, Colonel James Stratton. Stratton's career trajectory paralleled Mehaffey's in many ways. Born in Connecticut in 1898, Stratton attended West Point during WWI, enlisting in the Army Corps of Engineers after graduating. During the interwar years, Stratton worked on a variety of projects around the nation but showed a natural proclivity towards lock and dam engineering, helping build such structures in New Hampshire, Colorado, and on the Mississippi River. Stratton served with distinction in WWII, earning both the Legion of Merit and Distinguished Service Cross. After a brief stint reorganizing the Civil Works Program of the Corps of Engineers, he was transferred to Panama to take the lead on the studies for a new Isthmian canal in early 1946.[53]

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[51] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session," pg. i.

[52] Panama Canal Authority, "Joseph C. Mehaffey Biography", retrieved from https://www.pancanal.com/eng/history/biographies/mehaffey.html retrieved on 1/2/19

[53] Wilson Binger, "James Hobson Stratton" in *Memorial Tributes: National Academy of Engineering Volume 3,* National Academies Press, 1989, retrieved from https://www.nae.edu/189327.aspx retrieved on 1/2/19

Under the leadership of Stratton, the studies began in earnest. Stratton unified civilian and military personnel from a variety of backgrounds to carry out an extensive review of the literature on the Isthmus and to conduct studies to determine the feasibility of a new canal. While the sheer abundance of personnel led to competing visions of how the studies should progress, they eventually settled on four key criteria that would shape their quest for a new canal. After extensive study they determined,

> A. At no stage of the operation should we have less canal capacity that at present. B. The canal capacity should be increased as quickly as possible to accommodate the largest naval vessels. C. At no stage should the security of the canal either from a structural or military point of view be less than at present. D. The sequence of operations should be such that work could be terminated at any time without jeopardizing the capacity or security of the canal.[54]

With these four criteria in place, the engineers began an extensive program of study including experiments into the security of the Canal, reviews and comprehensive estimates of future traffic patterns, potential construction plans for lock and sea-level canals, plans for alternative sites for an Isthmian canal, and analyses of the costs of each route. Over the next two years, scientists and engineers from universities like Harvard and the University of Pennsylvania came together under the umbrella of Public Law 280 to attempt to deal with the shortcomings of the existing Canal, and finally, find a way to restructure the fixed locks that had remained unchanged over the previous three decades.

Understanding Atoms

Unsurprisingly, one of the challenges that Stratton directed the bulk of his resources towards, and personally involved himself in, was the determination of the threat presented by

[54] Various. *Annex D: Minutes,* "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers July 28 to 31, 1946." Department of Operations and Maintenance: Special Engineering Division, August 8, 1946, USNA, RG 185, Collection A1 152 Reports, Papers and Proceedings Related to the Improvement of the Canal, Box 4, pg. D-81.

atomic and conventional explosives. While there was ample data on the destructive capacity of conventional weapons, the increase in the explosive yields of conventional weapons raised questions about the accuracy of scaling models when applied to new bombs. More concerning was the complete lack of information on the impact of an atomic attack. To better understand these phenomena Stratton appointed a Board of Consulting Engineers, who conducted a variety of tests to determine not only the destructive capabilities of these new weapons but also how they would impact the unique Panamanian environment. Explosive tests, sandbox studies, scaling models, slope stability analyses, and data from larger explosions in the United States all helped scientists gain a better understanding of these weapons and the threat they presented to the Canal.

The Board held a series of conferences in the Canal Zone and at Harvard University in July, September, and October of 1946 to explore these questions. The engineers' objective was to better understand how the unique geological formations of Panama would respond to conventional and atomic bombing.[55] Their chief challenge was assessing the sheer diversity of terrain along the narrow stretch of land. In response to a question regarding the capacity to mitigate slope failures due to bombings one of the consultants provided an exasperated response, claiming, "When you have such a heterogeneous geologic formation as in Panama, I doubt whether anybody could give an unqualified answer, except one which would be applicable to a very limited bracket rather than to a total stretch of 50 miles."[56] Given that they couldn't answer questions about the impact of bombs without first understanding the geological realities of the

[55] Darling, James. "Isthmian Canal Studies (I.C.S.) Memo No. 85-P: Summary of Results of Harvard Conference," November 5, 1946, USNA, RG 185, Collection A1 124 Isthmian Canal Studies Memorandums and Meeting Minutes 1946-1948, Box 3, pg. 1.
[56] *Annex D: Minutes* "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 9.

region, the consultants began a concentrated study to better understand the formations that made up the Canal Zone.

The final report on the geological formations in the Canal Zone identified over a dozen different formations ranging from Atlantic and Pacific Muck- weak, silty substances that were easily excavated but highly viscous- to the hard but brittle shales of the Culebra region.[57] In many ways the report merely reinforced what the consultants already knew: the Canal Zone had a diverse array of soil compositions, each of which reacted to dynamic forces differently. And yet the report also displayed a considerable growth in the geological knowledge of the Canal Zone. The continual shock at the slides that plagued the Culebra Cut during Canal construction suggested that in the 1910s engineers were relying on trial and error to determine the stability of Isthmian soils. By 1947 their understanding of the local environment had evolved to the point that they could proactively plan slopes and cuts that could withstand or at least mitigate the force of explosions. This was a substantial step forward and helped Stratton and his engineers craft tests and formulas that helped them gain a better understanding of how explosive forces could unleash the entropy of the Panamanian environment.

The notion of conducting on-site tests in Panamanian formations was surprisingly a novel one in 1946. Certainly, the ICC had used tremendous amounts of explosives in the creation of the Canal, but since that point in time, there had been no experiments to understand how exactly

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[57] Geology Section, *Appendix G: Paper 2: Descriptions of Geological Formations Encountered Along the Cut*, "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Special Consultants: November 21-22 & December 23-28, 1946: Papers Presented at Conference of December 23-28, 1946." Department of Operations and Maintenance: Special Engineering Division, March 21, 1947, USNA, RG 185, Collection A1 120-A Isthmian Canal Studies and Memorandums 1946-1947, Box 1, Declassification NND 008022, pg. 1-2.

formations, particularly the Cucaracha and Culebra formations, responded to dynamic forces.[58] The 1946 tests consisted of a series of seven detonations in the Cucaracha formation. Engineers detonated three 25-pound charges, three 75-pound charges and a single charge of 200-pounds. While modest in size, the tests provided valuable data for the engineers. They suggested that the consultants' scaling formulas were accurate, at least as far as conventional explosives were concerned. In addition, they reinforced just how dramatic the impacts unleashed by explosives could be on the Panamanian Landscape. Reports of the tests warned, "Since Cucaracha is classed as rock, its tendency to crater as severely as clay was wholly unexpected."[59] These findings served to reinforce the security concerns of the existing Canal and provided indications of just how extensive security measures would need to be to create a waterway resistant to bombing.

These localized, on-site explosions were supplemented by a series of laboratory tests that provided broader data on explosions at various Canal facilities. Among the most frequently utilized of these tests were so-called "sandbox explosions" in which a four-foot by four-foot box, filled with a foot of sand, was molded into small-scale replicas of Canal features which were then subjected to controlled explosions. Scientists observed the craters left by these explosions and used the data to determine the potential hazards presented by high yield explosives. The tests reinforced the findings of the Cucaracha blasts and the engineers again concluded that crater size and diameter tended to be larger than anticipated.[60] Engineers used this data to try to determine

[58] Soehrens, John, *Appendix B: Crater Tests,* "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Dr. H.M. Westergaard at Diablo Heights, Canal Zone, October 14-19, 1946," pg. 39.

[59] Soerhens, John, *Paper VII: Crater Tests in Cucaracha*, located in "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Special Consultants: November 21-22 & December 23-28, 1946: Papers Presented at Conference of December 23-28, 1946," pg. 4.

[60] Soerhens, John *Paper VIII: Small Scale Tests in Cohesionless Material,* located in "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Special Consultants: November 21-22 & December 23-28, 1946: Papers Presented at Conference of December 23-28, 1946," pg. 2.

how susceptible the locks were to destruction in an attack. The findings were grim. The consensus was that a 40,000-pound bomb could damage locks and gates if it exploded at a distance of 70 feet, a 100,000-pound bomb at a distance of 100 feet and 400,000-pound bomb at a distance of 1,500 feet. A direct hit against any of the locks or bays would destroy the structure in question.[61] By any metric, conventional explosions held the potential to completely eradicate the value of a lock canal.

Conventional explosives were certainly a threat to the Canal, and yet they could be quantified, assessed and understood. Atomic explosives were a completely unknown entity. Their destructive power had only been unleashed a handful of times to seemingly cataclysmic effect. Thanks in part to the secrecy that shrouded nuclear weapons, their effects remained a product of conjecture and guesswork. While they gained access to some classified information to conduct their studies, Stratton and his underlings also found that they frequently ventured into the realm of the unknown in their studies of nuclear energy. This was not a cause for comfort. While studies were conducted into ways to safeguard the Canal against nuclear weapons, scientists became increasingly aware that they were undertaking an impossible task. The energy presented by the atom was so massive that no canal would be safe from its devastating consequences.

The threat of the atomic bomb cast a shadow over the 1947 study. In Colonel Stratton's welcome to the Board of Consulting Engineers, he identified the atomic bomb as the single most pressing threat to the Canal and emphasized that any plan for canal security would need to

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[61] P.J. Cannell, *Appendix E: Stability Analysis of Lock Walls Under Dynamic Loading*, located in Darling, James. “United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Dr. H.M. Westergaard at Diablo Heights, Canal Zone, October 14-19, 1946,” pg. 54.

mitigate the damage such a bomb could cause.[62] With this imperative in mind, the consultants attempted to conduct experiments and collect data that would allow them to fully understand the consequences of an atomic detonation.

Studies into the carnage unleashed by an atomic bomb were entirely speculative and the consultants were quick to point out that they could only really anticipate the physical destruction rendered by the weapon rather than the consequences of radiation.[63] Further complicating matters was the fact that no one knew quite how rapidly the yield of atomic bombs would expand. James Darling, one of the consulting engineers, didn't mince words when cautioning his fellow engineers, "The limitations of these data are readily recognized when one realizes that the present atomic bomb (Nagasaki type) is the equivalent of 20,000 tons of TNT and that future bombs may be 10 to 1000 times more powerful."[64] Despite these qualifiers, the consultants attempted to summarize the destructive capacity of the atomic bomb in the Canal. They worked with the data available to them, using the Nagasaki detonation as their guide and applying its force to the Panamanian environment.

Their focus wasn't necessarily on what would happen if an atomic attack was launched on a canal structure. It was a foregone conclusion that a direct hit from a nuclear weapon would

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[62] Stratton, James, *Introductory Statement*, from Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Discussion Presented at the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 5.
[63] Darling, James, *Appendix D: Effects of the Atomic Bomb,* located in "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Harvard Conference at Cambridge Massachusetts September 10, 11, 12, 13 and 21, 1946." Department of Operations and Maintenance: Special Engineering Division, March 6, 1947, USNA, RG 185, Collection A1 120-A Isthmian Canal Studies and Memorandums 1946-1947, Box 1, Declassification NND 008022, pg. 33.
[64] Darling, James in Stratton James, *Study of Channel Closure and Slope Failure from Atomic Bombing,* in O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947," pg. E-45.

vaporize the locks or dam if they were hit, rendering the Canal useless until they were repaired.[65] Instead, the consultants' primary concern was gauging how long it would take to recover from a strike on the Canal prism. As had been the case with conventional explosions, the size of the crater left behind depended on the material in which it detonated. H.M. Westergaard, a professor at Harvard and one of the consulting engineers tackling the atomic issue suggested that a 40 kt bomb would create a crater roughly 1,188 feet in diameter in marine muck, 943 feet in diameter in the Cucaracha formation, 848 feet in Gatun sandstone, and roughly 642 ft in some of the rockier regions of the Continental Divide.[66] Westergaard's figures were optimistic in comparison to the figures put forward by Darling, who suggested that a detonation would create a crater 450 feet deep and up to 1,550 feet wide in clay and that this explosion would be considerably bigger in muck and less cohesive material.[67]

Debating whether Darling or Westergaard's estimates were correct was an exercise in semantics. The more pressing issue was the fact that by any objective estimate the crater left by an atomic bomb would likely be wider than the Canal itself. The consultants estimated that a Nagasaki type explosion would displace anywhere between 1,000,000 and 2,700,000 cubic yards of material if it struck the Canal in muddier, more viscous terrain. They estimated that in the best circumstances this would take seven to eighteen days to fully dredge and that was assuming that no structures were damaged in the attack. If the bomb struck the rockier terrain of the Continental Divide it would likely displace at least 2,000,000 cubic yards of material and could

[65] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session," pg. 59.
[66] Westergaard, H.M. "Letter from H.M. Westergaard to James H. Stratton, June 30, 1947," June 30, 1947, pg. 5.
[67] Darling, James. *Appendix D: Effects of the Atomic Bomb*, "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Harvard Conference at Cambridge Massachusetts September 10, 11, 12, 13 and 21, 1946," pg. 34.

easily take 40 days or longer to repair.[68] These figures led the consulting engineers to determine that it was impossible to fully mitigate the danger presented by the atomic bomb. Instead, they sought to better understand the chief dangers it presented. To this end, they characterized the potential types of attacks the Canal might suffer in order to determine which would be the most devastating. After several weeks of discussion and debate, they settled on four categories of attack, ranked in order of the threat they presented. The most pressing concern was a crater in the canal prism as they worried this would block the entirety of the Canal and would create lips that would need to be removed before the Canal could reopen. Slides resulting from craters within the Canal were next on the list. While not as devastating as the crater itself, slides could still block part of the waterway, complicating the recovery effort. Next in magnitude were slides resulting from explosions outside the canal prism. While it wouldn't block the entire Canal, the consulting engineers were concerned that such an attack could cause slopes to fail, blocking part of the passage. Finally, they identified airblast as the least destructive force associated with an atomic detonation. While airblast could still cause slope failure it would likely only erode a small part of the slope and would not permanently halt traffic.[69]

The studies conducted by the consulting engineers into the dangers presented by conventional and atomic bombs forced the Canal to reckon with an uncomfortable reality: it was effectively impossible to protect the existing Canal from the dangers constituted by these new weapons. A direct hit on any structure could close the Canal for years and the unprecedented

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[68] Stratton James, *Study of Channel Failure and Canal Closure from Atomic Bombing,* located in O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947," pg. E-46, E-47.
[69] W.V. Binger in Stratton, *Study of Channel Closure and Slope Failure from Atomic Bombing,* located in O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947," pg. E-48

yields provided by nuclear energy meant that even an attack on the canal prism could block traffic for weeks or months at a time. While troubling, this information also helped the engineers focus their attempts at renovating the existing Canal. They accepted the fact that they could not prevent bombing from damaging the Canal. Instead, they focused their attention on creating structures, either by renovating the existing Canal or creating a new one, that mitigated the impacts of bombs. The plans for both lock-style and sea-level canals, motivated by the concerns expressed by the consulting engineers, would modernize the Canal, rendering it secure and ideally a crucial part of both America's national security and economic interests for decades to come.

Locked In

Now that Stratton and the consulting engineers had identified the major threats to the Canal, they focused their attention on the creation of a waterway that could meet the capacity needs of interoceanic commerce and provide adequate security. This was no small task, and they cast a broad net when searching for potential solutions to their issues. One of the most creative solutions was the creation of a ship railway that would carry vessels overland from ocean to ocean. Ultimately this idea didn't bear fruit due to the fact that it addressed neither the capacity nor security demands of interoceanic transit.[70] More realistic was the search for routes outside of Panama. The consultants examined possible routes in Colombia, Nicaragua, and Mexico amongst other locations. While some of these routes were alluring, the infrastructure already in place in Panama led them to decide that at the present time this Isthmus was the best site for the

[70] James Stratton, *Introductory Statement,* located in Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Discussion Presented at the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 5.

new canal.[71] The next question was whether they should build a sea-level canal or if a lock canal was still the best waterway for the Isthmus.

The consultants organized their vision for a lock canal into three distinct plans. Plan I maximized the capacity of the current lock canal by improving facilities, widening the Gaillard Cut, and limiting the necessity for regular lock overhauls. Plan I did not include any increase in the size of the locks nor did it improve the security of the Canal, focusing exclusively on maximizing traffic to extend the point at which the Canal reached capacity beyond 1964.[72] Plan II included all of these changes to maximize capacity, but added improvements that would increase the size of the locks, allowing larger ships to transit the Canal. In addition, Plan II also made modest security improvements to the Canal by separating lock sites, reinforcing structures, and adding defensive structures.[73] Plan III was the most ambitious of the lock-style plans. This plan increased capacity and the ability for larger ships to transit the Canal, but also included the most robust levels of security that could be afforded a lock canal.[74] The three different plans all presented their own merits. As the consulting engineers began examining these plans, they soon recognized that they all also suffered from considerable shortcomings.

Plan I was the most modest of the three lock canal plans. With a price tag of only $129,983,000, it was also the most economical and, as a result, potentially the most feasible plan. Plan I focused on maximizing the efficiency of the current lock canal. There were several areas where the engineers felt they could make relatively modest alterations to the existing Canal and

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[71] Various, "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. B1-B16
[72] Mehaffey, Joseph, "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Annex 6: Panama Lock Canals," pg. 11.
[73] *Ibid*, pg. 19.
[74] *Ibid*, pg. 29.

significantly increase its capacity. One of the most frequently discussed solutions was the widening of the Gaillard Cut, the narrowest point of the Canal and the most difficult to navigate. At only 300 feet wide it wasn't uncommon for traffic in the Cut to be limited to a single ship moving one way at a time.[75] This would be accompanied by a series of traffic aids and navigational tools that would help ships navigate in fog and other adverse conditions.

The bigger focus of Plan I was to modernize the existing locks to preclude the need for four-year overhauls of each lock. The overhauls were the chief factor limiting the capacity of the existing locks. Lock overhauls were conducted every two years, alternating between Pacific and Atlantic locks. During these overhauls traffic was confined to a single lane, resulting in a maximum of only 27 lockages over the course of a day.[76] Renovating the locks to avoid these delays would substantially increase the capacity of the Canal, allowing it to meet the projected needs of interoceanic commerce for decades to come. Despite this, the consultants were reluctant to support Plan I. While it was economical, the plan failed to address the security concerns or provide passage for larger vessels. In addition, the obsolescence of the existing structure was blatant. General Hans Kramer expressed the concerns of many of the consulting engineers when he stated, "The present locks are over 30 years old and before the adoption and execution of any of these plans they will be somewhat older. They have served well and are continuing to serve well but are undergoing obsolescence and admittedly are inadequate in size for universal use. It is poor overall economy to put money into an investment which already has definite bottlenecks

[75] Mehaffey, Joseph. "Digest Report of the Governor of the Panama Canal Rendered in Accordance with Public Law 280 79th Congress, 1st Session," pg. 3.

[76] E.H. Bourquard, *Memo 128: Capacity of the Present Panama Canal*, Various. "Papers Presented at the Meeting of the Board of Consulting Engineers of the Panama Canal at Diablo Heights, Canal Zone, February 11-18, 1947: Studies Under Public Law 280 79th Congress," pg. 2.

and limitations."[77] Despite its economy, Plan I simply failed to address the issues plaguing the Canal.

Plan II presented a middle ground between the lock canal plans. At $1,632,275,000, Plan II was considerably more expensive than Plan I, but allowed larger vessels to transit the locks and added a degree of security as well. Plan II explored several projects to accomplish these objectives including a complete redesign of the existing locks or the creation of a third set of locks, similar to the Third Locks plan of 1939. One of the most ambitious components of the plan was the creation of a Pacific Lake at the Miraflores Locks. Unlike the Atlantic Locks, all three of which were at Gatun, the Pacific Locks were split. Ships passed through two sets of locks at Miraflores before entering Miraflores Lake, a small body of water which didn't have enough room for mooring sites. From there ships passed through a single set of locks at Pedro Miguel. There was nowhere for ships to moor until they reached Gamboa several miles inland. Engineers proposed the creation of a third set of locks at Miraflores and the creation of a Pacific Locks Lake that would speed up traffic and allow vessels to moor at the Pacific end of the locks as well.[78] In addition to the increased capacity, this plan provided increased security by spreading the locks out and creating larger, reinforced structures. While Plan II met capacity for the foreseeable future, concerns remained about the vulnerability of the Canal to attack. Even with added safety features it did not meet the mandate set by Stratton.

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[77] Kramer in *Appendix D: Minutes*, located in Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 21-22.

[78] Duval, Miles. "Presentation before the General Board of Consultants of the Panama Canal at the Request of the Governor on the Marine Operating Problems Involved in the Proposed Modernization Studies of the Panama Canal Authorized by Public Law 280, 79th Congress," pg. 36-37.

Ultimately, the consultants looked to Plan III, the most ambitious, and, with a price tag of $2,307,686,000, by far the most expensive of the lock canal plans.[79] Plan III was proof that security did not come cheap, but it seemed as though the ambitious plan might be the best long-term investment for the Canal. Utilizing many of the same measures as Plans I and II including an increase in traffic capacity and the size of vessels, Plan III also directed considerable resources towards the development of new, reinforced, and diffused facilities, as well as defensive fortifications to help the Canal withstand any attack. The consultants were optimistic about Plan III's security features, arguing that the current Canal would be completely irrelevant in comparison to " a lock type of canal provided with two new two-lane locks at both ends of the canal, each lock within itself to be invulnerable to the bomb of the largest size likely to be used in saturation bombing..."[80] Furthermore, they were optimistic that, "We have shown that these two capacity deficiencies, volume and ship size, can be overcome with an improved lock canal."[81] The implication was clear. Despite its exorbitant price range, Plan III came the closest to meeting the mandate set forth in Public Law 280.

And yet closest was not quite close enough. The consultants were confident that a lock canal that would meet the needs of both traffic and ship size over the coming decades could be constructed. Despite this, regardless of how strong they made the walls of the locks of a lock canal, there was no way that the structure could withstand the hit of the largest conventional bombs, let alone an atomic bomb.[82] Much of this vulnerability stemmed from the fact that the

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[79] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Annex 6," pg. 47.
[80] Stratton, James, *Selection of Route in Panama and Vicinity and Determination of Type of Canal,* located in O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947," pg. E-312.
[81] *Ibid*, pg. E-311.
[82] *Ibid*, pg. E-314

lock canal was an inherently fragile construct. The need for specialized facilities in the forms of locks and a summit lake created too many potential targets to be effectively defended from a concentrated enemy attack. Ultimately it was Mehaffey who delivered the final verdict on the lock canal. In his report to Congress, he wrote, "Lock structures and a summit lake are essential elements of a lock canal. Because these features can be damaged or destroyed, and traffic interrupted for such long periods of time as to make the canal undependable in war, it follows that no lock canal can meet fully the future needs of national defense."[83] No lock canal, regardless of how stringent its defenses were, could ever truly be safe. If the consultants wanted to construct a truly secure canal they would need to look elsewhere, possibly to the past, to find their answer.

The Search for a Sea-Level Canal

If the issue with a lock canal was that it was susceptible to destruction due to the presence of locks and a summit lake, the best course of action was to get rid of those liabilities. A sea-level canal possessed none of these limitations and could easily meet the capacity needs laid out in Public Law 280. With this in mind, the consultants dedicated the majority of their time to the development of a sea-level canal plan. The sea-level canal met all the needs required of the waterway and the consultants were optimistic that it could be built. With a price tag of $2,482,810,000 the sea-level canal was by far the most expensive plan put forth by the consulting engineers, and yet the fact that it only cost about $200,000,000 more than Plan III for a lock canal did indicate that it would provide the most worthwhile long-term investment for the future.[84] As a result, the Board of Consulting Engineers and Governor Mehaffey recommended

[83] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session," pg. 62.
[84] *Ibid,* pg. 60.

the sea-level canal wholeheartedly. Ultimately, however, the steep price tag attached to the sea-level canal and concerns about developing the technology and obtaining the energy necessary to make it a reality prevented it from being realized in 1947.

Initially, the proposal for a sea-level canal was met with considerable optimism. Several plans for its development were put forward including the creation of a sea-level canal that would run parallel to the existing lock canal, but eventually the consultants adopted what was known as the "Panama sea-level conversion route." This plan would gradually alter the existing lock canal, lowering the bottom of Gatun Lake to create a sea-level route. This was not a new idea. French construction in the 1870s had been focused on the creation of a sea-level canal and initial American's briefly explored a sea-level canal before President Roosevelt, at the suggestion of John Stevens, overruled the Isthmian Canal Commission and mandated the construction of a lock canal instead.[85] By 1947 the assumption was that technology and available energy had advanced far enough that a sea-level canal was no longer a foolish fantasy, but rather a realistic alternative to the increasingly obsolete lock canal.

Plans for the size of the channel itself varied widely. The Board of Consulting Engineers suggested that the navigable prism should be as wide as it could feasibly be while still retaining a degree of economy. The rationale for this was twofold. On the one hand, the engineers hoped to appease the Navy. History had shown that the Navy tended to continually ask for increases in channel size. Admiral Ben Moreell, the Chief of the Naval Department of Yards and Docks and the Chief of Civil Engineers of the Navy, as well as the member of the Board of Consulting Engineers with the most familiarity with Navy politics, somewhat playfully suggested "Our

[85] F.S. Brown, *Panama Sea-Level Conversion*, located in Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Discussion Presented at the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 1.

experience in Pearl Harbor is interesting. I believe we started out using a 500-foot channel... and the ship operators insisted we widen it to 750'; then to 1000'. Of course, they had in mind getting out quickly, at very high speed, but I think you will find that no matter what width of canal you decide upon, the Navy will probably consider it insufficient."[86] In addition to appeasing the Navy, the size of the canal prism would have a substantial bearing on the Canal's resiliency in the face of attack. The wider the Canal channel was, the less likely an attack would be to close it. Wilson Binger, the consulting engineer most versed in slope stability dynamics, went so far as to suggest, "It is not thought that at this time that any design other than making the Canal wider than the crater diameter could protect against such a closure."[87] The consulting engineers ultimately settled on a navigable channel 600 feet wide and at least 60 feet deep.[88] This met all the needs laid out by Public Law 280 and ensured the Canal's relevance for the foreseeable future.

The plan for the Panama Sea-Level Conversion route was met with near universal approval by the Board of Consulting Engineers and by Mehaffey himself. The sea-level canal had the highest capacity of any of the routes with the potential to transit 174 vessels per day, a figure that nearly doubled the highest projections for traffic by the year 2000.[89] A sea-level canal would transit the largest vessels on the oceans with ease and could do so far more rapidly than a lock canal. Most importantly the sea-level canal seemed the only plan capable of adequately

[86] Ben Moreell in *Appendix D: Minutes*, located in Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 55.
[87] W.V. Binger *Appendix G: Preliminary Slope Studies*, located in Darling, James. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Harvard Conference At Cambridge Massachusetts September 10, 11, 12, 13 and 21, 1946," pg. 46.
[88] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Annex 7," USNA, RG 185, Collection A1 152 Reports, Papers and Proceedings Related to the Improvement of the Canal, Box 8, pg. 36.
[89] *Ibid*, pg. 6.

dealing with the threat of attack by conventional or nuclear bombing. The Board of Consulting Engineers was quite explicit in their suggestions to Governor Mehaffey, stating, "There is no absolutely secure canal in the sense that there would be no appreciable damage if the enemy were to have his will. But this much is certain- no matter what gauge of effort it is assumed that the enemy will apply, the answer will be the same: The sea-level canal can take it; the lock type canal, be it at Panama or elsewhere, cannot."[90] While a bit more diplomatic, Mehaffey shared a similar sentiment in his final report to Congress, writing, "A sea-level canal constitutes the only means of meeting adequately the future needs of both interoceanic commerce and national defense. Such a canal can be obtained most effectively and economically by converting the Panama Canal to a sea-level waterway."[91] In both cases, the consultants and the Governor made their preference for a sea-level clear.

The Limitations of Panama

The blatant preference for the sea-level canal expressed by those who had worked most closely on the project raises an interesting question. Why was such a waterway never built? Public Law 280 was passed with the intention of yielding actionable results and the previous projects at Madden Dam and the work on the Third Locks suggested that there was the political will to undertake a modernization of the Canal. While the sea-level canal was expensive, it also was comparable in cost to the most advanced lock canal and bore considerable long-term advantages over every competing route. In essence, it seemed the best possible solution to the myriad of problems plaguing the Panama Canal. And yet the situation was far more complicated

[90] James Stratton, *Selection of Route in Panama and Vicinity and Determination of Type of Canal*, located in O'Shaughnessy, P.S. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers at Diablo Heights: February 11-18, 1947," pg. E-315.

[91] Mehaffey, Joseph. "Digest Report of the Governor of the Panama Canal Rendered in Accordance with Public Law 280 79th Congress, 1st Session," pg. 12.

than the consultants' suggestions implied. The concrete infrastructure that had been emplaced in 1914 needed to be undone in order to create a sea-level canal and doing so would yield considerable challenges including flooding, slides, and an acute lack of energy. In addition, engineers still needed to find a way to gouge out the remarkable volume of material that lay in the way of a sea-level waterway. All these uncertainties rendered the sea-level canal, at least for the moment, an untenable proposition.

The consulting engineers and Governor Mehaffey were unified in their belief that a sea-level canal could be created. Mehaffey brushed aside caution, writing, "The construction of a sea-level canal across the Isthmus of Panama, although one of the largest projects ever contemplated, would present no more unusual problems than those which were met and overcome in the original construction."[92] Perhaps Mehaffey was unaware of just how close the American attempt to construct a canal had come to failure, but his assurances rang somewhat hollow in the face of the considerable engineering challenges presented by the excavation of a new sea-level canal. First and foremost was the exorbitant cost and power requirements necessary for the creation of a new sea-level canal. Of the proposed $2,482,810,000 budget set out in the proposal, over half the funding was intended to cover the cost of excavation with $1,047,986,000 directed towards dry excavation and additional 398,376,000 set aside for dredging.[93] This steep investment stemmed from the sheer volume of material that needed to be removed to create a sea-level canal. Estimates suggested that excavation required the removal of 1,070,000,000 cubic yards of material, of which 750,000,000 cubic yards would be removed in dry excavation and the remaining 320,000,000 cubic yards through dredging. This figure was

[92] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session," pg. 89.
[93] *Ibid*, pg. 60.

more than three times higher than the total amount of material removed to construct the existing canal three decades earlier.[94]

It was not only the sheer volume of excavation work that was concerning, but also the methods that would be implemented to accomplish this gargantuan task. For dry excavation, engineers predicted that shovels capable of excavating 25 cubic yards of material in a single scoop were necessary. These massive machines would be accompanied by smaller 5 cubic yard shovels. Blasting would loosen material which could then be removed by shovels or dragnets.[95] While an imposing task, the technology for dry excavation at least existed. The same could not be said for dredging. Initially, the dredging plan had been predicated on the gradual draining of Gatun Lake. Dredges would excavate as much as they could reach over the canal prism. Gatun Lake would then be lowered, giving the dredges access to more material. After several successive passes, this process would conceivably yield a working sea-level canal. The catch was that this approach was time-consuming and expensive. The consultants found it far more appealing to pursue deep dredging, which required the development of specialized dredges capable of dredging at depths of up to 145 feet.[96] There was optimism that such dredges could be developed, but at the time the plan was made the technology didn't exist.

If excavation proved feasible and a new sea-level canal was constructed, the removal of the existing structures in the lock canal would simultaneously unleash the entropy they held at bay, forcing the sea-level canal to deal with the issues of slides and flooding that had plagued

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[94] J.J. Rose, F.L. Dye, W.B. Watson, L.T. Crook, *Construction Planning and Methods,* located in "Proceedings of the American Society of Civil Engineers: Vol. 74, No. 4: Panama Canal: The Sea-level Project," pg. 610.
[95] *Ibid*, pg. 621.
[96] F.L. Dye, *Stage and Deep Dredging,* located in Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Discussion Presented at the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 2.

previous construction projects. Slides were an unavoidable result of construction in Panama and the Culebra and Cucaracha slides were very much in the minds of the consulting engineers. While they were confident that their understanding of slope dynamics had evolved over the intervening three decades, slope stability remained a concern, particularly in the continental divide. Of the 1,000,000,000 cubic yards to be removed, nearly 30% was concentrated in a 4-mile section of the Isthmus in the region of Culebra.[97] Accomplishing this task required unprecedented cuts of up to 600 feet in the Continental Divide.[98] Given the region's propensity for slides, the ability to create such deep cuts while still retaining stable slopes was a challenge. This sentiment was cast in even starker terms by the concern for an atomic attack which loomed over the entirety of the studies. Steep slopes would slide far more easily than flatter slopes in the event of an explosion. And yet flattening slopes increased the already extensive demands for power and capital that accompanied a sea-level canal.

It was not only in the realm of slope instability where Panama’s entropy complicated construction efforts. One of the major benefits of a lock canal was that it precluded the need to deal with the floods that had vexed infrastructural projects in Panama in the 1800s. The Gatun and later Madden Dams had held floodwaters at bay, turning what had been a liability into Gatun Lake, one of the key components of the Canal’s infrastructure. Creating a sea-level canal required the removal of Gatun Lake, however, and consequently would unleash the destructive potential of floods once more. While floods wouldn't have the potential to destroy the Canal itself they could create dangerous cross-currents, rendering the Canal unnavigable until flooding

[97] Wilson Binger, *Excavation Slopes*, located in Various. “Proceedings of the American Society of Civil Engineers: Vol. 74, No. 4: Panama Canal: The Sea-level Project,” pg. 570.
[98] Wilson Binger, *Appendix D: Static Analysis of Slope Cuts in Homogenous Rock*, located in Darling, James. “United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Conference with Dr. H.M. Westergaard at Diablo Heights, Canal Zone, October 14-19, 1946,” pg. 49.

stopped.[99] The engineers' solution to the problem was the construction of a dam to supplement the Madden Dam and contain the Chagres, as well as the creation of the "East Diversion" and "West Diversion" a collection of dams, locks, reservoirs, and channels that would redirect water away from the sea-level canal.[100] While these projects made flood control viable, they also included extensive environmental engineering. The reliability and efficacy of these systems were by no means certain, and Panama's track record for wreaking havoc with the best-laid plans suggested just how tenuous the sea-level canal's success may have been.

In addition to engineering challenges, the sea-level also was a victim of the energy crunches that had complicated construction projects in the Transit Zone for decades. The sheer scale of the project meant that it would have a far more voracious energy appetite than the lock canal had in the early 1900s. Meeting this need required the importation and creation of tremendous amounts of human labor, mechanical labor, and electrical energy.

Human labor and mechanical labor were perhaps the most easily obtained sources of energy for the creation of a sea-level canal. By 1946 there was a workforce of 24,150 involved in the operation of the Panama Canal. Estimates suggested that by the peak year of construction this figure would balloon to nearly 51,730 workers.[101] This was a formidable figure to be sure, but the engineers were confident that, as had been the case with the construction of the original Canal, with enough incentives they could attract the necessary number of laborers. They harkened back to the same methods of labor recruitment that had served the ICC so well in the

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[99] F.S. Brown, *Flood Control* located in, Various. "Proceedings of the American Society of Civil Engineers: Vol. 74, No. 4: Panama Canal: The Sea-level Project," pg. 481.
[100] Stratton, *The Future and the Panama Canal*, located in Various. "Proceedings of the American Society of Civil Engineers: Vol. 74, No. 4: Panama Canal: The Sea-level Project," pg. 466.
[101] D.M. Eggleston. "Reference Data: Isthmian Canal Studies 1947." Department of Operations and Maintenance: Special Engineering Division, May 11, 1949, USNA, RG 185, Collection A1 152 Reports, Papers, and Proceedings Related to the Improvement of the Canal, Box 3, pg. 64.

early 1900s, suggesting that, "Skilled and technical personnel would be obtained from the United States. The unskilled employees would be largely indigenous to the Caribbean area."[102]

The consultants were also optimistic about their ability to obtain the mechanized labor necessary to construct the Canal. There were questions as to whether suitable deep-water dredges could be developed for use in the deep dredging scheme, but stage dredging presented a reliable alternative should the worst come to pass. To successfully complete dredging in ten to twelve years they required four suction dredges, two dipper dredges, eight Vulcan drill boats, and 37 rotary drill boats. These 51 vessels would be supplemented by numerous scows, and tugs to help with the removal and dumping of material.[103] The demands for a dry excavation force were far more amorphous and never advanced beyond preliminary assurances that adequate plant could be obtained if necessary. Indeed, most reports had a fairly optimistic outlook on getting the necessary equipment for dry excavation, in one instance going so far as to state that, "a wide choice of equipment of various types and sizes is available."[104] In any case, it was at least feasible that the human and mechanical labor necessary to construct the new waterway could be obtained, albeit at considerable cost.

The more vexing challenge was obtaining the necessary stores of electrical energy to support the excavation and construction of the sea-level canal. Again, this challenge was primarily the result of the need to remove the Gatun Dam and lower the height of Gatun and Madden Lakes. In addition to keeping floodwaters at bay, the dams provided the bulk of energy

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[102] Rose, Dye, et al., *Construction Planning and Methods*, located in, "Proceedings of the American Society of Civil Engineers: Vol. 74, No. 4: Panama Canal: The Sea-level Project," pg. 613.
[103] F.S. Brown, *Panama Canal Sea-level Conversion*, located in Various. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Discussion Presented at the Meeting of the Board of Consulting Engineers July 28 to 31, 1946," pg. 11.
[104] Rose, Dye, et al., *Construction Planning and Methods,* pg. 618.

in the Canal Zone. By 1946 Gatun hydroelectric plant was running without issue and had seen the addition of another turbine and generator, bringing its output up to 22,640 kW. The more recently constructed Madden Dam had an output of 30,000 kW. While a series of diesel plants provided supplementary power in case of emergency, the hydroelectric stations were the chief source of energy in the Canal Zone.[105] Losing roughly 52,000 kW of generating power would significantly hinder the creation of the sea-level canal, a task engineers anticipated would require the generation of 116,800 kW of energy to meet the demands of construction and supply an adequate reserve.[106] This left the sea-level canal in a sort of energy limbo. The east and west diversions diffused water so much that constructing a hydroelectric facility to replace the energy lost at Gatun and Miraflores was deemed impractical. The only option was the creation of new power plants operating on costly fossil fuels, a proposal that would drive the sea-level canal's costs even higher.

Due to the inability to overcome the engineering, entropic, and energetic challenges that stood in the way of the sea-level canal, the plan set forth in Public Law 280 never came to fruition. The sea-level canal presented an unprecedented undertaking, and while it was alluring to the Board of Consulting Engineers and Governor Mehaffey, questions regarding the feasibility of the project were simply too substantial to warrant a nearly $2.5 billion-dollar investment, regardless of the benefits that might accompany the project. The idea was, for the time being, laid to rest, and despite growing concerns about its obsolescence, the thirty-year-old Panama Canal moved into the Postwar era.

[105] F.S. Brown, *Panama Sea-level Canal Conversion*, pg. 12.

[106] Mehaffey, Joseph. "Report of the Governor of the Panama Canal under Public Law 280, 79th Congress, 1st Session: Appendix 16: Power," November 21, 1947, USNA, RG 185, Collection A1 152 Reports, Papers, and proceedings Related to the Improvement of the Canal, Box 10, pg. 12.

End of an Era

The interwar years showed that the Panama Canal had aged far more rapidly than anyone could have anticipated. The waterway had weathered the ebbs and flows of commerce and war, and as time went on concerns about the Canal's longevity began to grow alongside the volume and size of ships passing through its fixed locks. The delicate structures that allowed the Canal to operate and held the entropy of Panama at bay were increasingly seen as a liability, bottlenecks that were being outpaced by the development of new technologies and larger vessels. During the 1920s and 1930s, these discussions suggested that the Canal's obsolescence was approaching but still resided in some abstract, far off date. The same could not be said of the 1940s. The rapid development of military armaments that took place in WWII, culminating with the development of the atomic bomb, rendered the Canal's shortcomings more immediate than ever before. The fixed nature of the Canal may have been able to stand up to the entropy of Panama, but it was no match for the power of the atom.

With this reality in mind, the government sought to conduct studies to determine the best method to fix the Canal. Under the guidance of Governor Joseph Mehaffey and Colonel James Stratton, a group of over 100 consulting engineers came together to determine the future needs for security and capacity in an interoceanic canal. After nearly two years of tests, conferences, and debates they suggested emphatically that the only way to fix the Canal was to unfix it. By demolishing the locks and summit lake that rendered a lock canal vulnerable to bombing attacks and creating a sea-level canal it was possible to create a waterway that could meet the needs of both America's military and interoceanic shipping.

Ultimately, the sea-level canal proved ill-fated. The ambitious plan to eradicate the lock canal and the Panamanian landscape surrounding it was untenable. The massive amount of excavation necessary to build the waterway required the use of unproven technologies. Additionally, the removal of the summit lake and the need to make steep cuts through the Continental Divide resurrected the potential that Panama's pesky proclivity for entropy could once more wreak havoc with American construction efforts. Finally, the significant challenges to obtaining enough energy to complete the project served as the nail in the coffin. It was a feasible, although admittedly imposing, task to obtain the human and mechanical labor necessary for construction but obtaining electrical energy for a sea-level canal was more vexing. Removing Gatun and Madden Lakes would simultaneously remove the utility of Gatun and Madden hydroelectric stations, the chief sources of energy production in Panama. While these stations could be replaced, the costs would be extensive, to say the least. Ultimately, the coalescence of these concerns proved prohibitive to the construction of the sea-level canal.

And yet the sea-level canal was not dead. Indeed, its salvation ironically lay in the force which presented an existential threat to the existing Canal: atomic energy. The chief obstacle to the creation of the sea-level canal was that its reliance on conventional excavation, which accounted for over half of the total projected budget, rendered it excessively expensive. If a new, more economical source of energy could be directed towards the task of excavation the sea-level canal could rise again from the radioactive ashes. Interestingly, in his report on the potential dangers presented by a nuclear explosion, James Darling acknowledged that, "Although the atomic bomb was neither designed nor has it been used to produce earth-shaking and cratering effects, our studies should consider such use particularly since the main structure components, both earthwork, and masonry, which are involved in the canal studies, appear to be at least as vulnerable to underground explosion effects as to air burst, if not more so."[107] While Darling was primarily concerned about the devastation that could be unleashed by an underground explosion, his comments proved surprisingly insightful. A little more than a decade after Darling submitted his report, engineers would once again explore the consequences of underground nuclear explosives, except this time it would not be a faceless adversary who brought the bomb, but rather the engineers themselves

[107] James Darling, *Appendix D: Effects of the Atomic Bomb*, located in Darling, James. "United States Isthmian Canal Studies- 1947 Under Public Law 280 79th Congress, 1st Session: Proceedings of the Harvard Conference at Cambridge Massachusetts September 10, 11, 12, 13 and 21, 1946," pg. 34.

Chapter V: A Radioactive Flash in the Pan: The Promise and Problems of Nuclear Energy in Panama, 1960-1970

To the engineers meeting in Diablo Heights, Panama in February of 1947, nuclear energy presented an existential threat to the Panama Canal. They felt the danger constituted by a nuclear attack was so great that it was worth exploring the potential of replacing the barely three decades old Canal with a new, more resilient Isthmian canal.[1] A decade later, scientists suggested purposefully detonating upwards of 300 nuclear explosives in Panama. Nuclear explosions still held the potential to destroy the Canal, but by 1960 scientists thought they might also be the key to its salvation. Scientists from the Atomic Energy Commission believed that the controlled detonation of nuclear explosives could provide a safe, cost-effective means of creating a new sea-level canal across Central America. Their faith in this plutonium panacea was so pronounced that they concluded, "It should be emphasized that it is considered feasible to construct the proposed canal with nuclear explosives and techniques presently available."[2] For the next decade, they conducted tests, experiments, and surveys to bring their vision to fruition.

Despite the optimism of AEC scientists, a combination of technical challenges, Panamanian environmental realities, and public relations issues prevented this plutonium

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[1] *The Panama Canal Isthmian Canal Studies- 1947 under Public Law 280- 79th Congress, 1st Session: Proceedings of the Meeting of the Board of Consulting Engineers of the Panama Canal,* (1947, Department of Operation and Maintenance: Special Engineering Division; Balboa Heights, Canal Zone) retrieved from USNA, RG 185, Collection: Reports, Papers, and Proceedings Relating to the Improvement of the Capacity and Security of the Panama Canal Zone, 1946-1951, Box 4, pg. E-48.

[2] Atomic Energy Commission, Panama Canal Company, *Isthmian Canal Plans- 1960, "Annex VII: Nuclear Construction of a Sea-Level Canal and Cost of Nuclear Excavation" (*Hereafter *Isthmian Canal Plans-1960 "Annex VII"*) (January 1960), retrieved from USNA, RG 59, Collection: A1 3164 Bureau of Inter-American Affairs Office of Central American and Panamanian Affairs Study Group 15, Box 1, Declassification NND 959067, pg. 15.

pipedream from ever being realized.[3] Over the last several decades, historians have explored Project Plowshare and the hunt for an atomic canal. They rightfully emphasize the hubris of American scientists and their unrealistic optimism about the future of nuclear engineering.[4] While effective, many of these books suggest that it was public opinion, primarily on the part of environmentalists, that doomed nuclear engineering. Public relations certainly played a role but did not exist in isolation. A focus on energy and the environment suggests that the linked challenges of crossing the continental divide and creating stable slopes doomed the atomic canal before environmentalists could enter the fray. Nuclear explosives and their awesome power impacted environments too dramatically, unleashing more entropy than they contained.

The tension between nuclear energy's promise and problems stemmed from its unprecedented efficiency. Nuclear fission and fusion (both reactions were present in the thermonuclear explosives used for nuclear excavation) were as radically alien to the combustion of oil and coal as those processes were to the oxidation of calories in human bodies. A single pound of uranium can produce as much heat as 2.5 million pounds of coal.[5] As a result, for the first time, nuclear energy's unprecedented capacity to "do work" forced policy makers and scientist to reckon with the limits of a new source of energy as much as its promise. This contrasted drastically with the relative lack of experimentation and foresight accompanying the

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[3] Atlantic-Pacific Interoceanic Canal Study Commission, *Interoceanic Canal Studies: 1970,* (Washington, DC; government printing office, 1970), retrieved from University of Florida Digital Collections at http://ufdc.ufl.edu/AA00006086/00001/3j on March 13, 2018, pg. Front Matter 1.

[4] Many historians have at least tangentially explored the Nuclear Canal. Among the most well-done books on this topic are Scott Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, NJ: Rutgers University Press, 2005), which focuses on Plowshare in its entirety including the pursuit of a new isthmian canal. A more Panamacentric view can be found in John Lindsay-Poland, *Emperors in the Jungle: The Hidden History of the U.S. in Panama*, (Durham N.C.: Duke University Press, 2003), which sees the nuclear canal as one of many American attempts to assert control in the Isthmus.

[5] Alfred Crosby, *Children of the Sun: The History of Humanity's Unappeasable Appetite for Energy,* (New York: W.W. Norton & Company, 2006), pg. 127.

adoption of coal and oil; processes which saw the marginalization and death of thousands of Afro-Antilleans. And yet fossil fuels were silent killers. Explosions, drowning, and diseases were disassociated from the energy-oriented infrastructures and labor hierarchies that enabled them. The visceral terror that accompanied mushroom clouds afforded the dangers of thermonuclear explosions no such anonymity. In this context, the decision to shy away from nuclear excavation was not the result of atomic energy's shortcomings, but rather its unrestrained power and the logistical challenges that accompanied it.

In nuclear excavation this manifested itself in the inherent chaos of nuclear blasts. Scientists could certainly attempt to direct these weapons, emplacing and detonating them in a manner that improved the likelihood of desired outcomes, and yet there was a level of unpredictability that accompanied these blasts. One scientist described nuclear explosives as "too crude" to be used in tasks where a degree of precision was required.[6] Another report emphasized that "It should be clearly understood that Plowshare is not concerned with slight, only marginal improvements of known procedures. Plowshare makes desirable changes in our environment possible that could not be contemplated before."[7] Nuclear excavation was what Paul Josephson has dubbed a "brute force technology," a heavy-handed attempt to impose order on a disorganized natural world.[8] That scientists believed they could control the awesome potential of this reaction was a testament to their audacity and pride.

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[6] David Brooks and John Krutilla, Peaceful Uses of Nuclear Explosives: Some Economic Aspects (Baltimore, Maryland: Johns Hopkins Press, 1969) from USNA, RG 220, Collection: A1 36040-B Atlantic Pacific Interoceanic Canal Study Commission Working Files, Studies, and Reports, Box 9, Declassification NND 968050, pg. 9.

[7] Oskar Morganstern and Klaus-Peter Heiss, "General Report on the Economics of the Peaceful Uses of Underground Nuclear Explosives" (Mathematica, August 31, 1967), Record Group 220, US National Archives, Collection: A1 36040-B, Box 4: Folder: General Report on the Economics of the Peaceful Uses of Underground Nuclear Explosives, NND 968805, pg. 7.

[8] While Josephson refers primarily to large scale, fixed infrastructural projects, nuclear earthmoving bears the same technocratic hubris that defined these projects as well as the disregard for environmental impacts. See Paul

Ultimately, the fearsome energy contained in atomic reactions was a double-edged sword. While nuclear explosions could radically restructure the natural geography of a region, they completely lacked the ability to maintain environments. The explosive shockwaves that accompanied nuclear blasts would likely have destabilized the already fluid Panamanian landscape. In addition, the steep slopes characteristic of nuclear blasts were prone to catastrophic slope failures, particularly in places like Panama where heavy rains and saturated soils rendered inertia hard to maintain. These technical shortcomings of nuclear energy need to be placed alongside public relations failures in histories of the rise and fall of nuclear earthmoving to fully grasp the complexity of this new, and daunting energy regime. In nuclear energy, American scientists and engineers saw a means of finally liberating themselves from the limitations presented by the Panamanian environment, and yet their desire to assert control over the impenetrable swamps, mountains, and jungles of the Panamanian interior was vaporized by their inability to fully control the awesome energy that resided inside the atom.

How Scientists Stopped Worrying and Learned to Love the Bomb

Nuclear energy's presence in the 1947 report foreshadowed its crucial role in visions of canal expansion. As early as the 1920s policy makers considered the limitations of the Canal, and yet plans for substantial renovations of the Canal, let alone the creation of a new sea-level canal, were prohibitively expensive and time consuming. The sheer amount of energy and capital invested between 1904 and 1914 made additional investments an unsavory proposition. Yet the threat of nuclear war reshaped questions of canal efficiency into questions of canal existence. The unprecedented amount of energy released by nuclear bombs could completely and utterly

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R Josephson, *Industrialized Nature: Brute Force Technology and the Transformation of the Natural World* (Washington DC: Island Press/Shearwater Books, 2002).

obliterate a lock type canal in less than an instant. Given the military and economic importance of the Canal such a possibility was unacceptable. However, the central problem of obtaining the massive amounts of energy necessary to reshape the Isthmus remained. How were engineers to carve through over one thousand feet of rock to create a sea-level canal?

A decade after the 1947 study, scientists began to think they might have found their answer. Nuclear energy was not only the problem, but also the solution. In February of 1957, nuclear scientists from several AEC affiliates met at the Lawrence Radiation Laboratory in Livermore, California for the "AEC Weapons Laboratory Symposium on Non-Military Uses of Nuclear and Thermonuclear Explosions." For the first time, scientists came together to discuss theoretical applications of nuclear energy for non-military applications.[9] Within a few short months of this program the AEC approved the organization of "Project Plowshare," the study of potential uses for peaceful nuclear explosions.[10] The awesome energy unleashed by nuclear reactions was simply too valuable to be reserved solely for military purposes. Nuclear energy could allow humanity to finally assert its control over the natural world through previously unimaginable engineering projects.

It didn't take long for nuclear explosives to become an atomic elixir for the challenges facing the Canal. Studies on potential improvements to the Canal were conducted every few years following the 1947 study. Most simply reiterated already established realities: within a few decades the Canal would be incapable of dealing with increasing traffic, many ships would be too large to transit the Canal, and a lock canal was increasingly susceptible to subterfuge, sabotage, and military threats. As the 1950s progressed, these studies became increasingly

[9] Scott Kirsch, *Proving Grounds*, pg. 12-13.
[10] *Ibid*, 15.

intrigued by the promise of nuclear engineering. The first group to seriously consider the nuclear alternative was a Board of Consultants appointed by Congress in 1957. In 1960, they formally presented their findings, suggesting that "the experimental development of excavation by nuclear explosives should be vigorously pushed by the appropriate government agency."[11] The idea of the nuclear canal had arrived. The rapid application of Plowshare's ideas to the Panama problem was unsurprising. Unlike previous energy sources in Panama, nuclear energy had the power to level mountains and remove tons of material instantaneously, and, more importantly, to do so economically. Plowshare ushered in a new era, one in which American ingenuity, technological prowess, and a dash of hubris would finally bring the dream of a sea-level Panamanian canal to fruition.

Plowshare scientists also found themselves lagging behind their Soviet counterparts in both the theoretical and practical development of nuclear engineering. The Soviets were gaining valuable data from a series of large chemical explosive projects. In 1956 they set off three blasts in China to improve access to mineral resources. Two years later they took their cratering experience further, detonating a row of charges to create a 1100-meter-long canal in the Pokrovsk Uralskii district. The canal drained a river which had been flooding local mines and simultaneously gave Soviet scientists vital information on detonation spacing for row charge explosions.[12] Given the prestige that accompanied large scale engineering projects, the Soviets' edge in engineering was unacceptable. Americans needed to clearly display their own prowess in

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[11] Unknown, "Justification of Program for On-Site Surveys of Potential Sea-Level Canal Sites Previous Studies," May 4, 1962, From USNA, RG 185, Collection: A1 156 Records Relating to a New Nuclear Excavated Canal, Box 1: Folder: Materials from the Canal Zone Office: AEC, pg. 2.

[12] Gerald Johnson, "The Soviet Program for Industrial Applications of Explosions" (Lawrence Radiation Laboratory, March 28, 1960), USNA, RG 220, A1 36040-B, Box 14: Folder: University of California, NND 968050, pg. 9.

environmental engineering and a nuclear excavated sea-level canal across the Isthmus would assert American primacy in spectacular fashion.

To this end the Panama Canal Company (PCC) and AEC worked together to create the first substantial study of nuclear canal feasibility in January of 1960. The report was quite optimistic on the potential of nuclear explosives as an excavation tool, particularly given the fact that as of 1960 no non-military nuclear explosive had yet been detonated. But AEC scientists refused to see their enthusiasm smothered by such an insignificant obstacle as a lack of applicable experiments. They looked to four military nuclear explosions conducted between 1951 and 1958 to determine the technical feasibility of nuclear excavation and supplemented this information with a series of chemical detonations.[13] These data sets provided the basis of their cratering formulas and hopefully contributed enough theoretical data to allow them to predict challenges that could arise from detonating nuclear explosives in Central America.

Scientists found the potential of nuclear excavation promising for a variety of reasons. Their report suggested that, "A nuclear excavating technique has several advantages over conventional excavation methods. The most significant of these are lower costs, shorter construction times, less maintenance of the resulting canal, and reduced vulnerability to attack."[14] These benefits resulted from the massive amounts of energy released by nuclear excavation. While blasting was frequently used in conventional excavation, chemical explosives merely loosened rock and soil, allowing mechanical excavation to proceed at a more rapid pace. Nuclear excavation expedited this process by combining the loosening of earth, rock, and soil with the act of excavation by ejecting the material out of the blast zone. Only minimal

[13] AEC, PCC, *Isthmian Canal Plans- 1960 "Annex VII",* pg. 4.
[14] *Ibid,* pg. 13.

mechanical labor was required after the detonation. Additionally, the massive yields of nuclear explosives were the only feasible means of cutting through the rocky Continental Divide which peaked at over 1000 feet above sea-level.

The 1960 study emphasized two potential sites for the construction of a canal. The Sasardi-Morti Route (Route 17) ran about fifty miles through the Darien region of Eastern Panama. At just over 100 miles from the Canal this route was isolated enough to avoid damages to existing infrastructure. Route 17 required an estimated 250 individual explosives and a total yield of 120 megatons to be constructed. The Atrato-Truando route (Route 25) ran roughly 100 miles through Northwestern Colombia, along the Panamanian border, and required 150 individual explosives with a total yield of 150 megatons.[15] Like Route 17, Route 25 was isolated, and had the added benefit of running alongside two rivers, which would make accessibility to the interior far easier. The report indicated that nuclear explosions provided enough energy for either route to be viable.

The energetic benefits of using nuclear explosions were accompanied by substantial financial benefits as well. Again, these were the direct result of the awesome potential held by the atom. By precluding the need for a massive mechanical labor force, the nuclear canal would cost a fraction of the price of conventional excavation. The AEC cautioned that their figures were purely speculative at this point but suggested that along the Sasardi-Morti route (Route 17) a nuclear excavated canal roughly 1000 feet wide could be constructed at roughly 25% of the 3.3 billion dollars the 1947 report estimated for a 600-foot-wide, conventionally excavated sea-level

[15] Atlantic-Pacific Interoceanic Canal Study Commission, *Interoceanic Canal Studies: 1970*, pg. 37-38.

canal at the same site.[16] With nuclear energy at their disposal, engineers could build larger, more efficient structures for substantially less.

These projections made the fervor surrounding nuclear excavation unsurprising. The power of the atom had the potential to enable previously unfeasible earthmoving projects with ease and reduce their prohibitively expensive costs. The AEC also suggested that nuclear explosives would allow the project to be completed in one-fifth the time it would take otherwise and, once it was completed, the sheer size of the canal would require only a small labor force to operate. Perhaps the most ironic benefit was that the nuclear canal would be far less susceptible to a nuclear attack because of its massive size and depth.[17] Nuclear energy seemed to be the key to the Canal's future and perhaps the future of mega-engineering.

This is not to say that the AEC was completely unaware of the hazards that accompanied nuclear explosives. They acknowledged that air blast, seismic events, and radioactive debris were all side effects of nuclear detonations, yet they suggested that these obstacles were inconsequential compared to the potential of nuclear excavation, concluding that, "A Trans-Isthmian canal can be excavated with nuclear explosives with negligible damage to mankind and his means of livelihood."[18] Damage from air blast or seismic shock was a trifling concern and could be easily mitigated through experimentation. The AEC recommended the detonation of six, 2400-pound heavy explosives each month for a year to obtain the necessary data. The AEC neglected to seek Panamanians' opinions on the subject of detonating explosives in their territory.[19]

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[16] AEC, PCC, *Isthmian Canal Plans- 1960 "Annex VII,"* pg. 13.
[17] *Ibid*, pg. 13.
[18] *Ibid,* pg. 23.
[19] *Ibid,* pg. 34.

Radiation, while problematic, was largely contained unground and could only endanger people if they, or the food they ate, came into direct contact with it. AEC scientists concluded that environmental studies could minimize any potential risk associated with radiation and furthermore that, given the aggressive nuclear tests being conducted by the United States, United Kingdom, and Soviet Union, any fallout associated with the creation of a new canal "would be only a very small fraction of the worldwide fallout even if not scavenged by dust."[20] In essence the radiation associated with peaceful nuclear explosives was just a drop in the bucket compared to military detonations and consequently wasn't worth worrying about.

The AEC was similarly nonchalant in dealing with local radiation. The small amount of radiation that was not trapped underground would not be concentrated enough to harm the general population, although as an added precaution "it would be desirable to protect human population up to 50 miles of the detonation during the fallout period (48 hours or more) to prevent ingestion of radioactivity and correspondingly higher exposure."[21] After the prescribed forty-eight hour window the AEC felt that radiation would diffuse so much as to no longer be an issue. The only lingering challenge was ensuring that radiation didn't contaminate any human food sources. To this end the AEC proposed a plan to control and monitor food production "in the canal, on the canal banks, and within a mile or two from the ends of the canal…"[22] In the eyes of the AEC, radiation was a concern that required only minimal precautions. This laissez-faire attitude was partially due to scientists' faith in the development of new, low-fission, thermonuclear explosives which minimized the spread of highly radioactive materials. However, it also reflected an excessive sense of optimism that permeated many studies. The potential of

[20] AEC, PCC, *Isthmian Canal Plans- 1960 "Annex VII,"* pg. 24.
[21] *Ibid,* pg. 25.
[22] *Ibid,* pg. 27.

nuclear energy was so vast that any potential problems seemed trivial in contrast. This was particularly true during the earliest stages of nuclear canal planning when concrete information and knowledge had yet to be developed. Ultimately it was this lack of information that made nuclear detonation so appealing.

The factors that the AEC failed to address in their report were a testament to their ignorant enthusiasm. While they were aware of radiation, air blast, and seismic shock, scientists failed to address two problems which, eventually, proved to be far more troubling to the realization of their atomic ambitions. The first of these issues was a lack of data and relevant tests. Of the four nuclear detonations the AEC used to write its report, three were in alluvium and one was in tuff. These media were dry, coarse, and loose, completely unlike the water saturated muck and rock native to Central America. While the AEC was confident in how cratering mechanics would work in the Nevada desert, they had little information of how craters would be formed and maintained in wet, heavy, compacted material. Their most substantive study of explosive mechanics in Panama stemmed from the 1947 study in which the Board of Consulting Engineers detonated a series of chemical explosives in materials ranging from marine muck to sandstone and basalt. That this data would apply to atomic explosions was highly suspect.[23]

The second major issue was the AEC's lack of local environmental knowledge. Since the creation of the railroad a century earlier, humans had struggled to control entropy. Mountains, hills, valleys, and swamps had to be eradicated before a sea-level canal could be created. Nuclear explosives seemed poised to finally be able to provide enough energy to overcome these physical barriers, however slides that covered railways and blocked the canal suggested that even if

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[23] AEC, PCC, *Isthmian Canal Plans- 1960 "Annex VII,"* pg. 5.

engineers could gouge out a sea-level waterway, control over entropy remained elusive. In fact, nuclear explosives stood poised to complicate the clash against chaos due to the tremendous craters they left in their wake. Nuclear energy's greatest asset in canal construction was that it would eject material entirely out of the canal prism, precluding the necessity of conventional excavation. The result was a deep crater with extremely steep raised lips. These unstable structures required only the slightest disturbance to generate spectacular slides and slope failures. Ultimately, the increased amount of material moved by nuclear explosives exacerbated the challenge of creating and maintaining stability in Panama

In the alluvial material the AEC was familiar with, slope stability was an issue, but seldom resulted in catastrophic slope failures that compromised the integrity of the crater. What these scientists failed to realize was that the humid rainforests of Panama and Colombia were completely different animals than the dry desert of the Nevada Test Site. Craters created in Central America would be subject to pummeling rains which could saturate crater lips and slopes with water weight, eat away at the supporting banks, and result in catastrophic slope failure. The AEC seemed completely obtuse to these potential threats, writing that "The banks of a nuclearly excavated canal would be natural angles of repose and therefore would be stable. If minor slides occurred, the additional depth of a nuclearly excavated canal would provide a convenient local disposal area for the material."[24] The AEC's dismissal of slope stability wasn't necessary surprising. At this early juncture, containing the spread of radiation and the energy contained in air blasts and ground shock seemed to be more pressing issues. However, this also pointed to the failure of imagination that plagued the AEC throughout Plowshare.

[24] AEC, PCC, *Isthmian Canal Plans- 1960 "Annex VII,"* pg. 13.

Of all the oversights made by the AEC, their lack of understanding of slope stability was the most egregious. Ironically, it was not issues of radiation, air blast, seismic shock, or even foreign policy that doomed the nuclear canal, although all certainly played a role in eroding confidence in the project. Instead it was the inability of scientists to obtain the necessary data and test results to determine if nuclear excavation was technically feasible that foreshadowed the obstacles that plagued Plowshare throughout its life. As the sun rose on Project Plowshare, scientists failed to fully acknowledge the limits of their control, largely because they had yet to fully comprehend them.

An Era of Optimism

While the AEC's 1960 report didn't result in the tests it had requested, it did engender a tremendous amount of enthusiasm. During the first few years of the sixties, three men took the lead in bringing the dream of a nuclear Panama to reality. Matthew (M.C.) Harrison, the Engineering and Construction Director of the Panama Canal Company, Ernest Graves, The Director of the U.S. Army Engineer Nuclear Cratering Group, and Bill Wray, Deputy Director of the U.S. Army Nuclear Cratering Group were integral to keeping the vision of a nuclear canal alive. Between 1962 and 1965, Graves, and Wray organized a series of tests at the Nevada Test site while Harrison worked on the logistics of getting information necessary to nuclear feasibility studies in Panama. All three faced the arduous test of lobbying for funding to carry out comprehensive tests. In the first half of the 1960s, these men played an essential role in promoting the nuclear canal and their efforts helped generate interest in a comprehensive study of the technology's feasibility.

Of the three, Graves was the most well versed with nuclear energy and unsurprisingly spearheaded the quest for a nuclear Isthmus. After obtaining a Ph.D. in physics from MIT, Graves was placed in charge of recruiting and training personnel for the construction of a nuclear reactor at Fort Belvoir, Virginia in 1954. Graves then briefly served as an engineer in Korea before he returned to nuclear research as an associate on Project Plowshare in 1959. He was then tasked with establishing the Nuclear Cratering Group (NCG) in the spring of 1962.[25] Graves' research connected to Panama prior to the creation of the NCG in 1962, but it was the creation of this entity that put him into contact with Harrison and led him to appoint Bill Wray as his Deputy.

Despite not being directly involved in the 1960 study, Graves echoed its sentiments. In a 1961 draft statement on nuclear excavation of a sea-level isthmian canal he wrote that not only did the technology seem to be feasible, but also that "Indications are that nuclear methods may save over one billion dollars in construction costs and can be used with complete safety to human life."[26] Excited by the potential of this new technology, Graves immediately began plans for safety tests and on-site surveys in Panama. Bill Wray took Graves' enthusiasm one step further by crafting a comprehensive budget for conducting site selections and field surveys. Wray's proposal focused specifically on geology, meteorology, air blast propagation, and seismic forces. He believed these topics provided scientists with the information necessary to adequately deal with the issues of air blast, seismic shock, and radiation that had been identified in the 1960 study.[27]

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[25] Ernest Graves and Frank N. Schubert, *Engineer Memoirs: Lieutenant General Ernest Graves, U.S. Army.* (Alexandria, Virginia: Office of History: U.S. Army Corps of Engineers, 1997), pg. viii.
[26] Ernest Graves, "Draft Statement on The Technical Feasibility of Constructing a Sea-Level Canal Across the American Isthmus Using Nuclear Explosives," November 9, 1961, USNA, RG 185, Collection UD UP 106: Canal Feasibility Studies 1964-1969, Box 2: Folder: Canal Construction: Nuclear, pg. 1.
[27] William Wray, "Letter from William Wray to Ernest Graves, January 5, 1962," From USNA, RG 185, Collection A1 156, Box 1: Folder: Materials from the Canal Zone Office- AEC.

As 1962 progressed, Graves, Wray, and Harrison became increasingly committed to nuclear excavation. They were particularly excited by the execution of the .4 kt Danny Boy detonation on March 5, 1962. Danny Boy was remarkable for two reasons. It was the first test conducted in basalt and provided valuable information on how nuclear craters worked in rockier media like the Continental Divide. Danny Boy also was the first cratering test at the Nevada Test Site in nearly four years and suggested that interest in nuclear excavation was growing. There was no guarantee that a nuclear canal was imminent, but Graves struck a cautiously optimistic tone in a letter to Wray in which he wrote "There are two things I have learned about this Plowshare business. One is that it shows enough technical promise to be worth looking into. The other is that overcoming the political problems is going to be a long, slow process."[28] Graves, Wray and Harrison recognize that public anxiety surrounding nuclear explosions was monumental. If they wanted to gain acceptance for nuclear engineering they needed to find ways to show that nuclear explosions were safe, and practical for peaceful applications.[29] To this end, they set about trying to overcome these political challenges by focusing their attention on gaining legislative support for a substantial canal study which they hoped would both provide the information necessary to determine the best site for a new, nuclear canal, and also increase public support for the project.[30]

While progress was slow, a series of developments bolstered their case. Increasing interest in nuclear excavation from the Kennedy Administration suggested that political obstacles

[28] Ernest Graves "Letter from Ernest Graves to Bill Wray, March 18, 1962" from "Materials of the Canal Zone Office"

[29] The best account of the fear surrounding nuclear explosives can be found in Spencer R. Weart *The Rise of Nuclear Fear*, (Cambridge, Mass: Harvard University Press, 2012). For the tension between the promise of the Atoms for Peace movement and public opinion see Chapter 8 "Good and Bad Atoms".

[30] Matt Harrison, "Letter from M.C. Harrison to Ernest Graves, March 27, 1962" from "Materials of the Canal Zone Office"

were crumbling. On April 30th, 1962, Kennedy directed the AEC and Army Corps of engineers to undertake a five-year study to determine the feasibility of nuclear excavation.[31] A few months after the Administration's announcement another nuclear test was held in July of 1962. At 104 kt, Sedan was the largest test conducted by Plowshare and provided invaluable information about cratering mechanics from higher yield explosives. While fallout was higher than had been predicted, its spread was minimal and both air blast and ground shock were lower than anticipated. The one major issue which remained unresolved however was the steep angle of the crater slopes. The resulting crater was 320' deep and 1200' wide and the slopes were far more extreme than anticipated, varying from 30-35 degrees at a depth of 100-250' below ground level and 40-45 degrees at depths of 50' to ground level. These slopes were so extreme that one side of the crater saw a major slide in the lip and upper portion of the crater wall.[32] It was increasingly obvious that slope stability needed to be dealt with for nuclear excavation to become a reality.

Despite these obstacles, the Kennedy Administration's support and the increasing resources directed towards Project Plowshare garnered the nuclear canal some allies in Washington. Herbert Bonner, a Democratic representative from North Carolina and longtime champion of the nuclear canal, introduced a bill to the House Committee on Merchant Marine and Fisheries on June 27, 1962. Less than two weeks later, on July 7th, Warren Magnusson, a Democratic senator from Washington, introduced an identical bill to the Senate Commerce Committee. Both bills failed to get out of committee during the 87th Congress, but their introduction initiated the process of Congressional recognition that Graves, Wray, and Harrison

[31] R.G. MacDonnell, "Letter from Major General R.G. MacDonnell to Dr. John Foster, May 4, 1962" From USNA, RG 185, Collection: A1 156, Box 1: Folder: Corps of Engineers Organization.
[32] Graves, "Letter from Ernest Graves to Robert Fleming, October 25, 1962." Enclosed in "Letter from Ernest Graves to M.C. Harrison, October 25, 1962" from USNA, RG 185, Collection A1 156, Box 1: Folder: Estimates for a Sea-Level Canal.

had been promoting.[33] Congressional support granted nuclear excavation an air of legitimacy and suggested that the technology was feasible enough to receive serious consideration.

The next step for Graves, Wray, and Harrison was to justify their potential studies so that when the proposed bills made it out of committee they would be greeted with enthusiasm. At the Nevada Test Site, Graves focused on developing additional nuclear tests to refine the understanding of nuclear excavation mechanics, particularly in row charge detonations. Row charge detonation was the simultaneous detonation of several devices buried at regular intervals. The explosions' energy forced the material outwards creating a long trench rather than a single crater. This excavation technique was imperative to the creation of a nuclear canal as scientists needed to find a way to dig trenches without refilling them with the debris of subsequent shots. While nuclear energy was awesome it was clumsy and brutish and thus could prove counter-productive if its force was not adequately directed and harnessed. To this end, Graves and others at the AEC began planning "Buggy," a row charge experiment of five, 10 kt explosives set for 1964.[34]

Meanwhile, in Panama, Harrison focused on the logistics of carrying out on-site surveys to determine the optimal site for a nuclear canal. Harrison felt deeply that he, Graves, and Wray needed to focus on the economic justifications for such a study if they intended to get congressional approval. They hoped to contrast the potential costs of nuclear excavation with those of conventional excavation to emphasize the dramatic financial benefits that accompanied the adoption of this new source of energy. The catch was that estimates of the cost of nuclear excavation were almost entirely speculative due to the lack of information about potential sites

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[33] Robert Fleming, "Letter from Robert Fleming to Armistead Selden, October 1962." From "Estimates for a Sea-Level Canal".
[34] Graves, "Letter from Ernest Graves to Robert Fleming, October 25, 1962" from "Estimates for Sea-Level Canal".

for the new canal. Harrison proposed a $12 million-dollar study to deploy scientists and surveyors to Panama to identify a route. This also reflected a continuing trend in the deployment of American energy in Panama. Nuclear energy did not act in isolation. To unleash atomic energy, a vanguard of human energy had to first make its way into the interior to pave the way for the deployment of nuclear energy. Nuclear energy's utility was still predicated on the capacity of human energy. While nuclear energy was exponentially more powerful than human energy it was also relatively specialized, being effective in Panama only as a brute force technology meant to reshape the environment on a drastic scale. This was a reality Harrison recognized all too well. Responding to Graves' assessment of tests carried out at the Nevada Test Site, Harrison wrote, "It appears that you are raising Hell with the landscape there in Nevada—with a little rainfall you might have some good swimming holes."[35]

Progress towards the adoption of nuclear engineering moved rapidly in Panama. In January of 1963, a group of AEC and NCG representatives descended on Panama to meet with members of the PCC and voice their support for the proposed studies on the Isthmus. The conference resulted in a more refined plan of study for Panama. Particularly important was the fact that, for the first time, scientists clearly expressed their awareness of the unique hydrological conditions in Panama, and the consequences that Panama's humidity and rainfall could have on fallout distribution. This recognition marked a decided shift from the disinterested approach the AEC and NCG had previously taken in assessing the impact of Panama's unique environment.[36] While nuclear energy's potential was significant, it was mediated by environmental realities

[35] Harrison, "Letter from M.C. Harrison to Ernest Graves, October 30th, 1962" from "Estimates for Sea-Level Canal"
[36] John Kelly, James Reeves, Gary Higgins, Ernest Graves, "Summary of Current Plans for Action by AEC Operational Safety Organizations in Support of Panama Feasibility Studies", 1963, from USNA, RG 185, Collection UD UP 106, Box 2: Folder: Canal Construction- Nuclear, pg. 8-9.

which dictated its efficacy and shaped the consequences of its deployment. Unfortunately, scientists only seemed to be aware of this in the context of fallout distribution. They still failed to adequately acknowledge the impact that Panama's propensity for entropy had on slope stability.

The fault in this oversight did not lie exclusively with the AEC or NCG. Even those working in Panama, Harrison among them, seemed to underestimate the potential challenges that slope stability presented. Rather than concerning Harrison and his colleagues, the January meeting seemed to encourage them. In February of 1963, Graves suggested that support for a study in Washington was growing as "There is every indication that the Administration's emphasis on our authorization bill, as demonstrated by the attitude of the Board of Directors, will continue."[37] The success of Plowshare tests, and the international prestige offered by a practical example of nuclear excavation, became increasingly alluring to policy makers. Harrison too was growing excited. Shortly after receiving Graves' message he received approval to send twelve technicians to Route 17, the most promising nuclear canal site in Panama.[38] By the spring of 1963 it seemed only a matter of time before Panama was bathed in the radioactive light of an atomic future.

Unfortunately for nuclear advocates, this positivity decayed faster than the radionuclides scientists sought to harness. In October, negotiations surrounding the Nuclear Test Ban Treaty made the Kennedy Administration hesitant to conduct nuclear explosions, a position that contrasted starkly with the stance it had taken just a few months earlier. The Administration's about face on atoms reflected a dirty truth; nuclear energy was perceived of as a weapon first, and a tool second. The awesome amounts of energy unleashed in nuclear reactions made it next

[37] Graves, "Letter from Ernest Graves to M.C. Harrison, February 5, 1963" from "Estimates for Sea-Level Canal"
[38] Harrison, "Letter from M.C. Harrison to James Reeves, May 13, 1963." From "Estimates for Sea-Level Canal Folder 2".

to impossible to avoid this reality. Nuclear excavation was an exercise in palatable devastation. Rather than turning the atom towards the task of creation, "Plowshare" sought to find places where destruction made landscapes more beneficial to humans. In this sense the application of nuclear energy was still an act of violence. Peaceful nuclear explosives simply directed this violent energy towards landscapes rather than people.[39] The message was clear: it was laudable to turn one's swords into plowshares, but plowshares could easily become swords once more.

As 1963 ended it seemed that the best efforts of Graves, Wray, and Harrison had been for naught. On-site studies had not been carried out, information about the Panamanian landscape was dangerously spotty, slope stability had yet to be dealt with, and governmental support for Plowshare was evaporating. A dejected Graves asked "Will this kill nuclear excavation? I doubt it, but I have no idea under what penury the program will struggle on."[40] Graves' frustrations were directed less at the government and the Limited Test Ban Treaty and more towards the lack of action taken by the AEC and PCC during 1962 and early 1963. Graves believed that if these organizations had pursued the nuclear canal more aggressively, they might have been able to weather the Limited Test Ban Treaty negotiations more effectively. As it stood, he sensed that his years of work on the project were going to amount to nothing. Graves might have been more dejected, had the Dodgers not tempered the blow. "Yes, there was joy at 436 Jackson Avenue when Koufax pitched that curve for a called third strike on Mantle and two out in the ninth inning of the fourth world series game," Graves admitted. The AEC wasn't conducting any blasts, but at least Mantle hadn't either.

[39] Graves, "Letter from Ernest Graves to Bill Wray, October 16, 1963" From USNA, RG 185, Collection A1 156, Box 2: Folder: General Information on Nuclear Excavation December 1961-December 1963.
[40] *Ibid*.

Riots, Radiation, and Foreign Relations

The nuclear canal might have remained stagnant had a different energy not interceded. Anger, hostility, and resentment towards sixty years of American authority in the Canal Zone catalyzed a different sort of explosion on January 9th, 1964, as students from the Instituto Nacional stormed the Canal Zone, attempting to raise their flag at a Canal Zone high school. Canal Zone police were instructed not to interfere, but several Zonians resisted and, in the ensuing scuffle, the Panamanian flag the students brought was ripped. Over the next three days violent clashes broke out along the Canal Zone border between Zonians and Panamanians. By the time the violence ended, twenty-eight people lay dead and Panamanian President Roberto Chiari broke relations with the US until an alternative to the 1903 treaty was negotiated. The fate of the Canal hung in the balance.[41]

President Johnson quickly acquiesced to Chiari's concerns by opening renegotiation of the treaty, a process that spanned three administrations and lasted nearly fifteen years. The question of what was to become of the Panama Canal lay at the center of these negotiations. In this context, a new nuclear excavated sea-level canal took on greater importance. A sea-level canal was a more efficient waterway and could be operated by a relatively small number of American employees, mitigating conflict between Panamanians and Americans in Panama. Tensions between Americans and Panamanians pointed to one of the major complications regarding human energy. Human energy in Panama was intimately entwined with international concerns. American laborers, while allegedly essential to the operation of the Canal, were also

[41] Lindsay-Poland, *Emperors in the Jungle,* pg. 86-87. The Martyr's Day Riots and the diplomatic fallout that resulted from them has been covered extensively by historians of the diplomatic relationship between Panama and the United States. For more information see Walter LaFeber, *The Panama Canal: The Crisis in Historical Perspective. Updated edition*. (New York; Oxford: Oxford University Press, 1990), or Michael L. Conniff, *Panama and the United States: The End of the Alliance,* (Athens: University of Georgia Press, 2012).

seen as manifestations of unwanted American influence in Panama. A more energy efficient sea-level canal that relied less on American manpower could assuage this problem by removing many laborers from Panama. An estimate from a 1964 report suggested that a sea-level canal could be operated with as few as 200 Americans, a dramatic departure from the thousands who were currently working on the Canal.[42] The Martyr's Day Riots, as they would come to be called, breathed new life into the nuclear canal, suggesting that, remarkably, detonating nuclear explosives in Panama could actually improve relations between the two countries.

The need for an alternative to the Panama Canal kicked studies for a new canal into high gear. The AEC, PCC, and Army Corps of Engineers began compiling all the information they could find on Panama and revised their earlier estimates for the feasibility, cost, and location of a new canal. The PCC released a report in 1964 detailing the current state of the Canal. The study dealt with a variety of concerns including cost comparisons between sea-level and lock canals, potential upgrades to modernize the Canal, the potential of creating a new canal by conventional excavation, and the nuclear canal. Interestingly however, while scientists and engineers remained enthused about the potential of nuclear excavation, they had grown more reserved in their optimism. The report emphasized the fact that "Tests and studies to date support earlier conclusions that the construction of a sea-level canal by nuclear methods is feasible." However, they also acknowledged that "Further nuclear device development and testing are necessary to assess positively the effectiveness, economy, and safety of nuclear explosives in applications of the magnitude that would be required in constructing a sea-level canal."[43]

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[42] Panama Canal Company, *Annex to V to Isthmian Canal Studies 1964: Comparison of Costs of Operation-Present Canal vs. Sea-Level Canal,* from USNA, RG 185, Collection UD UP 106, Box 1, pg. 2.
[43] Panama Canal Company, *Isthmian Canal Studies 1964: Summary Report,* from USNA, RG 185, Collection UD UP 106, Box 1, pg. vi.

Scientists were becoming increasingly aware of the limitations of their knowledge and the fact that much of the energy released in a thermonuclear explosion was effectively uncontrollable. Consequently, the lack of concrete examples and nuclear cratering explosions to draw from was a vexing problem for engineers. Danny Boy and Sedan presented a wealth of information, but questions about row charges and slope stability had been gauged only with chemical explosives and had still been almost exclusively carried out in loose alluvial desert soil.[44] For a nuclear canal to be deemed technically feasible more nuclear explosions were necessary.

Despite these limitations, by 1964 the PCC felt far more comfortable predicting a construction program than they had in previous studies. Engineers envisioned three-phases of construction. An initial period of detailed studies along the proposed blast site would obtain data on topics ranging from rainfall totals to population densities among the inhabitants of the proposed canal site. Simultaneously, the company would mobilize the necessary labor and material along the proposed canal site. Once engineers felt comfortable with their data, they would begin construction of essential facilities, including access roads to the centerline, the drilling of emplacement holes, and construction of storage facilities for the nuclear devices and housing for the workers. Those individuals, both hired workers and indigenous peoples, living next to the blast sites would be relocated to an area outside of the projected fallout zone and the detonations would take place on a rolling basis over the span of one to two years. Once all the detonations were carried out, conventional construction would take place to stabilize canal walls, construct navigational aids, tidal barriers, and support buildings; and dredge the final sections of

[44] Panama Canal Company, *Isthmian Canal Studies 1964: Summary Report,* pg. 35-36.

the canal. All said and done this project would take roughly seven years to complete and engineers were confident that cost and time would be similar along both routes.[45]

The 1964 report emphasized several areas of concern. Similar to the 1960 report, scientists emphasized the need for environmental tests and meteorology to gauge the spread of radiation as well as the potential impacts of air blast and ground shock. Additionally, by 1964, scientists were far more aware of the public relations concerns that accompanied nuclear engineering, the substantial amount of conventional energy and construction that would be necessary to enable nuclear excavation, and the dramatic role that slope stability played in mitigating the efficacy of a new sea-level canal. Scientists were recognizing not only the benefits of nuclear excavation, but also its significant limitations. However, they were disheartened by these challenges. The report suggested that "Undesirable side effects often accompany a new and revolutionary technological advance. Development of a deeper understanding of the basic scientific phenomenon and improvement of equipment generally lead to adequate control and open the way to broader acceptance and use. Significant progress along these lines has already been made in nuclear excavation."[46] Their optimism might have been well founded on the topics of air blast, ground shock, and radiation, however slope stability, political hurdles, and the local environment of Panama were far more vexing concerns.

Air blast, ground shock and radiation were still governed by the same perceptions in 1964 as they had been in 1960. All three were deemed manageable so long as the necessary data was

[45] Army Corps of Engineers, Atomic Energy Commission, Panama Canal Company, *Appendix II to Annex III to Isthmian Canal Studies- 1964: Construction of an Isthmian Sea-Level Canal by Nuclear Excavation Methods: 1964*, 1964, from USNA, RG 185, Collection UD UP 106, Box 1, pg. 3-4.

[46] Army Corps of Engineers, Atomic Energy Commission, Panama Canal Company, *Appendix I to Annex III to Isthmian Canal Studies- 1964: Nuclear Excavation Plan: 1964*, 1964, from USNA, RG 185, Collection UD UP 106, Box 1, pg. 24.

obtained to determine their spread. Containing Air blast was fairly straightforward. The massive amounts of energy released in an atomic detonation released a shockwave that was strong enough to break glass and cause damage at distances of up to 300 miles.[47] There was nothing that could be done to mitigate these concerns at locations close to the blast site, however at greater distances air blast conveyance correlated with winds and jet streams. On a windy day these forces carried the air blast hundreds of miles. In a small location like Panama this was an unacceptable possibility, particularly if the air blast was carried west to Panama City. The AEC suggested conducting rocket wind measurements in which rockets carried chaff to an altitude of 200,000 feet before releasing it. Radar stations tracked the chaff's descent, determining average windspeeds based on the chaff's trajectory.[48] Using this data scientists could select dates and times for detonations that minimized the area impacted by air blast. That some air blast would cause damage was merely a side effect of atomic energy's awesome power; the trick was minimizing it.

While air blast was conveyed through the relatively open medium of air, ground shock travelled through the earth itself. To gain an understanding of the impact of ground shock, surveyors and geologists needed to determine the geological make up of proposed canal sites. This required a substantial investment of human and mechanical energy to get access to interior regions of both routes and to bore holes to acquire the necessary geological data. As was the case with air blast, ground shock was an unavoidable side effect of the awesome power of atomic bombs. The underground explosions sent powerful shockwaves through the ground, creating significant reverberations throughout the earth that could crack foundations and cause structural

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[47] Atomic Energy Commission, "III. Air Blast: AEC on Site, 1964," from USNA, RG 185, Collection A1 156, Box 1: Folder: Materials from the Canal Zone office- AEC, pg. 1.
[48] *Ibid*, pg. 4.

damage dozens of miles away. Understanding ground shock transmission through various media was crucial to determining how it would spread in Panama, and the steps necessary to protect nearby structures.[49]

Scientists seemed most optimistic about the question of radiation. They emphasized that the most hazardous radioactive particles were a function of fission reactions. The thermonuclear bombs used for nuclear excavation were catalyzed by a fission reaction, but fission only had to provide enough energy to begin the fusion reaction, a process which released far less malignant radionuclides. Scientists were confident in the progress they had made in this area, suggesting "Improvements in nuclear explosives design since 1959 studies have materially reduced the amount of radioactivity which would be deposited as fallout near the project."[50] By making less of the yield of the explosive come from fission, scientists could minimize fallout without sacrificing efficiency. Additionally, scientists clung to the claim that underground detonations mitigated the spread of radioactive materials. While they did acknowledge that groundwater might play more of a role in conveying radiation than they thought, they were confident that cratering formation rendered much of the radiation inaccessible to plant, animal, and, most importantly, human life.[51]

Between 1960 and 1964, scientists' concerns about controlling the negative impacts of nuclear explosives remained static. While they acknowledged that air blast, ground shock, and radiation created problems, they found nuclear energy so alluring that they assumed, perhaps correctly, that proper meteorological, hydrological, geological, and environmental studies

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[49] Corps of Engineers, AEC, PCC, *Appendix I to Annex III: Nuclear Excavation Plan,* pg. 25.
[50] Army Corps of Engineers, Atomic Energy Commission, Panama Canal Company, *Annex III to Isthmian Canal Studies- 1964: Construction of an Isthmian Sea-Level Canal by Nuclear Excavation Methods- 1964,* 1964, from USNA, RG 185, Collection UD UP 106, Box 1, pg. 6.
[51] Corps of Engineers, AEC, PCC, *Appendix I to Annex III: Nuclear Excavation Plan,* pg. 24.

allowed them to execute nuclear explosions safely, or at least safely enough to make these risks well worth the potential rewards that this revolutionary new technology offered. Despite this enthusiasm, several lingering issues remained. One of the most dramatic shifts between 1960 and 1964 was the growing awareness of the less direct hindrances that accompanied nuclear excavation. Concerns over political obstacles, slope integrity, and the environmental realities of the tropical environments were addressed in meaningful ways for the first time in 1964. While scientists still felt comfortable in their ability to make nuclear explosions a viable source of energy, they were beginning to recognize the limits of their control.

Slope stability had been a problem for nuclear excavation since its inception. However, it failed to garner much attention throughout the early 1960s. Slope stability was seen as an afterthought in the 1960 report and even though some scientists began discussing it in the aftermath of the Danny Boy and Sedan explosions, the issue still failed to carry the same clout as air blast, ground shock, and radiation. The 1964 report marked a departure from this rather dismissive attitude as scientists began to acknowledge that slope stability wasn't merely an inconvenience, but rather a potentially catastrophic issue that could undermine the nuclear canal.

Steep slopes were a direct result of cratering mechanics. As the underground explosions expanded, the surface became the only area where the extreme pressure could escape. Thus, much of the energy of the detonation was channeled upwards resulting in more extreme slopes than in conventional excavation. Consequently, nuclear detonation was infeasible in swampy lowland areas where saturated soils and muds could not retain the parabola of the canal prism. For this reason, scientists admitted that nuclear excavation was impractical along much of Route 25 due to the swampy lowlands flanking the Atrato and Truando rivers. Here dredges needed to deepen and widen these river channels to make them navigable.[52] This conclusion differed from earlier reports that suggested the universal applicability of nuclear excavations. Scientists were starting to realize that this new form of energy significantly altered landscapes in the short term but was incapable of maintaining them over time.

In the rockier terrain that spanned Route 17, nuclear energy seemed to be more practical for excavation, however, here too uncertainty clouded optimism. Two major issues concerned scientists along Route 17. First was the small yield of the Danny Boy test. At only .4 kt Danny Boy had less than 1% of the yield of the smallest devices (100 kt) scientists intended to use to excavate the new canal which were themselves only 1% of the largest explosions (10 Mt).[53] Danny Boy provided the only data on how nuclear cratering operated in rocky media and scientists had no idea if their scaling models applied to exponentially larger detonations. This created an array of problems, but perhaps the most substantial was whether crater slopes would be stable in explosions of higher yields. This issue was complicated by the fact that the basalt in Nevada had far lower moisture content than the rocky clay shales of Panama. Scientists were forced to admit that "a serious question arises as to whether these weaker, saturated rocks will stand on the same steep slopes as the Danny Boy crater, particularly as the scale increases and the slopes become much higher."[54] It was very possible that nuclear explosions simply altered environments to an effectively unsustainable extent: an untenable proposition in a tropical environment where landslides were common and stability was difficult to maintain.

Scientists identified six potential causes of slope failures in Panama and acknowledged that should such failures transpire they could destroy the economic and energetic advantages of

[52] Corps of Engineers, AEC, PCC, *Appendix I to Annex III: Nuclear Excavation Plan,* pg. 16.
[53] *Ibid*, pg. 6.
[54] *Ibid,* pg. 17.

nuclear excavation. Scientists pointed to a variety of potential issues including geological failures from weak formations, terrain failures on sloping landscapes, rebound failures from cratering, liquefaction failures from the loss of strength of saturated materials, hydraulic failures from slopes undercut by rushing waters, or fractures induced by the explosion itself.[55] In essence, a lot could go wrong. By 1964, Bill Wray was growing increasingly concerned about the issue of slope stability. In a letter to Ernest Graves in March of 1964, he admitted "The more I think about the problem of slope stability in the deep cuts we would plan to make, the more I am concerned about the likelihood of major failures requiring the movement, by conventional equipment, of some rather large quantities of rubble."[56] Again the root of the problem lay in the sheer amount of energy released by nuclear explosives. Wray pointed to projections suggesting that in high risk areas, particularly through the Continental Divide, the explosions could create crater lips up to 700 feet tall. Wray believed the presence of so much rubble was a recipe for disaster.

The discussion then wasn't oriented around the question of whether slope instability was possible- it certainly was- but rather the consequences that would result from a large slide. One camp suggested that the Canal itself would be so large that a slope failure could only temporarily block a small section of the waterway. In 1960 this view was commonplace, but by 1964 more scientists were concerned with a complete blockage of the Canal and the cessation of all traffic. This growing chorus of voices suggested that to minimize the risk of catastrophic slope failure conventional excavation was necessary to create more gradual slopes. They predicted that fully halting the potential threat of slope failure required the conventional excavation of up to one

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[55] Corps of Engineers, AEC, PCC, *Appendix I to Annex III Nuclear Excavation Plan,* pg. 18-19.
[56] Wray, "Letter from Bill Wray to Ernest Graves, March 16, 1964" from USNA, RG 185, Collection A1 156, Box 2: Folder: General Information on Nuclear Excavation January 1964-March 1964.

billion cubic yards of material. The mutated fly in the ointment was that "Remedial construction of this magnitude would essentially wipe out the advantage of nuclear excavation."[57] Slope failures possessed the potential bury nuclear excavation. Nuclear energy's economy stemmed from the fact that it not only broke up rock and soil, but also ejected them from the canal prism, minimizing the need for conventional excavation. If slope instability necessitated a tremendous investment of mechanical energy it would eradicate the economic advantages that made nuclear excavation appealing.

The issue of slope stability also reflected a broader lack of knowledge about the ways nuclear explosives would operate in the Panamanian environment. To successfully create a sea-level canal across Panama, engineers needed to cut through the rugged mountainous terrain of the Continental Divide. In the Darien region where Route 17 was planned, this required blasting through terrain over 1000 feet above sea level. Nuclear energy could certainly accomplish this task; indeed, it could do so with an economy and efficiency unrivaled by any conventional energy source. The catch was that doing so required tremendous amounts of energy and consequently would release tremendous amounts of entropy. Scientists suggested that felling the Continental Divide would require the detonation of several substantial nuclear devices with yields upwards of 10 Mt if not more.

Increasing the yield of explosives was not a problem. Indeed, nuclear explosives were tremendous beneficiaries of economies of scale. As the yield of the device went up the concurrent cost per BTU of energy declined significantly.[58] For instance, a 2 Mt nuclear device

[57] Corps of Engineers, AEC, PCC *Appendix I to Annex III Nuclear Excavation Plan,* pg. 19.
[58] David Brooks and John Krutilla, *Peaceful Uses of Nuclear Explosives: Some Economic Aspects* (Baltimore, Maryland: Johns Hopkins Press, 1969), pg. 10.

cost \$0.075 per million BTU's while a 10 kt device cost \$8.75 per million BTU's.[59] The issue stemmed from the fact that increases in device yields also resulted in greater impacts from air blast, ground shock, and radiation. The key was to try to find a sort of thermonuclear goldilocks zone where leveling the Continental Divide was financially viable but wouldn't harm Panama City only 110 miles away. They begrudgingly conceded that one of their biggest worries was "The uncertainty about our ability to blast the section of a channel through the highest levels of the continental divide with a single nuclear explosive of safe yield."[60] This proved to be one of the ironic realities of the Panamanian environment. Its lack of land was a tremendous asset to excavation of a canal as it could be crossed far more easily than a larger country- Route 25 through Colombia for example would span over 100 miles compared to Route 17's 45 miles- however, this also meant that there was no location in Panama that was truly isolated enough for scientists to deploy their full arsenal of atomic energy.

The final issues facing the nuclear canal were the political and public relations obstacles that lay in its path. The Nuclear Test Ban Treaty continued to challenge the feasibility of nuclear excavation, particularly in Panama. One of the central tenets of the Treaty was that fallout from a nuclear detonation had to be contained within the territory of the country in which the explosion took place. In the Nevada Testing Site (NTS) this was inconvenient; in Panama it was impossible. In Nevada the AEC found that regulations imposed by the treaty significantly limited both the size and number of experimental explosions they could undertake. One projection from February of 1964 suggested that under these conditions it would take roughly 16 years to

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[59] Oskar Morganstern and Klaus-Peter Heiss, "General Report on the Economics of the Peaceful Uses of Underground Nuclear Explosives" (Mathematica, August 31, 1967), USNA, RG 220, Collection A1 36040-B: Box 4: Folder: General Report on the Economics of the Peaceful Uses of Underground Nuclear Explosives, Declassification NND 968050, pg. 29.
[60] Corps of Engineers, AEC, PCC *Annex III to Isthmian Canal Studies- 1964,* pg. 11.

establish the technical feasibility of nuclear excavation.[61] In Panama the problem was more pronounced. At the proposed canal site, the Isthmus had a width of less than 50 miles. Even under the best weather conditions it was impossible to keep fallout from drifting over international waters, thus violating the stipulations of the treaty.[62] The only way to create a nuclear canal while still abiding by the treaty was to renegotiate or amend the treaty to create an exception for peaceful nuclear explosions.

Unsurprisingly, the proponents of the nuclear canal were not going to have their enthusiasm dampened by minor obstacles like internationally ratified treaties. They were confident that the treaty could be easily amended. They even assumed that the Soviet Union would be enthusiastic to exempt peaceful nuclear explosives so they could advance their own nuclear excavation program. In a hearing before the Senate Commerce Committee AEC Chairman Glenn Seaborg suggested that if other countries saw smaller explosions that didn't violate the guidelines of the treaty they would see the practicality of nuclear excavation and "would also be able to assure themselves that nuclear excavation does not provide us an opportunity to obtain weapons information that cannot already be obtained by underground weapons tests."[63] Seaborg implied that if other countries felt assured of this they would be more open to amending the treaty, allowing for the larger tests required to determine the feasibility of nuclear excavation.

[61] John Finney, "A.E.C. Sees Delay in Canal Project," *New York Times*, February 26, 1964, from USN, RG 185, Collection UD UP 106, Box 2: Folder: Canal Construction- Nuclear, pg. 1.
[62] *Ibid*, pg. 1.
[63] "Minutes from the Senate Commerce Committee Meeting with the AEC Regarding a Panamanian Isthmus March 4, 1964," March 4, 1964, from USNA, RG 185, Collection UD UP 106, Box 2: Folder: Canal Construction- Nuclear, pg. 16.

This optimism permeated agencies affiliated with the project and led them to be somewhat dismissive of the broader public concerns about fallout and radiation. In that same hearing with the Senate Commerce Committee, John S. Kelly, the AEC's director of the Division of Peaceful Nuclear Explosions, suggested that it would be possible to limit radiation from explosives to just 1% of their 1962 levels, effectively rendering radiation a moot point. Senator Philip Hart from Michigan sought to blunt Kelly's optimism by pointing out that concerns over radiation would not go away so easily. "There is going to be plenty of gnashing of teeth," Hart commented, "and that doesn't mean they are communist inspired or anything else."[64] Despite the best efforts of Hart and others to open the eyes of scientists to the widespread concerns the public held regarding nuclear energy, scientists remained aloof and at times condescending in their understanding of the issue. On the topic of public concern, they suggested "The safety issues, particularly those dealing with radioactivity, are not well understood by the general public. This lack of knowledge forms the basis for a natural resistance to the execution of a project such as this one." The 1964 report went as far as to identify the Nuclear Test Ban Treaty as a symptom of this public ignorance, claiming, "The wide acceptance of the Nuclear Test Ban Treaty is ample testimony to the general nature and seriousness of this problem."[65] The dismissal of public concerns reflected the inability of nuclear scientists to realistically acknowledge that shortcomings of nuclear energy. The sheer potential offered by the technology seemed to outweigh any potential suggestion that it might be flawed or impractical. It appeared they were blinded by the light. Ernest Graves suggested that perhaps there was a more practical reason for this optimism. In a letter to Bill Wray he wrote that while he was at times overwhelmed by the

[64] "Minutes from the Senate Commerce Committee Meeting with the AEC Regarding a Panamanian Isthmus March 4, 1964," pg. 18.
[65] Corps of Engineers, AEC, PCCPCC, AEC, *Annex III to Isthmian Canal Studies- 1964*, pg. 13.

obstacles that lay in their path, “Great endeavors require a fundamental faith in the ability of man."[66] The line between necessary optimism and naïve faith was razor thin.

Despite the unfortunate side effects of nuclear excavation, the awesome amounts of energy the technology could provide, accompanied by the growing reality that the current canal was both practically and politically inconvenient, led the federal government to throw its full weight behind the proposed nuclear canal. As 1964 progressed both the Senate and House considered bills to provide funding for on-site surveys in Panama and Colombia. This process kicked off the final phase in the quest for the nuclear canal, a phase which started with optimism, but soon revealed the task of harnessing the atom was far more daunting than anyone anticipated.

Congressional Debates and Missed Dates

The debates regarding on-site tests and the creation of the Atlantic Pacific Interoceanic Canal Study Commission (ICSC) were surprisingly muted given the controversy surrounding nuclear detonations. By September of 1964 the bill made its way through Congress and the ICSC had been given $17.5 million dollars to conduct its study.[67] Unlike the organizations previously tasked with determining the feasibility of a nuclear canal, the ICSC was a civilian run organization. Robert Anderson was named Chairman of the Commission as well as the lead negotiator in the search for a new treaty with Panama. John Sheffey served as the Commission’s Executive Director, overseeing organization and logistics. Alongside these two were four other members: Robert Storey, Milton Eisenhower, General Kenneth Fields, and Raymond Hill. These six men were tasked with a variety of charges, including determining the capacity of the existing

[66] Graves, “Letter from Ernest Graves to Bill Wray, March 20, 1964” from “January 1964-March 1964”
[67] Lindsay-Poland, *Emperors in the Jungle,* pg. 87.

canal, potential sites for a new canal, and finally assessing the technical feasibility of using nuclear explosives to create a new sea-level Isthmian canal.[68]

Despite their best efforts, progress on the study itself was slowed by a variety of obstacles that all centered around one issue: the rainy season. Despite technological developments in harnessing new sources of energy, Americans in the 1960s still faced the same challenge that G.M. Totten had faced over a century earlier. The rains of Panama between April and December effectively slowed work to a crawl. The proposed plan of study for the Commission suggested that "Under these adverse circumstances which will increase costs, we will get considerably less field data for our programed resources."[69] This issue complicated the fact that the ICSC was also working on a fixed schedule and was expected to submit its findings to the President by June 30th, 1968.[70] In essence this left them with four dry seasons to compile their information and determine the best course of action for a new canal. A series of delays and budget issues soon rendered this goal untenable.

The dry season of 1965 was a wash from the very beginning. The ICSC was not approved until September of 1964 and didn't appoint all six of its members until early 1965. It was impossible to employ surveyors, scientists, and engineers and obtain the materials necessary to construct facilities in the interior on such short notice. Additionally, the Commission had to negotiate rights of access with Panama before they could even consider sending personnel into

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[68] John Sheffey, "Atlantic Pacific Interoceanic Canal Study Commission," 1965, from USNA, RG 185, Collection UD UP 106, Box 4: Folder: Atlantic-Pacific Interoceanic Canal Study Commission, pg. 12.
[69] R.P Tabb, "Plan for Study of Engineering Feasibility Presented to the Atlantic Pacific Interoceanic Canal Study Commission," September 17, 1965, from USNA, RG 185, Collection A1 156, Box 2: Folder: Atlantic-Pacific Interoceanic Canal Study Commission, pg. 2.
[70] *Ibid,* pg. 2.

the region.[71] These two challenges meant that throughout 1965 much of the ICSC's work focused on tasks that could be done domestically. The only major attempt to obtain on-site information was the deployment of Field Director Alex Sutton to Panama for brief surveys. Sutton's initial report was not optimistic and even senior members of the Panama Canal Company recognized the challenges the survey faced. In response to Sutton's report, Canal Zone Governor Robert Fleming wrote, "Without immediate access to work areas, without helicopter resupply, without adequate potable water, without preparation and conditioning of the native population, the field parties' energies and endeavors will be concentrated on survival with a consequent detriment to the basic mission of the surveys."[72] The Panamanian interior still demanded tremendous investments of energy to breach, particularly during the wet season.

Because of these challenges the ICSC made only gradual progress during 1965. Commission members made their way to Panama in August of 1965, and in October of that year they visited the Nevada Test Site to get information on Plowshare's progress.[73] Nuclear device development was also stalling. The Limited Test Ban Treaty and a popular perception of nuclear explosives as doomsday devices limited public acceptance of any nuclear detonation. Consequently, AEC scientists were forced to focus on theoretical cratering formulas using data from previous nuclear detonations and chemical explosives to extrapolate the outcomes of larger

[71] "Hearing Before the Committee on Commerce United States Senate Ninetieth Congress First Session on S. 1566 to Amend Public Law 88-609 Creating the Atlantic-Pacific Interoceanic Canal Study Commission" (U.S. Government Printing Office, June 1, 1967), from USNA, RG 220, Collection A1 36040-B, Box 2: Folder: Hearing Documents, Declassification NND 968050, pg. 8.
[72] Robert Fleming, "Letter from Robert Fleming to Stephen Ailes, Jan 1965," January 1965, from USNA, RG 185, Collection A1 156, Box 2: Folder: General Correspondence Sea-Level Canal Studies.
[73] Interoceanic Canal Study Commission "Second Annual Report of the Atlantic Pacific Interoceanic Canal Study Commission," July 31, 1966, from USNA, RG 185, Collection A1 156, Box 1: Folder: Atlantic Pacific Isthmian Canal Study Commission Second Annual Report, pg. 1.

detonations.[74] Meanwhile, the AEC hired consultants from MIT and Duke to try to deal with the vexing issue of slope stability. These studies focused particularly on the challenges of creating stable slopes in the weak, saturated rocks that were common to Panama. While they made some headway in exploring potential ways of generating more gradual slopes and promoting stability in weak media, they were forced to admit that "It becomes obvious that no valid stability analysis can be made without adequate site data."[75] Until more nuclear tests could be conducted, or access to proposed canal sites could be obtained, scientists could only speculate on the consequences of deploying atomic energy.

Despite these challenges, the ICSC separated itself from its predecessors by taking public concerns about nuclear explosives seriously and developing an informal program to assuage public misgivings. The ICSC undertook a "Study of Public Information Aspects of Sea-Level Canal Construction" which intended to “anticipate and evaluate the public reaction to each of the courses of action under the consideration by the Commission and to weigh the influence of public opinion on the feasibility of each." Additionally, the Commission adopted a policy of responding to requests for unclassified information as expeditiously and thoroughly as possible.[76] These new practices marked a tangible shift from the approach of earlier organizations. Public fears about nuclear explosions were no longer dismissed as hallmarks of ignorance but acknowledged as legitimate concerns. This more realistic interpretation of the challenges presented by public resistance to nuclear energy reflected the ICSC’s far more nuanced and cautious interpretation of the feasibility of nuclear engineering. Consequently, while the

[74] “Hearing Before the Committee on Commerce United States Senate Ninetieth Congress First Session on S. 1566 to Amend Public Law 88-609 Creating the Atlantic-Pacific Interoceanic Canal Study Commission” pg. 2.

[75] Paul Fisher, “Study Program: Engineering Properties of Nuclear Craters” (Lawrence Radiation Laboratory, October 1965), from USNA, RG 220, Collection A1 36040-B, Box 4: Folder: Study Program Engineering Properties of Nuclear Craters, Declassification NND 968050, pg. 97.

[76] ICSC, *Second Annual Report of the Atlantic Pacific Interoceanic Canal Study Commission,* pg. appendix 7-1.

Commission failed to accomplish much in 1965 it did distinguish itself from its predecessors by suggesting that policy makers were no longer as enthralled by the promise of nuclear excavation as they had once been.

The ICSC's slow progress continued as the dry season of 1966 approached. In this case stagnation stemmed not from the Commission, but rather from Panama and Colombia's reluctance to grant Americans access to their territory.[77] This too reflected the political limitations to the deployment of atomic energy. The concerns of Panama and Colombia were two-fold. Both countries were reluctant to make concessions to the American government considering the ongoing conflict over the status of the existing canal. More concerning to both governments was the future potential of Americans detonating nuclear devices in their territorial borders. Colombian accounts suggested they weren't worried about on-site surveys per se, but rather the fact that these surveys were ostensibly conducted to gauge the feasibility of nuclear engineering. Colombia was intrigued by the potential of a new sea-level canal; they were far warier of this canal being excavated with nuclear energy.[78] Panama had similar reservations about nuclear energy. Sheffey testified before the Senate that Panama wanted to see a substantial demonstration of the technology first "But they very clearly indicated that they don't want to be the guinea pig for this."[79] Surprisingly, Isthmian nations weren't lining up to have nearly 200 Mt of nuclear explosives detonated within their borders.

[77] "Hearing Before the Committee on Commerce United States Senate Ninetieth Congress First Session on S. 1566 to Amend Public Law 88-609 Creating the Atlantic-Pacific Interoceanic Canal Study Commission," pg. 8.
[78] Luis Umana, "Letter from Luis Restrepo Umana to Maurice Quade, February 15, 1965," February 15, 1965, from USNA RG185, Collection A1 156, Box 2: Folder: General Correspondence Sea-Level Canal Studies.
[79] "Hearing Before the Committee on Commerce United States Senate Ninetieth Congress First Session on S. 1566 to Amend Public Law 88-609 Creating the Atlantic-Pacific Interoceanic Canal Study Commission", pg. 21.

Finally, by the dry season of 1967, site surveys were able to begin in earnest in Panama. Panama agreed to rights of access in February of 1966 (still too late to carry out substantial work that dry season) and Colombia finally agreed in 1967 (too late to carry out substantial work during that dry season). Yet the loss of two dry seasons in Panama and three in Colombia made the July 1968 deadline for report submission impossible to meet. A hearing was held in June of 1967 to push the date back. In addition, the ICSC also requested an additional $7 million dollars to cover the costs of more extensive surveys.[80] While the Senate denied the ICSC's funding request, the organization was granted an extension of its work until December 1, 1969 largely because of issues in the AEC.[81]

The Senate was hesitant to act on the ICSC's request, particularly for increased funding, thanks in large part to the hiatus of nuclear detonations. The AEC had not carried out an underground nuclear explosive test in nearly four years and, as a result, technical information on the potential of nuclear engineering had stalled. The ICSC found it impossible to fulfill its task of gauging the feasibility of nuclear excavation without this information. John Kelly, the Chair of the Division of Peaceful Nuclear Explosions for the AEC, suggested that not only could the AEC not determine whether nuclear excavation was feasible for a new canal, they couldn't determine if it was feasible at all at higher yields. Kelly suggested that "To demonstrate the feasibility of nuclear excavation, we must have the capability to more accurately predict the characteristics of craters produced by nuclear explosives. Experience to date indicates that an empirically based predictive capability does not suffice for higher yield detonations or for detonations in different

[80] "Hearing Before the Committee on Commerce United States Senate Ninetieth Congress First Session on S. 1566 to Amend Public Law 88-609 Creating the Atlantic-Pacific Interoceanic Canal Study Commission", pg. 1.
[81] "Hearing before the Committee on Merchant Marine and Fisheries of the House of Representatives Ninetieth Congress, Second Session on H.R. 15190" (U.S. Government Printing Office, March 7, 1968), from USNA, RG 220, Collection A1-36040B, Box 2: Folder: Hearing Documents, Declassification NND 968050, pg. 32.

media."[82] The unpredictability and uncontrollable nature of nuclear energy was too substantial to deploy without more tests.

And yet, despite the lack of data, many scientists felt that the adoption of nuclear excavation was a foregone conclusion. The disconnect between atomic enthusiasts and the general apprehension surrounding nuclear explosions remained vast. An AEC contracted report on the economics of peaceful nuclear explosives suggested that the technology was simply too promising to abandon despite its risks. The report stated that "Even if Plowshare should be rejected for the immediate future, the needs of the human race, in view of its vast and rapid increase in numbers and the developing shortages of resources accessible by conventional means eventually will force the use of this technology upon the world."[83] This logic suggested that the hazards of nuclear excavation were insignificant next to the demands of human development. An exponentially more powerful source of energy needed to be adopted regardless of costs for humanity to thrive. In some ways this sentiment reflected earlier trends in the adoption of new energy regimes in Panama. Loss of life had been justified in both railroad and canal construction on the grounds that these developments were essential to the bettering of the human condition. And yet when this metric was applied to nuclear energy the sheer amount of energy that was in play complicated matters. Coal, oil, and chemical explosives all lacked the sheer destructive potential of nuclear reactions. The visceral power within the atom ensured that it was held to a different standard than other technologies, a standard that many worried could not be met.

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[82] "Hearing Before the Committee on Commerce United States Senate Ninetieth Congress First Session on S. 1566 to Amend Public Law 88-609 Creating the Atlantic-Pacific Interoceanic Canal Study Commission," pg. 18.

[83] Morganstern and Heiss, *General Report on the Economics of the Peaceful Uses of Underground Nuclear Explosives,* pg. 20.

Despite growing concerns regarding Plowshare, the quest for peaceful nuclear explosions was not dead. Indeed, it rose from the irradiated ashes of the Nevada Desert again in 1968 to carry out a series of tests which suggested that the dream of the nuclear canal could finally be realized. The Cabriolet and Buggy tests, conducted in January and March respectively, were the cause of this excitement.[84] Buggy was particularly important. For the first time the AEC had conducted a nuclear row charge experiment and proven, at least on a small scale, that the technique created a trench. Members of the ICSC were pleased to report that both tests had "results that equaled or exceeded expectations."[85] These tests also increased Congressional approval of the ICSC as hearings were held in the House in March and in the Senate in April to again extend the deadline for report submission, this time to December 1, 1970, and increase ICSC funding. An excited Robert Anderson suggested that these tests would allow the ICSC to finally gauge the feasibility of a nuclear canal.[86]

Despite the rosy outlook for nuclear excavation, several issues remained unresolved. The AEC had four additional tests planned, yet their record suggested that planned tests didn't always yield conducted tests. More problematic was the reality that, despite the best efforts of the AEC, nuclear energy could not be fully contained. Substantial relocation programs needed to be implemented before detonations took place. The utilization of thermonuclear explosives in Panama would require the forced removal of at least 40,000 people from the rainforest surrounding Route 17.[87] The major issue was that the potential evacuees were native members of

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[84] Kirsch, *Proving Grounds,* pg. 186.
[85] Interoceanic Canal Study Commission, "Fourth Annual Report of the Atlantic Pacific Interoceanic Canal Study Commission," July 31, 1968, from USNA, RG 185, collection A1 156, Box 1: Folder: Commissioner's Visit APICSC, Nov. 1968, pg. 1.
[86] "Hearing before the Committee on Merchant Marine and Fisheries of the House of Representatives Ninetieth Congress, Second Session on H.R. 15190", pg. 32.
[87] ICSC, *Interoceanic Canal Studies: 1970*, pg. 38.

the Choco and Cuna tribes. Engineers were worried that these individuals viewed their lands with “primitive cultural attachments that could not be easily overcome.”[88] Removing the Choco and Cuna from their ancestral lands was problematic not so much from its technical infeasibility, but rather the public relations nightmare that would inevitably result.

The importance of these removals could not be overstated. The AEC’s first attempt at a practical application of Plowshare had proposed the use of a nuclear explosion to create a deep-water harbor in Alaska. This project, codenamed Chariot, aimed to both provide a functional harbor and unequivocally display the utility of nuclear excavation. It never happened. Scientists, concerned with how the blast could impact local ecology and the Inuit who relied on it, raised the alarm and public sentiment quickly turned against the program.[89] Alaska Senator Bob Bartlett cautioned the ICSC that "I am not going to pose this as a question, but there has always been this thought in my mind, and I compare the relatively small population in the Cape Thompson undertaking with the very considerable population down in Central America, and I apprehend that there is a distinct possibility that those people who oppose this sort of thing will be tremendously more active in this situation than they were in the Alaska one."[90] Relocation was not an issue that could be solved by experimentation or tests, and it had the potential to thwart any canal across the Isthmus.

Despite the concerns about relocation, the ICSC moved ahead at a remarkable pace in the months following Cabriolet and Buggy. Site surveys on Route 17 in Panama were effectively completed during the dry season of 1967 and data analysis was already underway by 1968. The

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[88] ICSC, *Interoceanic Canal Studies: 1970*, pg. 44.
[89] For a full account of Project Chariot see Kirsch, *Proving Grounds,* Ch. 3.
[90] “Hearing Before the Committee on Commerce United States Senate Ninetieth Congress Second Session on S. 2948” (US Government Printing Office, April 2, 1968), from USNA, RG 220 , Collection A1 36040B, Box 2: Folder: Hearing Documents, Declassification NND 968050, pg. 30.

ICSC also managed to obtain rights of access in Colombia and was able to hit the ground running in 1968. This onsite data answered crucial questions about the meteorology, hydrology, and geology in both regions and helped engineers gain a better understanding of where and when nuclear energy could be implemented. They believed that field work on both sites could be completed by the end of the year, giving them time to compile data and obtain more information from the AEC about its cratering experiments.[91] Remarkably, even the AEC seemed poised to meet its deadline, carrying out another nuclear detonation, Schooner, in December of 1968.[92] The nuclear canal seemed to be closer at hand than it had been in years.

More Sizzle than Substance

As the ICSC entered 1969 and prepared to complete its studies, the enthusiasm that had accompanied the nuclear excavation tests in early 1968 rapidly evaporated. Budget cuts limited personnel numbers on the Isthmus and halted Plowshare experiments in the US. Meanwhile questions remained about technical feasibility issues. Slope stability had yet to be dealt with and scientists could not guarantee that they could successfully cut through the Continental Divide in Panama with explosions of a safe yield. These questions were further complicated by the reality that any sort of nuclear excavation required the relocation of tens of thousands of people, a proposal that demanded the investment of tremendous political and financial capital. The verdict on nuclear excavation was still out, but it did not look promising.

As 1969 began, the AEC and ICSC encountered a test that could not be overcome by experimentation and theory: budget cuts. Less than a month into his first term, Richard Nixon delivered on his campaign promises to limit government excess by cutting the number of

[91] ICSC, "Fourth Annual Report of the Atlantic Pacific Interoceanic Canal Study Commission," pg. 1.
[92] Kirsch, *Proving Grounds,* pg. 186.

government employees.[93] While Nixon's mandate impacted the entire federal government, its impacts were felt acutely in Panama where nearly every service was operated by the federal government. The result was a freeze in new hiring, an emphasis on internal promotion, and a constant review of necessary personnel.[94] In this climate, theoretical studies for a new canal were not a priority.

The ICSC approached its deadline as these cuts came into effect and, in many areas, the organization had already completed on-site surveys and data collection studies. As a result, it was not directly impacted by budget cuts. However, personnel cuts did substantially impact the progress of Plowshare. Unfortunately for the AEC, the Schooner test in December of 1968 was the last test conducted under the purview of Plowshare and marked the end of the development of the safe, high yield explosives necessary for canal construction. While the ICSC could interpret chemical explosions, theoretical work, and scaling models, the lack of a large-scale tests meant that they could not confidently determine the feasibility of nuclear excavation. Cabriolet, Buggy, and Schooner provided exciting new information, but scaling accuracy remained elusive.[95]

Despite these substantial roadblocks to the adoption of the nuclear canal, the AEC remained obliviously optimistic about the program. An AEC report from August of 1970 parroted many of the results from early findings. While the report accepted that the Continental Divide rendered Route 17 unviable it clung to the hope that Route 25 through Colombia provided a cost-effective site of a canal. The study suggested that Route 25 was even more

[93] Richard Nixon, "Memorandum for the Heads of Executive Departments and Agencies," February 17, 1969, from USNA, RG 185, Collection A1 156, Box 1: Folder: Correspondence OICS- General.
[94] Walter Leber, "Memorandum: Force Limitations," February 24, 1969, from Correspondence OICS- General.
[95] John Toman, "Summary of Results of Cratering Experiments" (Lawrence Radiation Laboratory, April 2, 1969), from USNA, RG 220, Collection: A1 36040-B, Box 14, Declassification NND 968050, pg. 1.

isolated from major population centers than Route 17, mitigating issues of ground shock and air blast. It indicated that slope stability wouldn't be as big an issue in Colombia and that the tests in 1968 had given them far more information regarding the formation of slopes. Finally, the report echoed earlier findings that claimed radiation was a nonfactor due to the creation of cleaner explosives.[96] A perplexed John Sheffey wrote a letter to Chairman Robert Anderson stating, "Note that this evaluation is considerably more optimistic than that of the commission, i.e., fewer explosives and lesser total yields required for canal excavation than estimated by the Corps of Engineers. It is also downplaying the problems of nuclear excavation."[97] In the face of seemingly conclusive evidence to the contrary, the AEC still saw the viability of nuclear explosives through rose colored glasses.

Unfortunately for the AEC, the findings of the ICSC overshadowed nuclear optimism when they finally delivered their report the President on December 1, 1970. The Commission expressed itself unequivocally, writing, "Unfortunately, neither the technical feasibility nor the international acceptability of such an application of nuclear excavation has been established at this date." While they acknowledged that nuclear explosions might become viable for large scale construction projects at some point in the future, they cautioned the President that "no current decision on United States canal policy should be made in the expectation that nuclear excavation technology will be available for canal construction."[98] The nuclear canal was dead in the water with no sign of help on the horizon.

[96] Glenn Werth and John Toman, "A Technical Assessment of a Nuclearly Excavated Sea-Level Canal Across the Central American Isthmus" (Lawrence Radiation Laboratory, August 12, 1970), from USNA, RG 220, Collection: A1 36040-B, Box 9, Declassification NND 968050, pg. 1-4.
[97] Letter from John Sheffey to Robert Anderson, October 8, 1970" October 8, 1970, from USNA, RG 220, US Collection: A1 36040-B, Box 9, Declassification NND 968050.
[98] ICSC, *Interoceanic Canal Studies, 1970*, pg. Front Matter 1.

The rationale for the ICSC's decision was unsurprising. They lacked the information necessary to justify nuclear excavation. Interestingly, their concerns had little to do with questions of air blast, ground shock, and radiation as they felt "extensive knowledge" of these phenomena was available from earlier nuclear tests.[99] Instead the ICSC emphasized the fact that "The higher yield nuclear cratering experiments of the magnitude required for the Isthmian canal excavation, however, remain to be carried out."[100] The ICSC's acknowledgment of these limitations was a remarkable shift from the position taken by the AEC, which assumed that any obstacle could be overcome with future experimentation and improvisation. The ICSC, more focused on the practical application of the technology to real world situations, quickly recognized that such an approach wasn't sustainable given the economic, political, and societal constraints surrounding the adoption of nuclear energy. While nuclear explosions could cut through earth and rock, they were incapable of cutting through bureaucratic red tape.

In addition to a lack of information, the ICSC also identified several major problems that had yet to be dealt with. Unsurprisingly, these concerns were focused on slope stability, public acceptance, and the unique challenges presented by the Panamanian environment, forces which had become increasingly central to the Isthmian canal discussion since 1964.

Slope stability remained the chief obstacle to technical feasibility. Scientific understanding of slope stability had improved over the course of the 1960s and yet there were still no solutions to this problem. In coastal and swampy areas saturated soils would simply erode over time, or flash floods would sweep them away with terrible efficiency. These landscapes were too fluid to have stability imposed on them and so nuclear excavation was considered

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[99] ICSC, *Interoceanic Canal Studies, 1970*, pg. 34.
[100] *Ibid*, pg. 36.

infeasible for many areas, particularly along the Atrato and Truando rivers of Route 25. Conversely, rocky areas were too rigid to effectively use nuclear engineering. Nuclear explosives left sheer slopes in rocky terrain. If these slopes were subjected to high levels of water, extreme weight, or even the shock of subsequent detonations they could fracture, creating catastrophic slope failures.[101] Nuclear energy had an awesome potential to restructure landscapes, yet in doing so it often made it next to impossible to maintain them. Humans simply could not control the power of the atom.

The central obstacle presented by the Panamanian environment remained the challenging issue of crossing the Continental Divide. The interior of the Isthmus was comprised almost entirely of rock and, while nuclear energy could certainly remove this material, questions remained over whether the high yield explosives required to level the Continental Divide could be safely used. This was certainly tied to questions over fallout, air blast, and ground shock, but increasingly it was linked with questions over slope stability. For the canal to work it needed to level one thousand feet of rock while simultaneously creating slopes at stable angles. The ICSC determine that "Such slopes cannot be produced by single-row explosive excavation and the chemical explosive experiments conducted this far indicate that it is unlikely that multiple-row techniques can be developed to produce flatter slopes."[102] Ultimately a new canal through Panama was technically infeasible thanks to the varied terrain of the region. The landscape was too fluid for the technology to work.

The issue of slope stability was exacerbated by continued public relations challenges that had dogged the technology since its inception. The ICSC's appreciation of these concerns made

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[101] ICSC, *Interoceanic Canal Studies: 1970*, pg. 42-43.
[102] *Ibid,* pg. 38.

them uniquely qualified to gauge the impact that they had on the creation of an atomic canal. While they suggested that these obstacles could be overcome if nuclear excavation was proven technically feasible, the lack of progress on Plowshare rendered the potential for public acceptance of nuclear engineering moot. If anything, the 1970 study showed that public relations concerns were growing even more complicated. The ICSC argued that concerns about radiation release were becoming entwined with questions of foreign policy and domestic dissent. The Limited Test Ban Treaty had been joined by the Nuclear Non-Proliferation Treaty and the Treaty of Tlatelolco as obstacles to the international acceptance of nuclear detonations, and both Panama and Colombia were growing skeptical of nuclear earthmoving.[103] While the ICSC reported that considerable foreign relations, education, and reimbursement campaigns could overcome this resistance, they worried that "the political and financial costs to the United States in obtaining such acceptance could offset any potential saving in construction costs and gains in intangible benefits."[104] Unless nuclear energy's utility could outpace the technology's hazards, public opinion would continue to work against it.

The message of the ICSC was clear. Nuclear excavation, while promising, remained far too unproven to be used on the monumental scale demanded by an Isthmian canal project. This was not to say that the ICSC rejected nuclear energy outright. They adamantly suggested that they believed eventually this technology might pay tremendous dividends.[105] Unfortunately, the risk of testing this new technology in Panama was unacceptable. Nuclear excavation was too unproven and the task too great. The dream of an atomic canal was, at least for the present, put to rest.

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[103] ICSC, *Interoceanic Canal Studies: 1970,* pg. 43-44.
[104] *Ibid*, pg. 45.
[105] *Ibid,* pg. 43.

The Beginning of the End

Ten years of studies doomed the quest for a nuclear canal. The lack of progress on a feasible nuclear technology and a broad array of public concerns relegated nuclear excavation to the realm of science fiction. The idea reemerged in the 1970s, however, the ICSC's decision dealt a significant blow to nuclear engineering that it never fully recovered from. Plowshare lingered on throughout the early 1970s but received no funds for large scale experiments after 1970. After several years of private studies and schemes to keep the program alive, Plowshare was effectively defunded entirely in 1974.[106]

It's ironic that the decision to shy away from nuclear excavation in Panama was primarily reflective of the awesome power of this new source of energy. Atomic energy's tremendous yields and uncontrollable nature created a series of unique challenges stemming from nuclear explosions' overabundance of energy rather than dearth of it. Nuclear explosions altered landscapes too radically, creating steep sloped banks that were recipes for disaster in the entropic Panamanian landscape. The hubris of some scientists allowed them to discount the concerns of environmentalists and citizens as ignorance or a lack of understanding, but they could not overlook the fact that the technology was fundamentally untenable in the Panamanian environment. While public resistance and political challenges certainly impacted the decision to shy away from nuclear earthmoving, technical infeasibility ultimately vaporized the project. As the ICSC suggested, public and political relations issues could be overcome, but before this could be accomplished the utility of nuclear earthmoving had to be established. The AEC's inability to do this made a public relations campaign a moot point.[107]

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[106] Kirsch, *Proving Grounds*, pg. 204

[107] ICSC*, Interoceanic Canal Studies: 1970*, pg. 43.

The decision to avoid nuclear energy was a remarkable development in the history of American energy in Panama. This was the first time that a new source of energy lay untouched by Americans seeking to restructure the Panamanian environment. A decade of admittedly inconsistent study preceded the decision to abandon nuclear technology and, while at times the AEC's optimism towards nuclear energy seemed insulated from real world realities, the ultimate decision to shy away from Plowshare was indicative of a realization of the limits of a new energy regime rather than a single-minded focus on its benefits.

Unlike coal and oil, which also certainly possessed destructive side effects, the consequences of nuclear energy were brutal and explicit. The unrestrained destruction that accompanied nuclear excavations proved an insurmountable obstacle to feasibility regardless of how much energy the federal government brought to bear on it. Nuclear explosions were too instantaneous and powerful to be safely and effectively controlled. The potential side effects of a failed or even successful nuclear detonation were equal to the awesome energy the new technology promised. Rob Nixon's idea of "slow violence" is useful in understanding this tension.[108] Compared to the problems associated with coal or oil, the potential hazards of nuclear exaction were literally explosive. Nuclear skepticism didn't stop with nuclear excavation. Thanks to the disasters of Three Mile Island and Chernobyl, hostility towards nuclear energy grew to encompass nuclear power plants as well. This movement rightfully identified the dangers that came from the application of nuclear energy, and yet it's worth noting that the fervor

[108] Nixon's idea of "slow violence" suggests that environmentalists have been far more effective at garnering public response and resistance to those environmental dangers that constant blatant, visceral, and rapid threats to human populations. More insidious, intangible, and gradual threats are far more difficult to realize. Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, Mass: Harvard University Press, 2011., 2011).

directed against nuclear energy allowed fossil fuels and their insidious byproducts to continue to flourish in the radioactive shade cast by the mushroom cloud.

Ultimately the ICSC's 1970 report spelled the end of not only the atomic canal, but also American hegemony over the Canal itself. The ICSC suggested that the US explore conventional excavation of a sea-level canal, but with an estimated price tag of $2.88 billion dollars the venture constituted a significant financial risk.[109] A slowing economy and an increasingly expensive foreign policy made such a price tag hard to justify. While the treaty negotiations that had begun in the 1960s had not yet borne fruit, Panama had clearly indicated that the status quo was unacceptable, and that the governance of both the Canal and the Canal Zone needed to change. These discussions defined the 1970s, setting the stage for the next chapter in the complex energy history of the Canal Zone. While nuclear energy might have been the focus of attention during the 1960s, fossil fuels still ruled the Canal behind the scenes. The discovery of oil on Alaska's northern shore in 1968 pushed fossil fuels to the forefront. As America was forced to reckon with the limits of its thirst for energy domestically, Panama's importance as an energy highway came to impact treaty discussions, suggesting that the importance of American energy in Panama was far from finished even though nuclear excavation had proven to be little more than a radioactive flash in the pan.

[109] ICSC, *Interoceanic Canal Studies: 1970,* pg. Front Matter 1.

Chapter VI: A Crude Form of Survival: Alaskan Petroleum and Panamanian Pipelines: 1945-1990

Barrow, Alaska (or as it is known today Utqiagvik) was hardly a war zone. And yet it was to Barrow, the northernmost town in the United States, that Navy Lieutenant W.T. Foran ventured in the spring of 1944. Foran was leading the Navy's survey of Naval Petroleum Reserve No. 4 which ran through northern Alaska. For the next several years the Navy, U.S. Geological Survey, and Arctic Contractors sent hundreds of researchers to the inhospitable landscape to search for signs of oil.[1] As Foran and others trudged through the arctic tundra, construction workers employed by Williams Brothers Corporation laid an oil pipeline from the Gatun tank farm near the Atlantic terminus of the Panama Canal to the Arraijan tank farm near the Pacific terminus.[2] Separated by over 5000 miles, the two developments seemed to be isolated from one another, and yet two decades later their fates became inextricably entwined. The discovery of a massive oil field near Prudhoe Bay on Alaska's north shore catalyzed an energy bonanza in which companies sought to determine the most economical means of transporting millions upon millions of barrels of Alaska North Slope (ANS) oil to markets around the world. Panama once again was the centerpiece of one of the most lucrative trades in the world, and yet in wedding itself to the ANS oil trade Panama encountered a new source of entropy. One connected not only to physical forces, but also the instable and erratic nature of the global oil trade and diplomatic crises. Questions about the Canal's utility, domestic developments in the US and Panama,

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[1] John Reed, "Letter from Dr. John Reed to Dr. Bill Bradley," June 25, 1947. Retrieved from USNA, RG 57, Collection: A1 267: Geological Division Records Relating to Fossil Fuel Investigations, located in Box 1: Folder: Alaskan Naval Petroleum Reserve: July 1947-July 1948, pg. 2.

[2] F.R. Johnson, "Letter from F.R. Johnson to Governor David Stuart Parker," June 21, 1972. USNA, RG 185, Collection: P11 Negotiation and Planning Relating to 1977 Panama Canal Treaty, Box 3: Folder: Transisthmian Pipeline, declassification NND 008039, pg. 2.

diplomatic disputes, and shifting global markets all threatened to undermine the potential benefits that accompanied ANS oil shipments.

Since WWII, questions of the Canal's obsolescence dogged the waterway, emerging from hibernation a few times every decade before being subdued by more immediate concerns. The failure of nuclear excavation and the sea-level canal project seemed to provide a conclusive end to these debates by suggesting that, while the Canal had limitations, there was simply no feasible way of economically restructuring the waterway. Petroleum complicated this narrative. Long among the most important commodities to transit the Canal, petroleum provided economic arguments for the continued relevancy of the Canal, and yet as oil production boomed during the postwar years the Canal's inability to transit the largest tankers was a sobering reminder of its limitations. It was perhaps unsurprising then that the Canal became the site of a new set of interoceanic transportation networks, passages specially tailored and designed for the transportation of oil: pipelines. The emergence of Panamanian pipelines emphasized both the continued geographic importance of Panama itself and the challenges presented by the confines of the lock canal.

The complexity that defined Panama's relationship with petroleum was exacerbated by the increasingly volatile relationship between Panama and the United States. The fallout of the Marty's Day riots reverberated through the next decade-and-a-half as, starting in 1964, the Johnson, Nixon, Ford and Carter Administrations sought to renegotiate treaties between the two nations. Among Panama's chief concerns during these negotiations was a desire to capitalize on the financial opportunities offered by its position as a global crossroads. Ambassador Ellsworth Bunker, one of the lead negotiators of the new treaties, was quick to note that as early as 1975 "Already Panama has plans which call for the construction of an oil pipeline which would reduce the cost of transporting petroleum across the Isthmus."[3] In this sense, Panama's own economic ambitions also called the Canal's utility into question. Panama's frustration with the small financial benefit it extracted from tolls led it to pursue alternative methods of transporting petroleum products across the Isthmus. In the years following the Treaties' ratification in 1979, Panama doubled down on this commitment, creating a pipeline that proved immensely valuable to the nation until the late 1980s.

Ultimately, the expansion of the global oil trade proved a bit of an enigma. It certainly made Panama once more a focal point of global commerce, but the financial benefits that accompanied oil ebbed and flowed, as fluid as oil itself. By becoming a crossroads for ANS oil, Panama once again reasserted its intimate relationship with energy and accepted the entropic consequences that accompanied it. Unlike previous eras of the Transit Zone's history however, the entropy was no longer solely physical, but rather diplomatic and economic. The erosion of diplomatic ties between the two nations threatened to undermine the ANS oil trade and even after new treaties were negotiated in 1979 the rise of General Manuel Noriega, a man whose volatility made him entropy personified, caused the oil boom to come crashing down.

The postwar years gave rise to an increasingly global energy market that emphasizes the connections between seemingly disparate regions on an unprecedented scale. As Daniel Yergin has pointed out, the quest for energy stability is inherently beset by unforeseen "surprises" which have the potential to radically alter the global status quo.[4] Riots, dictators, international incidents, and economic developments could easily restructure global energy networks. In wedding itself to

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[3] Ellsworth Bunker, "Panama and the United States," May 22, 1975. USNA, RG 185, Collection: A1 168 PCC Records Related to Negotiation and Planning for the 1977 Panama Canal Treaty, Box 1: Folder: Kissinger, Bunker, GOP Negotiations- Statements, declassification NND 988086, pg. 17.

[4] Daniel Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World,* (New York: Penguin Books, 2012), pg. 8.

ANS oil, Panama was also subjecting itself to a globalized world in which developments 5000 miles or more away could dramatically alter the status quo at home. This unpredictable relationship between America, Panama, and petroleum shaped the postwar era. Petroleum seeped into discussions of the Canal's future and emerged as the dominant source of energy impacting the Canal in the 1970s and '80s. These developments ushered in the final chapter of American energy in Panama. While the relationship between the two nations changed during the era, the incessant importance of energy remained.

The Promise of Alaska

Alaska's potential as a site for crude oil extraction had been well established by the 1940s. The U.S. Geology Survey itself noted in January of 1945 that "Indications of oil in Alaska are widespread and have been well known for many years" before qualifying its statement by acknowledging, "investigations of potential oil areas by the Geological Survey have been deferred in recent years because of even more pressing duties."[5] Katalla, located about 150 miles east of Anchorage had been tapped as early as 1902, producing 154,000 barrels during the three decades it was in operation.[6] And yet by the 1940s, this was the only source of Alaskan oil. The abundance of reserves in California forestalled the relative expense of transporting oil from Alaska to energy-hungry markets in the Atlantic and the lack of a demand for the product meant that energy speculators looked for easier ways to turn a profit. Here too, WWII radically altered the status quo. The war effort's insatiable demand for oil rapidly dried up wells in California to the extent that in July of 1944, Secretary of the Interior and Petroleum Advisor for the War

[5] US Geological Survey. "Petroleum Investigations in Alaska in 1944," January 1945. USNA, RG 57, Collection: A1 267, Box 1: Folder: Alaska, pg. 1.
[6] US Geological Survey. "Petroleum Possibilities in the Katalla Area, Alaska," May 12, 1945. USNA, RG 57, Collection: A1 267, Box 1: Folder: Alaska, pg. 1.

Harold Ickes bluntly declared "we are running out of oil."[7] Such pessimistic assertions of America's energy security were far from universal, but even the most optimistic projections were accompanied by a growing realization that existing reserves were finite. In light of these concerns it was unsurprising that the Navy began exploring Northern Alaska with renewed vigor in 1944 in hopes of finding a supply of oil that could meet demand for years to come.

Created by Executive Order in 1923, Naval Petroleum Reserve No. 4 (or as it came to be known "PET 4") consisted of a 150-mile-wide stretch of land bound by the Arctic Ocean to the North and the Brooks Range to the south. From its western boundary at Icy Cape the parcel extended all the way to the Colville River in the east. The Reserve contained over 35,000 square miles of the most rugged terrain on Earth and, with the exception of a few anecdotal reports of oil seepages along the northern coastline, it was unexplored by the Navy.[8] Small scale reconnaissance surveys were undertaken between 1923-1926 but even these provided only basic topographical and geological data.[9] As a result, when Lieutenant Foran launched his preliminary investigation on March 21, 1944, he and his party were quite literally entering uncharted territory. Despite this, the reconnaissance survey found indications of oil and, upon returning, Foran immediately recommended the Navy conduct a full-scale investigation into the region. Foran suggested there was an unusual abundance of seepages throughout the area and,

[7] Gareth Muchmore, "Forecasts of World's Oil Supply Differ Widely." Associated Press. July 29, 1944. USNA, RG 57, Collection A1 267, Box 10: Folder: Petroleum: General- 1944-'45

[8] John Reed, "Exploration of Naval Petroleum Reserve No. 4 and Adjacent Areas, Northern Alaska, 1944-53; Part 1, History of the Exploration." (USGS Numbered Series. Professional Paper, 1958.) http://pubs.er.usgs.gov/publication/pp301. Pg. 1,3.

[9] John Reed, "Letter from Dr. John Reed to Dr. Bill Bradley," June 25, 1947. USNA, RG 57, Collection A1 267, Box 1: Folder: Alaskan Naval Petroleum Reserve: July 1947- July 1948, pg. 2.

furthermore, he believed there were indications of productive oil-bearing strata at relatively shallow levels. In his mind, the potential of the area was simply too robust to ignore.[10]

Interestingly, it was at this moment that Alaskan oil forged its first connection with the Panama Canal. One of Foran's chief advocates in the Navy was Rear Admiral Ben Moreell, the chief of the Navy Bureau of Yards and Docks, who would go on to participate in the 1947 Isthmian Canal Studies commissioned under Public Law 280. Upon Foran's return, Moreell wrote a memo in which he argued that investigations into the potential of PET 4 should begin immediately. Moreell was so enthused about Foran's initial findings that he suggested not only full-scale reconnaissance but also the drilling of core holes and exploratory wells as well as dispatching survey and reconnaissance parties to scout potential pipeline sites. While Moreell wasn't thinking explicitly about Panama in 1944, he was careful to point out that it was important that the reconnaissance parties determine whether it would be economical to get oil out of the Reserve.[11] After several months of navigating political red tape, the project received formal approval and, on July 20, 1944, 196 Seabees and 235 stevedores set out from Tacoma, Washington en route to Barrow under the command of Lieutenant Command W.H. Rex.[12]

Work progressed slowly. The remainder of 1944 consisted primarily of attempts to construct a camp at Barrow and obtain all the materials and supplies necessary to conduct the studies. As a result, while some geological and topographical information was gathered during the year, the more intensive ventures, particularly the drilling of exploratory wells, needed to wait until 1945. As work began in 1945 the expedition was forced to reckon with new challenges. Political jockeying between members of the Navy and surveyors of the U.S.

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[10] Reed, "Exploration of Naval Petroleum Reserve No. 4," pg. 22.
[11] *Ibid*, pg. 23.
[12] *Ibid*, pg. 25.

Geological Survey sidelined much of the work. These two entities both wanted to assert their ownership over the project and, as a result, personal rivalries hindered the work. The passage of a $9,000,000 appropriation for the exploration rendered this question moot as the Navy and Geological Survey used the funding to hire Arctic Contractors, a consulting firm consisting of several companies formed specifically to help with the PET 4 surveys.[13] As 1945 came to an end, the shift towards a civilian-contractor model promised to ease the tensions between the Navy and Geological Survey and a year's worth of work in Arctic conditions had also familiarized engineers with the peculiarities of drilling in icy conditions.[14]

The shift from a military to a civilian-run project coincided with transitions in the oversight of the project as well. While Moreell was still nominally involved in the project, direct oversite was transferred to an operating committee headed by Commodore W.G. Greenman and consisting of members of the Navy, U.S. Geological Study, and Arctic Contractors. The committee provided the operational guidance for the project and directed Arctic Contractors' employees. On the ground, the project was now led by a civilian, Arthur Daily, who was appointed project manager. These changes were adopted without incident and soon the study found itself on track. Labor was divided between the Geological Survey which was overseeing aerial explorations and Arctic Contractors which took over the administration of the exploratory wells.[15] The result was a far clearer administrative hierarchy, alleviating the infighting that had derailed work over the initial year.

The next several years saw the expedition generate substantial volumes of data and yet massive oil fields still proved elusive. While the $9,000,000 granted to conduct the expedition

[13] Reed, "Letter from Dr. John Reed to Dr. Bill Bradley, June 25, 1947," pg. 2.
[14] Reed, "Exploration of Naval Petroleum Reserve No. 4," pg. 47.
[15] *Ibid*, pg. 48.

was extensive, it was not limitless and forced the project be prudent in drilling exploratory wells.[16] Unfortunately for the contractors, while some wells showed indications of oil, there was no definitive identification of substantial oil-producing strata as the years rolled by. Still, optimism surrounding the region remained unabated and the Geological Survey put out a flurry of reports in 1945, ’46, and ’47 all of which painted the future of Alaskan oil in a positive light.[17] The largest coup for the Geological Survey during the 1940s was the Navy Department’s decision to publish geological information and initial findings regarding PET 4 in 1947.[18] In addition to showcasing the work done by the Geological Survey and Arctic Contractors, the Navy’s decision also legitimized future explorations in Alaska, sparking commercial interest in the development of the region.

By the early 1950s surveys of PET 4 were dwindling. The initial appropriation was intended to run only through 1950, and while it was extended to 1953, the lack of major oil strikes made it difficult to justify further extension of the project. The most substantial find was at Umiat Field in the southeastern part of the Reserve. Eleven wells were drilled at Umiat and while estimates varied wildly, the consensus was that the field contained roughly 70 million recoverable barrels of oil. This was a considerable amount of oil, and yet it appeared to be a bit of an outlier as the next most enticing site, Simpson Field, was estimated to contain only 12 million barrels. Ironically, oil wasn't even the most common source of energy in PET 4. Natural gas deposits proved far more abundant in the region and by the time studies were ended,

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[16] Reed, “Letter from Dr. John Reed to Dr. Bill Bradley, June 25, 1947,” pg. 3.

[17] R.C. Wells, “Admiralty Island, Alaska: Oil,” February 18, 1944. USNA, RG 57, Collection: A1 267, Box 1: Folder: Alaska, pg. 1; US Geological Survey. “Petroleum Possibilities in the Katalla Area, Alaska,” pg. 1; US Geological Survey. “Geological and Oil Possibilities of the Southwestern Part of the Wide Bay Anticline, Alaska,” September 12, 1945. USNA, RG 57, Collection: A1 267, Box 1: Folder: Alaska, pg. 1.

[18] Don Carroll, “Memorandum from Don Carroll to W.H. Bradley,” May 21, 1947. USNA, RG 57, Collection A1 267, Box 1: Folder: Alaskan Naval Petroleum Reserve: July 1947- July 1948, pg. 1.

projections suggested that Barrow Field alone contained between 5 to 7 billion cubic feet of recoverable gas. This quantity was dwarfed by the 22 billion cubic feet of gas projected to be at Gubik Field.[19]

Despite the inconclusive findings in PET 4, the expedition was considered a success. Oil had been discovered and the geological qualities of the region indicated the potential of additional deposits that could be found with more extensive searches. Arctic Contractors employee E.W. Beltz summed up the feelings of many involved in the PET 4 surveys when he claimed "In the writer's opinion, similar structural conditions in any oil country would justify additional tests."[20] The survey was careful to point out that it had carried out only 44 core tests, drilled only 36 test wells, and been forced to cover tens of thousands of miles of rugged landscape with only a modest supply of manpower and machinery.[21] John Reed, a member of the U.S. Geological Survey who visited PET 4 in 1947, summarized this perspective, arguing, "If the present drilling program is unsuccessful, it can still be demonstrated that northern Alaska may well have petroleum possibilities and that the small number of tests were not sufficient to prove the possibilities."[22] In addition, there were questions about the oil-bearing potential of the remainder of Alaska's North Slope. PET 4 only extended as far east as the Colville River. In a letter sharing his experiences, Reed insightfully noted that "The oil possibilities are by no means confined to the Reserve and some of the best structures may well be outside the Reserve."[23] Reed didn't realize how shrewd his assessment was.

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[19] Reed, "Exploration of Naval Petroleum Reserve No. 4," pg. 170.
[20] E.W. Beltz, "Oil Possibilities of the Barrow Regional High," October 31, 1949. USNA, RG 57, Collection: A1 263: Miscellaneous Records of the Navy Oil Unit, Box 1: Folder: Arctic Contractors Contract NOy-13360, pg. 5.
[21] Reed, Exploration of Naval Petroleum Reserve No. 4," pg. 170.
[22] Reed, "Letter from Dr. John Reed to Dr. Bill Bradley," pg. 6.
[23] *Ibid*, pg. 6.

Had the boundaries of PET 4 extended just 50 miles east of the Colville River and encompassed Prudhoe Bay, the findings of the survey may have been radically different. Lying just below the surface of the Prudhoe Region was a massive oil reserve that would redefine American energy production. It took another fifteen years before the Prudhoe Bay reserve was discovered, and yet PET 4 had already paved the way for the development of Alaskan energy. The survey not only assessed the region's potential as an energy producer but also identified some of the challenges that would be involved in getting Alaska North Slope oil to market. While Panama wasn't explicitly mentioned in conjunction with Alaskan oil in the 1950s and 1960s, (largely because it was assumed most of the oil would be consumed and processed on the West Coast) there were rumblings of the important role the Isthmus would play in the expanding global energy market.

<u>Pipelines and Profits</u>

Petroleum products had already been established as a staple of Panama Canal traffic prior to WWII thanks in large part to the need to transport oil from California to Gulf Coast refineries. Despite predictions that petroleum's importance to the Canal would wane over time, the emergence of WWII served to redouble the centrality of oil on the Isthmus, both as an important commodity and a component of American national security. These concerns led Americans and Panamanians alike to explore the potential of expediting the transportation and distribution of petroleum products in Panama. And yet the concerns of the two nations seemed to be fundamentally at odds. The American government and Panama Canal Company saw oil as a means of regulating traffic through the Canal by expeditiously fueling ships and preventing delays in transit times and ensuring that American Naval vessels could promptly refuel as they traveled between oceans en route to conflicts around the world. To the Panamanian government, petroleum presented the promise of profits, a promise the Canal had never delivered on. In WWII and the decades following, both parties sought to bring their visions of the Isthmus's potential to reality through the creation of pipelines.

The first pipeline to cross the Isthmus was created solely as a means of improving American national security. As WWII raged on in 1944 and the Panama Canal was utilized to transport men, materials, and military vessels between the oceans, the navy became increasingly cognizant of the need to provide a constant supply of oil for these ships. The Canal Zone presented the perfect site for the creation of a pipeline that could be used to move fuel between the coasts. The Navy hired Williams Brothers Corporation of Tulsa, Oklahoma to oversee construction. The structure consisted of four main lines: two twenty-inch pipelines designed to carry fuel oil, a twelve-inch pipeline meant to carry gasoline and a ten-inch pipeline for the transportation of light diesel oil. Designed primarily to transport oil from Atlantic to Pacific, The two twenty-inch lines could transport a maximum of 5,800 barrels per hour each from north to south and a maximum of 3,400 barrels per hour each from south to north.[24] The relatively small volume of oil the pipeline could handle and the emphasis on transporting oil from Atlantic to Pacific suggests it was not meant to serve as a means to transport oil between ships en route to distant markets, but rather to transport oil to storage facilities on the Isthmus itself where it could then be used to fuel naval vessels at the Atlantic and Pacific docks.[25] This was an approach meant not to generate a profit, but rather to improve national security.

Through the early 1960s, the perception of pipelines in Panama tended to mirror the Navy's approach of perceiving oil and fueling as supplemental to the effective administration of

[24] Johnson, "Letter from F.R. Johnson to Governor David Stuart Parker, June 21, 1972," pg. 2.
[25] *Ibid*, pg. 2.

the Canal. The Panama Canal Company (PCC) managed its oil fields and reserves in this same manner. The PCC operated four tank farms by the 1960s split evenly between the Atlantic and Pacific terminals. These facilities contained 87 tanks which held roughly 3,320,000 barrels of oil collectively. 55 of the tanks were owned by commercial interests, suggesting they were operated for profit. And yet over the course of a calendar year, the facilities only handled roughly 18,300,000 barrels, a relatively modest sum, which suggested the continued preponderance of local consumption.[26] To the PCC these oil fields were a means of ensuring efficient flows of traffic through the Canal. Delays in fueling forced ships to be delayed entering the locks, which, in turn, delayed the next vessel hoping to enter the locks, generating a traffic jam that diminished the Canal's already dwindling capacity.[27] Neither the American government nor the PCC was concerned with the large scale commercial transportation of oil through pipelines in the 1960s and 1970s. In their mind, the Panama Canal remained an adequate solution to this problem. This was unsurprising as Americans had invested considerable resources into the Canal and, during these decades, particular the 1960s, still operated under the assumption that expanded canal facilities could increase the capacity of the Canal, allowing it to handle the global oil trade and the larger tankers that would accompany it.

Panama exercised far more foresight in its interest in transisthmian pipelines, identifying their potential economic benefits far earlier than Americans. Panamanians explored numerous opportunities to realize this potential throughout the 1960s and particularly during the 1970s.

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[26] Jack Donohew, “Report on the Impact of the Draft Treaty on Utilities and Community Service Support Functions,” July 23, 1965. USNA, RG 185, Collection P11: Negotiation and Planning Relating to 1977 Panama Canal Treaty, pg. 1.

[27] Joint Military/Civilian Port Ad Hoc Committee of the Joint Logistical Committee. “Study of US Government Requirements for Piers, Dicks, Shipyards, Marine Bunkering (Ship Fueling), Pumping, and Storage Facilities, and Evaluation of Specified Land Areas in the Canal Zone,” September 28, 1971. USNA, RG 185, Collection P11, Box 3: Folder: Study of US Government Requirements for Piers, Dicks, Shipyards, Marine Bunkering (Ship Fueling), Pumping, and Storage Facilities, and Evaluation of Specified Land Areas in the Canal Zone, pg. 11-12.

Indeed, Panama seemed to be interested in positioning itself as a major energy crossroads, developing refineries in its territory while it advocated for the creation of pipelines.[28] Panama's first forays into pipeline exploration were somewhat modest and never extended beyond preliminary surveys and discussions with contractors. Nonetheless, they displayed a far more concentrated interest in the potential of pipelines as a means not only of augmenting the operation of the Canal, but also generating a profit.

Panamanian and commercial interests first explored the creation of a pipeline in 1962 when Otra Costa Corporation pitched the creation of a twenty-inch and a thirty-inch pipeline across the Isthmus. Interestingly, the proposed route followed the Roosevelt-Boyd Highway and lay predominantly outside the Canal Zone, suggesting that Panama hoped to develop a pipeline that it could administer with minimal involvement from Americans or the PCC.[29] A year later, this plan formed the foundation of a proposal put forward by the Colon Free Zone. The Free Zone sought to hire Williams Brothers, the creators of the Navy pipeline, to construct a transisthmian pipeline that could carry crude and bunker oil across Panama. The projected pipeline would be capable of transporting 100,000 barrels daily and would be connected to storage facilities of 860,000 barrels on the Atlantic and 1,210,000 on the Pacific.[30] The Panama Canal Company was somewhat uncomfortable with the long-term implications of Panama's ambitious position on the pipeline. Governor Robert Fleming noted, "We see little probability of a successful venture in the pipeline field in the near future, but we cannot dismiss entirely the

[28] Ragan and Mason. "Letter from the Law Firm Ragan and Mason to the U.S. Navy, October 23, 1968," October 23, 1968. Record Group 185. USNA, RG 185, Collection A1 164: General Correspondence 1945-1979, Box 18, pg. 2.
[29] Johnson, F.R. "Letter from F.R. Johnson to Governor David Stuart Parker," June 21, 1972, pg. 3.
[30] Robert Flemming, "Memo to the Board of Directors of the Panama Canal Company Regarding the Creation of a TransIsthmian Pipeline System," October 11, 1963, USNA, RG 185, Collection A1 164, Box 18, Declassification NND 988086, pg. 1.

possibility of its eventual development."[31] While the PCC was confident that a pipeline couldn't immediately undermine the Canal's role in international oil transportation, it was increasingly concerned about the long term consequences of a pipeline if future levels of petroleum consumption continued to rise or if tanker size continued to increase.

These fears seemed to be realized as the 1960s came to a close. On July 18, 1968, Atlantic-Richfield Company (ARCO) Chief Executive Officer Robert Anderson announced that his company had found a historically massive oil field at Prudhoe Bay on Alaska's North Slope.[32] The dream of Foran, Moreell, and Reed had finally been realized and Alaska's potential as a source of energy seemed limitless. This discovery radically altered global energy networks, and the Panama Canal soon found itself drawn into the burgeoning energy bonanza.

Accessing Alaskan Oil

The discovery of ANS oil was met with near universal enthusiasm. Experts eagerly debated the size of the find with some estimates going so far as to suggest it would be the largest field ever discovered, even larger than the 62 billion barrel Greater Burgan Field in Kuwait.[33] More modest assessments established a safer (and extremely accurate), but still remarkable estimate of 25 billion barrels. As one industry insider put it "That, as I'm sure someone has remarked, is a lot of oil."[34] And yet the volume of the Prudhoe Bay Field would be for naught if it could not be accessed. Retired General L.J. Lincoln, a representative for energy speculator

[31] Fleming, "Memo to the Board of Directors of the Panama Canal Company Regarding the Creation of a TransIsthmian Pipeline System," pg. 2.
[32] L.J. Lincoln, "The Transport of Alaska Oil And Use of a Mexico Pipeline," June 1969. USNA, RG 185, Collection A1 164, Box 18, Declassification NDD 988086, pg. 1.
[33] Phillip Areeda, "Memo from Phillip Areeda, Executive Director of the Cabinet Taskforce on Oil Import Control," October 27, 1969. USNA, RG 185, Box 18: Folder: Special Report to Governor- Use of Transisthmian Oil Facilities by Private Interests, Declassification NND 988086, pg. 3.
[34] *Ibid*, pg. 4.

Eugene Callis who sought to create a pipeline across Central American, argued "However, as great as is the challenge and achievement of oil production at the wellhead in the Alaska Arctic, the key to its use now becomes economical, reliable transportation to refineries and users."[35] This was no small task.

In the months following the announcement, a slew of proposals sought to provide a solution to the issue of getting ANS oil to refineries in the Gulf Coast. Among the most ambitious was the $50 million-dollar overhaul of the 115,000-ton tanker *SS Manhattan* to turn it into an icebreaker. The *Manhattan* would carve out the fabled Northwest Passage, allowing a fleet of six 250,000 deadweight ton (dwt) tankers to travel directly from Prudhoe Bay to east coast refineries. This would shorten travel time and allow for the use of the largest tankers in the world.[36] In the United States, the debate swirled around the creation of a Trans-Alaska Pipeline System (TAPS) to connect Prudhoe Bay with the port of Valdez, 800 miles away.[37] The flurry of activity surrounding potential routes for ANS oil naturally came to encompass Panama as well.

It was unsurprising that Panama was considered as a route for ANS oil. The Canal had long served as a crossroads of energy. In 1968, well before ANS shipments began, petroleum products accounted for 18% of the commercial tonnage that made its way through the Canal and generated 17.9 million dollars in tolls, roughly 21% of the tolls generated during that year.[38]

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[35] Lincoln, "The Transport of Alaska Oil And Use of a Mexico Pipeline," pg. 1.

[36] *Ibid*, 5; for a more complete overview of the *Manhattan's* remarkable voyages see Ross Coen, *Breaking Ice for Arctic Oil: The Epic Voyage of the SS Manhattan through the Northwest Passage*, (Fairbanks: University of Alaska Press, 2012).

[37] The creation of TAPS has thus far been surprisingly removed from a great deal of historical debate. Aside from several books detailing the construction of the system in the 1970s the major academic work on TAPS is Peter Coates, *The Trans-Alaska Pipeline Controversy: Technology, Conservation, and the Frontier*. (Lehigh University Press, 1991).

[38] Hugh Norris, "Memo on the Economic Implications of a Commercially Operated TransIsthmian Pipeline," March 4, 1969, USNA, RG 185, Collection: A1 164, Box 18, Declassification NDD 988086, pg. 1.

Given the substantial role petroleum products were already playing in the Canal it seemed natural that the potential of shipping ANS oil would be lauded by the PCC, yet this was not the case. The chief concern among PCC officials was the continued inability of the Canal to transit large tankers. A report assessing the economic impacts of ANS oil on the Canal noted "The oil cannot be competitive in that (global) market if the movement is restricted to tanker sizes that are capable of using the Canal."[39] The most economical way of shipping the large quantities of oil would be in tankers of over 200,000 dwt. The largest ships capable of transiting the Canal were only 90,000 dwt, or the equivalent of roughly 450,000 barrels. Even these smaller tankers were subject to clear-cut daylight only transits (CCDO) which meant that they had to go through the Gaillard Cut individually during daylight, restrictions which further strained the Canal's capacity.[40] For these reasons, the PCC didn't actively pursue transportation of ANS oil beyond assurances that the Canal could handle some of the trade if it were transported in smaller vessels.

Panama suffered from no such failures of imagination. A scant three months after ARCO announced the discovery of the Prudhoe Bay Field, the law firm Ragan and Mason submitted an unsolicited offer to the Navy, asking that their clients, Williams Brothers and National Bulk Carriers, be granted a fifteen-year lease to use the Navy pipeline to transport oil across the Isthmus. While the Panamanian government didn't formally make the offer, it had worked closely with both parties in the previous decade. In addition to constructing the Navy pipeline in 1944, Williams Brothers had also been tapped to build the proposed pipeline in 1963, and National Bulk Carriers had signed a contract with the government of Panama to operate the

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[39] Hugh Norris, "Memo on the Economic Implications of a Commercially Operated Transisthmian Pipeline," pg. 3.
[40] John McDonald, "Letter to Congress from Sohio (BP) Oil Company President John G. McDonald on March 18, 1988," USNA, RG 185, Collection: UD UP 114: Treaty Implementation Records Relating to the Panama Canal, Box 1: Folder: Panama Controversy- ANS oil, pg. 1-2.

nation's lone refinery.[41] That Panama would benefit from the transportation of ANS oil under this contract was a foregone conclusion. The Navy and PCC, however, were reluctant to lease the pipeline. Governor Walter Leber expressed concern that using the pipeline to transport ANS oil between foreign ports might directly curtail traffic through the Canal.[42] The Navy's chief concern wasn't economics, but rather security. The Navy mandated that they be able to repossess and use the pipeline at any time should there be a conflict, suggesting that such an arrangement was essential to national security.[43] Negotiations failed to overcome these obstacles and gradually the Navy pipelines ceased to be considered as an option for the transportation of ANS.

Panama's interest in moving ANS oil would not be extinguished easily, however. As the negotiations between the lawyers and the Navy stretched on, the government of Panama looked elsewhere to find parties interested in the creation of a transisthmian pipeline. They soon found their partners not in the United States, but rather in Europe. The English company International Management and Engineering (IMEC) would oversee the design of the pipeline while the West German firm Thyssen would be placed in charge of construction. The $76,000,000 project would create a 30-inch pipeline capable of moving 700,000 barrels of oil a day.[44] The venture progressed rapidly and Panama explicitly tied to it ANS crude transportation arguing that they

[41] Ragan and Mason. "Letter from the Law Firm Ragan and Mason to the U.S. Navy, October 23, 1968," October 23, 1968, pg. 1-2.
[42] Walter Leber, "Letter from Governor Walter Leber to Deputy Undersecretary of the Army James Siena, March 14, 1969," March 14, 1969. USNA, RG 185, Collection A1 164, Box 18: Folder: Special Report to Governor- Use of Transisthmian Oil Facilities by Private Interests, Declassification NND 988086, pg. 4.
[43] James Siena, "Letter from Deputy Under Secretary of the Army James Siena to Governor Walter Leber, November 10, 1969," November 10, 1969, USNA, RG 185, Collection: A1 164, Box 18: Folder: Special Report to Governor- Use of Transisthmian Oil Facilities by Private Interests, Declassification NND 988086, pg. 1.
[44] American Embassy. "American Embassy Airgram No. 371 to the Department of State Regarding the Proposed PanIsthmian Pipeline," December 10, 1969. USNA, RG 185, Collection: A1 164, Box 18: Folder: Special Report to Governor- Use of TransIsthmian Oil Facilities, pg. 1.

would be able to meet the need for transportation as early as 1972.[45] With this objective in mind, Panama appointed Dr. Eduardo Tejeira to oversee exploratory surveys and by August of 1970, the surveys were underway. Despite its enthusiasm, Panama realized that the success of the pipeline relied upon the creation of TAPS to turn a profit. One shrewd Panamanian government official noted that "the crucial decisions regarding the Panama pipeline will be made not by the PJG (*Pueblo Junto Gobierno or* United People's Government of Panama), but rather by the U.S. government…"[46] Unfortunately for Panama, their faith in America's appetite for oil may have been misplaced. By the early 1970s TAPS was caught in a political quagmire as government officials, oil companies, and environmentalists battled over the future of the project. The European companies' interest in the project waned as TAPS negotiations dragged on and by November of 1970 they had pulled out altogether.[47] Other companies expressed interest in the pipeline, but without assurances that ANS oil could even get out of Alaska, there was simply not enough enthusiasm to turn a Panamanian pipeline into a reality.

A few projects sputtered into and out of existence over the first few years of the 1970s. In 1972 the Litton Group proposed a slurry pipeline that would transport both coal and oil across the Isthmus, theoretically diminishing the potential financial risk presented by the debates over ANS oil. The pipeline would move coal from the Atlantic to the Pacific where it would be loaded onto massive 200,000 dwt freighters and shipped to Japan. These vessels would stop in Alaska to load up on ANS oil before making their way to Panama where the oil would be pumped from

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[45] American Embassy. "Memo from the American Embassy in Panama to the Department of State Regarding the Propose Transisthmian Pipeline," January 29, 1970. USNA, RG 185, Collection: P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 2.
[46] American Embassy. "Memo from American Embassy in Panama to the Department of State," August 5, 1970, USNA, RG 185, Collection P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 1.
[47] Panama Review Committee. "Oil Pipeline in Panama," November 18, 1970. USNA, RG 185, Collection P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 1.

Pacific to Atlantic en route to Gulf Coast refineries.[48] Panama too continued to remain interested in the construction of a pipeline, working with several American companies to explore the financial and engineering viability of a pipeline.[49] And yet Panama was patient in its approach, recognizing that until the TAPS project received approval there was no need to begin serious preparations.[50] As the TAPS debate stretched over months and years, the economic potential of ANS oil grew increasingly suspect. This obstacle pointed to the complexity of the global energy network into which the Panama Canal had thrust itself. Domestic policy debates in the United States prevented Panama from being able to capitalize on its position as the crossroads of the world and emerge as a major player in the global energy trade.

The slow progress of TAPS was not the only concern. The increasingly strained diplomatic relationship between Panama and the United States also complicated the creation of pipelines. Unless the two nations could find a way to deal with the tensions stemming from administration of the Canal, it would be impossible to fully explore the economic potential offered by ANS oil. As the 1970s progressed, the push for a new treaty between the two nations obtained an unprecedented level of support and brought with it the promise that Panama could finally capitalize on the economic opportunities presented by its location.

A New Era Emerges

The Martyrs' Day Riots of January 9th, 1964 were a clear indication that the existing relationship between Panama and the United States was unsustainable. Decades of animosity had

[48] American Embassy. "Memo from American Embassy to Secretary of State," May 30, 1972. USNA, RG 185, Collection: P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 1.
[49] American Embassy. "Memo from American Embassy in Panama to Secretary of State Regarding a Transisthmian Pipeline," June 1972. USNA, RG 185, Collection P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 2.
[50] American Embassy. "Memo from American Embassy to Secretary of State Regarding Oil Pipeline Survey," June 1972. USNA, RG 185, Collection P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 1.

boiled over in Panama and the seemingly unlimited autonomy of the United States in the Canal Zone was no longer an acceptable reality to Panamanians. These clashes embodied a new diplomatic source of entropy that had to be dealt with in order for oil transportation to flourish. To this end, starting in 1964 and extending through the Johnson, Nixon, Ford, and Carter administrations, the United States and Panama conducted intermittent treaty discussions in hopes of alleviating these problems.[51] Americans were chiefly preoccupied with obtaining continued access to the Panama Canal in a manner that alleviated the foreign policy issues stemming from the 1903 treaty. Panamanians, on the other hand, were irate over a provision of the 1903 treaty which allowed the United States to "act as if sovereign" in the Canal Zone.[52] Underpinning these major grievances were smaller concerns that impacted the future of Panama as a center of the global energy trade. Americans were reluctant to invest in infrastructural networks in Panama if there was the potential that domestic upheaval could damage those assets. Panamanians argued that they were not allowed to develop economically under the provisions of the existing treaties. Solving these issues would both mitigate the international tensions between the two countries and provide an impetus for economic growth in the region through the distribution of ANS oil.

Throughout the 1960s, discussions between the two countries were far from amicable. In the immediate aftermath of the Martyrs' Day Riots, Johnson set out to ease tensions and the President's promise to renegotiate the treaties improved relations marginally, but the U.S. was reluctant to make substantial concessions in their authority in the Canal Zone. Indeed, the U.S.

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[51] The Torrijos-Carter Treaties, signed in September of 1977, have been a topic of considerable study amongst diplomatic historians and for that reason doing a complete overview of the Treaty process would be redundant. For the most authoritative accounts of this process see Walter LaFeber, *The Panama Canal: The Crisis in Historical Perspective. Updated edition*. (New York; Oxford: Oxford University Press, 1990), or Michael Conniff, *Panama and the United States: The End of the Alliance*. Third edition. (Athens: University of Georgia Press, 2012).
[52] Department of State. "Background of US Decision to Resume Panama Canal Treaty Negotiations," August 20, 1971, USNA, RG 185, Collection P11, Box 2: Folder: National Security Council & National Security Decision Memos: June 1970-August 1975, Declassification NND 008039, pg. 3.

seemed entirely unwilling to negotiate a fixed length treaty at this point in time, preferring to maintain control of the Canal indefinitely. Negotiations dragged on until 1967 when a treaty was put forward, however, the document's lack of engagement with Panamanian concerns made it highly unpopular and ultimately the Panamanian government took no steps to ratify it, an approach mirrored by their American counterparts.[53] While the treaty negotiations contained the discontent spreading through Panama and provided a degree of stability, they failed to address the core disputes between the two countries.

As the 1970s opened, the United States and Panama again sought to redefine their relationship. Under the leadership of Richard Nixon, the United States took a more moderate approach to their discussions. Nixon still desired a treaty that cemented indefinite US control over the canal but approved the negotiation of a treaty with a fixed date for Canal transition so long as it extended US control for at least thirty years and was accompanied by assurances that Panama would maintain canal neutrality. This was a major shift in American policy and suggested that treaty discussions may actually create a document acceptable to Panama. Additionally, Nixon committed to providing more economic opportunities to Panama.[54] Of particular interest to Panama was taking over the harbors at Cristobal and Balboa. Among their chief interests was greater investment in commercial fueling. D.A. Dertien, the chief of Canal Zone Executive Planning Staff, noted that in his conversations with Panamanian government officials he had learned "The Government of Panama views marine bunkering as a profitable commercial operation and has expressed a desire that the Canal Administration cease

[53] Department of State. "Background of US Decision to Resume Panama Canal Treaty Negotiations," August 20, 1971, pg. 1.

[54] Nixon, Richard. "National Security Decision Memorandum 131," September 13, 1971. USNA, RG 185, Collection P11, Box 2: Folder: National Security Council & National Security Decision Memos: June 1970-August 1975, Declassification NND 008039, pg. 1.

commercial bunkering operations under a new treaty."[55] This idea, in conjunction with Panama's plans for a transisthmian pipeline, suggested that Panama was acutely aware of the financial benefits that could come with greater involvement in the oil trade. A new treaty was crucial to recognizing this potential. While there was still considerable progress to be made, the Nixon administration's concessions created a foundation that later talks could expand on.

Despite Nixon's insistence that the talks should be complete by 1972, in time for the general election, the difficulty in ironing out contentious issues between the two countries including control over specific Canal facilities and the timeline for Canal transition made the timeline impossible to meet. As a result, the treaty put forward by the United States in December of 1971 was ignored and in 1972 Panama adopted a nationalistic stance in which they attempted to apply international pressure to the United States. This tactic came to a head with the introduction of a motion before the UN Security Council in which Panama condemned the United States and its "colonialist" actions in the Canal Zone.[56] By 1973, the hardline Panamanian approach seemed to be working and the United States felt compelled to adopt a new approach to negotiations. The appointment of Ambassador Ellsworth Bunker to lead negotiations and a series of meetings between Secretary of State Henry Kissinger and Panamanian Foreign Minister Juan Antonio Tack reflected the growing desire to find common ground. The announcement on February 7, 1974, of the Joint Statement of Principles between Kissinger and Tack outlined in

[55] D.A. Dertien, "Memo from the Chief of the Executive Planning Staff to the Governor of the Panama Canal Zone: Discussion of Marine Bunkering Operation, and Maintenance Dredging Costs for Atlantic Docks and Piers," December 20, 1971. USNA, RG 185, Collection: A1 168 PCC Records Related to Negotiation and Planning for the 1977 Panama Canal Treaty, Box 23: Folder: United States-Panama Treaty Discussions: Piers & Docks & Port Authority, Declassification NND 966086, pg. 1.
[56] NSC Undersecretaries Committee. "NSC Undersecretaries Committee Memo to the President Regarding Panama Canal Treaty Negotiations," September 17, 1973. USNA, RG 185, Collection P11, Box 4: Folder: Treaty Implementation: Cut Widening Study, Canal Alternative Study, RUSH Study, Treaty Negotiations, Declassification NND 008052, pg. 5.

broad strokes the framework of an acceptable treaty and detailed the path negotiations would take. These eight principles included such longstanding issues as Panamanian sovereignty in the Canal Zone, enhanced economic benefits for Panama, increased Panamanian administration of the Canal, a fixed expiration date for U.S. control of the waterway, and promises of Canal neutrality under Panamanian administration. A new era in Canal relations was at hand.[57]

At the core of the agreement was a shifting position on the part of the U.S. government. Unlike negotiations under the Johnson government, and even the first years of the Nixon government, the Joint Statement of Principles suggested that the U.S. was willing to make concessions to mitigate Panamanian hostility to ensure long term access to the Canal. In some ways, this approach served as a diplomatic parallel to the construction efforts that shaped the early 1900s. While Goethals and his foremen had used concrete to hold the physical entropy of Panama at bay, Kissinger and his fellow negotiators used compromise and concessions to keep the diplomatic entropy of Panama at bay. In both cases the ultimate objective was the same: access to and use of an interoceanic waterway in Panama.

Despite the support for a new relationship with Panama at the executive level and in the State Department, the Nixon and later Ford and Carter administrations had no misgivings about the challenge of getting domestic support for a treaty. As early as 1973 the National Security Council acknowledged that "We are pessimistic about the possibilities of developing significant support for any policy involving important concessions to Panama."[58] Consequently, while

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[57] Henry Kissinger, "Statement of Secretary of State Henry Kissinger at Panama, February 7, 1974, on the Occasion of the Signing of the Joint Statement of Principles for Negotiations on a New Panama Canal Treaty." Department of State Office of Media Relations, February 7, 1974. USNA, RG 185, Collection A1 168, Box 1: Kissinger, Bunker, GOP Negotiations- Statements, Declassification NND 988086, pg. 1.
[58] NSC Undersecretaries Committee. "NSC Undersecretaries Committee Memo to the President Regarding Panama Canal Treaty Negotiations," September 17, 1973, pg. 10.

negotiations progressed between 1974 and 1977, American politicians and diplomats launched a massive public relations campaign to prepare Americans for the concessions contained in the new Treaty. One of the most effective tactics implemented by Treaty lobbyists was emphasizing the economic shortcomings of the 1903 treaties. Bunker, in an overview of the Panama crisis, was careful to note that one of Panama's chief grievances with the existing treaty was the paltry annuity of $2.3 million dollars the country received from the Canal. Indeed, some Panamanians went so far as to suggest that they were effectively subsidizing the cost of the Canal. Bunker suggested that a new treaty could not only make this annuity more competitive for Panama, incentivizing the efficient operation of the Canal, but also encourage the economic development of the Canal Zone in general. "Already Panama has plans which call for the construction of an oil pipeline which would reduce the cost of transporting petroleum across the Isthmus," Bunker noted, suggesting that this development would modernize the Canal, allowing free market principles to increase competition and lower shipping and fueling costs.[59]

It wasn't only attempts to build a new pipeline that came up during discussions. Panama once again expressed its desire to utilize the Navy Pipelines that ran through the Canal Zone, going so far as to discuss the potential for such a deal in the treaty negotiations. Americans were starting to warm to the proposal, but by 1975 the Navy pipeline was falling into disrepair and only two of the pipes were still in use.[60] In addition, while the US was becoming more flexible in its positions, lingering concerns over a pipeline's capacity to bypass the Canal made American negotiators cautious. It was one thing for Panamanians to create a new pipeline outside of the

[59] Ellsworth Bunker. "Panama and the United States," May 22, 1975. USNA, RG 185, Collection A1 168, Box 1: Folder: Kissinger, Bunker, GOP Negotiations- Statements, Declassification NND 988086, pg. 16-17.
[60] Hunt. "Memo from Acting Governor Hunt to Mr. Vesey Regarding Panamanian Interest in the Transisthmian Pipeline," November 18, 1975, USNA, RG 185, Collection P11, Box 2: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 1.

Canal Zone. It was another thing entirely for them to bypass Canal traffic by utilizing a structure that had been created to facilitate Canal transit.[61] In addition, there were some rumblings that the United States should maintain the pipelines and use them to transport ANS oil across the Isthmus themselves. Because Panama would have no access to the trade and would receive no benefit from it, the American government decided that this course of action might antagonize Panama and complicate treaty negotiations.[62] While the pipelines weren't central to the Treaty discussions, the fact that both Panama and the United States were actively discussing pipelines indicated just how aware both parties were of the future economic potential of ANS oil shipments.

In addition to discussing the direct economic benefits of a new treaty, advocates also often emphasized the value of American access to the Canal rather than American control of the Canal. While the Canal still certainly contributed to America's economy, its significance had declined by the time treaty discussions reached a fever pitch. Ambassador Sol Linowitz, who was actively involved in negotiations, was careful to note in a speech before the American Legion, "Today approximately 8 percent of all US exports and imports by value pass through the canal each year. About 7 percent of US seaborne trade traverses the Isthmus. To a substantial extent, therefore, the canal, though still important, is obsolescent."[63] This was not to say that the Canal was unimportant, but instead that it no longer was as instrumental to American economic and security concerns as it had been over the previous decades. This realization led many in the

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[61] Hunt. "Memo from Acting Governor Hunt to Mr. Vesey Regarding Panamanian Interest in the Transisthmian Pipeline," pg. 2.
[62] Panama Review Committee. "Transisthmian Pipelines," June 2, 1976. USNA, RG 185, Collection P11, Box 3: Folder: Transisthmian Pipelines, Declassification NND 008039, pg. 1.
[63] Sol Linowitz, Address in Favor of Treaties Before the American Legion Convention, Denver, Colorado, August 19, 1977, located in, "The Meaning of the Panama Canal Treaties." US Department of State, September 1977, USNA, RG 185, Collection UD UP 30: Treaty Implementation Records, Box 4: Folder: State Department Texts of Treaties Relating to the Panama Canal No. 6, 6A, 6B, 6C, pg. 13.

State Department to adopt the perspective that maintaining access to the Canal was far more valuable to American interests than maintaining control over the Canal and indeed pushing for ownership of the Canal in the face of Panamanian resistance could undermine American use of the Canal altogether.

The growing concern among many diplomats was that the discontent many Panamanians felt about the existing treaty would lead them to take substantial steps to eradicate relicts of American authority in the Canal Zone, perhaps going so far as to attack or sabotage Canal facilities. This was an ultimate manifestation of diplomatic entropy. Disaffected Panamanians could easily cripple the fragile locks or summit lake of the Canal with a single act of sabotage. Faced with this dilemma, Secretary of Defense Harold Brown bluntly stated, "Use of the Canal is more important than ownership."[64] In essence these concessions were an attempt to impose a diplomatic order that would allow American shipping to continue to use the waterway, albeit not with the same degree of authority it once had. This realization, in conjunction with a growing willingness to acknowledge the damage the Canal issue was doing to America's international image abroad, led American diplomats to finally accept a treaty with a fixed date for canal administration to transfer to Panama. With this concession in place, negotiations could finally reach their conclusion.

On September 7, 1977, pen met paper and the Torrijos-Carter Treaties were signed. The treaties ceded control of the Canal to Panama through a gradual process that would come to fruition on December 31st, 1999, when Panama took over the administration of the Canal. In addition, they guaranteed that the Canal would remain neutral, a provision that ensured

[64] Harold Brown, "Address of Secretary of Defense Harold Brown before the Senate Foreign Relations Committee, September 27, 1977", located in, "The Meaning of the Panama Canal Treaties," pg. 20.

America's continued access to the waterway. While there was some discontent on the part of both countries, and indeed the treaties would not enter into force for another two years, the fact that Panama and the United States had renegotiated their relationship suggested that the Canal had a viable future, and, more importantly, could be used to explore long term solutions to the energy trade questions that had been percolating over the last decade. The fact that TAPS also came online in 1977 provided even more incentive for the two countries to explore the potential the Isthmus had for transporting ANS oil. As the 1980s emerged so too did a new and promising era for Panama and the United States, one in which billions of barrels of oil would flow through the Canal, and later a Panamanian pipeline, bringing wealth to both Panamanian and American companies. The only lingering question was how long this arrangement could last.

The ANS Era Arrives

The successful negotiation of a new set of Canal treaties coincided with a new age of economic development in Panama. The erasure of the formal "Canal Zone" allowed Panama to pursue economic ventures in the Transit Zone, and the shift in the administration of the Canal also incentivized further exploration of energy transportation. Americans simultaneously recognized how beneficial it was to expedite transportation between Alaska and the Gulf Coast. As time went on and the sheer scope of the Prudhoe Bay Field became clear, it was increasingly apparent that this oil could not be consumed exclusively on the West Coast. As a result, even before the treaty entered into force, both Panama and the United States explored potential options for the most rapid means of transporting the material between the oceans. Initially, the Canal itself proved a viable means of transporting ANS oil and hundreds of thousands of barrels passed through the Canal daily. To help deal with the resulting increases in traffic, Panama began creation of their own pipeline across the Isthmus in the early 1980s. A project that had been envisioned for decades finally came to fruition. The utility of the Panama route once again asserted itself to remarkable benefit, but the increasing concentration of oil in the Isthmus was not without challenges, some of which called into question the long-term viability of the route.

In the immediate aftermath of the treaties, both Panama and the United States agreed that ANS oil needed to move through Panama, and yet the new treaties complicated conversations that had been going on for a decade. Panama, long an advocate for the creation of a pipeline, preached patience in the late 1970s. The improved financial benefits they received from the Canal's operation led Panama to advocate, at least initially, that oil shipments should actually be routed through the Canal to maximize tolls.[65] Americans on the other hand, recognizing the terminal nature of their administration of the Canal, were interested in exploring alternative arrangements to the Canal to expedite traffic. Harold Parfitt, the last governor of the Canal Zone, emphasized that even though an average of 450,000 barrels of ANS oil moved through the Canal daily in 1978, he predicted this figure would decline. He suggested that thanks to proposed alternatives to the Canal "There are still many variables in the West Coast supply/demand equation and pipeline alternatives to the Canal are not a closed issue. Further, there is still much talk about the advantages and possibility of swap arrangements with Japan. All of this leaves us pretty much up in the air as to the levels of our planning."[66] Parfitt was so sure of the emergence of alternatives to the Canal that he completely removed ANS shipments from predictions of future canal traffic.

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[65] Panama Review Committee. "Oil Transport Hearings," August 16, 1978. USNA, RG 185, Collection P11, Box 3: Folder: Transisthmian Pipeline, Declassification NND 008039, pg. 1.

[66] Harold Parfitt, "Presentation of Governor H.R. Parfitt to the Panama Canal Subcommittee of the House Merchant Marine and Fisheries Committee," September 1978, USNA, RG 185, Collection UD UP 30, Box 8: Folder: Company/Government Speeches/Briefings September 1977-September 1978, pg. 7.

Despite the assumptions of Parfitt and others that the ANS oil boom through the Canal would be short-lived, the trade exploded in the early 1980s, generating tremendous revenue for the Canal and Panama. The trade began modestly enough upon the opening of TAPS. Oil made its way from Valdez on board large 120,000-260,000 dwt vessels. As it approached the mouth of the Canal it was transferred to smaller vessels that carried the oil through the Canal and on to Gulf Coast refineries. This wasn't necessarily problematic during the first few years of the ANS trade as daily movements of oil averaged roughly 450,000 barrels, a volume which could be accommodated by one to two transits of the Canal depending on the size of the tanker. And yet the Canal route was not without limitations. Very Large Crude Carriers (VLCC), massive 200,000-320,000 dwt vessels, first started to emerge in earnest in the 1960s. Thanks to the economy provided by this style of bulk transportation, many oil companies began adopting these large tankers.[67] The Canal simply could not handle these larger, cheaper ships, a reality exacerbated by the fact that the Jones Act forced oil companies to use American vessels, which were more expensive to build and crew then foreign vessels.

Despite these concerns, the expansion of production in Alaska and a growing global demand for oil helped expand ANS shipments in the early 1980s. By November of 1980, there were over 500,000 barrels of oil transiting the Canal daily. Less than a year later, in May of 1981, traffic hit its highest levels in over seven years. Canal Administrator Dennis McAuliffe, who oversaw the first ten years of the Canal transition process, was quick to note that "The most significant aspect of Canal traffic during May was the record Alaska North Slope crude oil

[67] Strauss Center at the University of Texas, "Types of Tankers", https://www.strausscenter.org/hormuz/types-of-tankers.html, retrieved on 1/27/19.

movement and its effect on total traffic and tolls revenue."[68] Daily traffic exploded to well over 600,000 barrels per day and generated $4.6 million dollars in tolls for the month. This trade continued to explode as the early '80s progressed. In March of 1982, the trade hit another milestone as, for the first time, ANS shipments averaged over 800,000 barrels per day. The $5.7 million in tolls generated by this remarkable figure helped drive up the Canal's earnings and McAuliffe once again excitedly reported "Canal traffic for the month of March was substantially above budget targets, primarily as a result of a record Alaska North Slope (ANS) oil movement."[69] Thanks to the sheer volume of ANS oil transiting the Canal, the waterway was thriving, laying to rest concerns that the Canal administration's transitionary period would be marked by inefficiency.

The benefits reaped from the ANS oil trade did not come without challenges, however. ANS shipments were straining the limits of the Canal's capacity. March 1982 not only saw a record in ANS movement through the Canal but also an average traffic of 42 transits per day, a figure not seen in over a decade. This in and of itself was not problematic. The challenge lay in the increasing size of the vessels making the trip through the locks. In that same month, 51.7% of transits were made by ships with beams of 80' or wider.[70] This limited the number of double lockages that could be undertaken and, more concerningly, led to a greater number of clear cut daylight only (CCDO) transits. CCDO's placed a considerable burden on canal traffic as they substantially impacted the speed at which other vessels could transit the Canal. While the Canal

[68] Dennis McAuliffe, "Report of Significant Commission Activities for the Month of May 1981," USNA, RG 185, Collection UD UP 30, Box 17: Folder: Correspondence to the Asst Secretary of the Army (CW) January 1980-August 1982, Declassification NW 51932, pg. 1.
[69] Dennis McAuliffe. "Report of Significant Commission Activities for the Month of March 1982," USNA, RG 185, Collection UD UP 30, Box 17: Folder: Correspondence to the Asst Secretary of the Army (CW) January 1980- August 1982, Declassification NW 51932, pg. 1.
[70] *Ibid*, pg. 1.

could manage to accommodate roughly 40 vessels with minimal delays, Canal administrators believed that they could only handle roughly sixteen to seventeen large vessels without substantially impacting traffic.[71] The steady increases in ANS traffic between the signing of the treaty and March of 1982 suggested that this capacity might be reached sooner than the Canal could hope to manage.

In addition to straining the traffic capacity of the Canal, increasing ANS shipments also were accompanied by greater risk for oil spills. In a waterway as complicated as Panama any spill could have disastrous consequences and risked violating a treaty provision which charged Panama and the United States with minimizing the environmental impacts of Canal operations. Indeed, as the Panama Canal Commission (PCC, the organization that administered the Canal after the 1977 treaty went into force) was jointly administered by Panamanians and Americans, it was still operating under the purview of the Environmental Protection Act. These fears came to a head on June 7, 1980, when the 39,366 dwt *Texaco Connecticut,* laden with ANS oil and traveling north through the Canal, collided with the eastern bank of the Gaillard Cut, ripping holes in its number 1 and 2 cargo tanks. Roughly 4,000 barrels of oil were spilled over 35 miles as the ship made its way to Limon Bay where it could be anchored and repaired.[72] While modest, the spill served as a sobering reminder of the hazards that accompanied the increase in tanker traffic thanks to ANS shipments. As more large vessels used the Canal there was an increasing risk that they too could spill their cargo, particularly when navigating the dangerous Gaillard Cut.

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[71] Michael Rhode, "Memo from Michael Rhode to the U.S. Congress, March 23, 1988," USNA, RG 185, Collection UD UP 114, Box 1: Folder: Panama Controversy- ANS oil, pg. 1.

[72] Cesar Von Chong, John C. Jordan, and Ricardo Gutierrez (1983) THE TEXACO CONNECTICUT'S OIL SPILL INCIDENT IN THE PANAMA CANAL. International Oil Spill Conference Proceedings: February 1983, Vol. 1983, No. 1, pp. 367-370, pg. 367.

The combination of traffic limitations and concerns for oil spills led Panamanians to reconsider a pipeline as a means of moving ANS crude. A pipeline administered by Panama could still provide an immense financial benefit to the small country, allowing it to continue to serve its role as an energy crossroads, while also mitigating traffic and environmental concerns in the Canal. The negotiations into the construction of the pipeline progressed rapidly. Starting in 1981, Petroterminal de Panama (PTP) and the Panamanian Government began negotiations for the construction of a $250 million pipeline project that would pump oil from Puerto Armuelles in the Pacific to Chiriqui Grande in the Caribbean. This project precluded the need to transfer oil from large 200,000 dwt in the Pacific to smaller vessels that could transit the Canal and would save an estimated $1 per barrel in shipping costs. In July of 1981 the two parties came to an agreement, and a month later, before an environmental impact study could be carried out, construction began. Despite the controversy surrounding the environmental impacts of the pipeline, construction progressed rapidly and fifteen months later, in October of 1982, the pipeline was completed at a cost of $365 million dollars.[73]

The pipeline immediately proved its utility, fulfilling its promise of lessening canal traffic and providing a more cost-effective route for the movement of oil. With 40% of the pipeline owned by the government of Panama and the remaining 60% split between two American companies, the pipeline, like the Canal, suggested that both countries were acutely aware of the economic advantages offered by such infrastructure. The pipeline could transport 700,000 barrels daily, and the continued presence of the Canal provided a safety valve should volume surpass its capacity. Companies began utilizing the pipeline immediately and it soon became an essential

[73] Daniel Suman, "Socioenvironmental Impacts of Panama's Trans-Isthmian Oil Pipeline." Environmental Impact Assessment Review 7, no. 3 (09/1987): 227-246, pg. 228-230.

component in Panama's emerging energy economy. By 1985 the pipeline had become so instrumental to the global energy trade that it generated 7.8% of Panama's GDP.[74]

By the middle of the 1980s, the sky seemed the limit for Panama's booming energy trade. The Canal Treaties appeared wildly successful as the waterway, thanks in large part to the stability created by ANS oil shipments, was thriving. Traffic in the Canal was lucrative, below capacity, and suggested that the transition from American to Panamanian control was progressing smoothly. The waterway's success, in conjunction with the creation of the PTP, streamlined transportation of ANS oil across the Isthmus, allowing both oil companies and the Panamanian government to reap the rewards. There was optimism that the wealth offered by the energy boom would be there to stay, and yet, as had often been the case in Panama's energy history, domestic issues and conflict with the United States once again upset the status quo, this time with devastating consequences to Panama's role in the burgeoning ANS oil trade.

Evaporating Energy

In August of 1981, a small plane flying over central Panama suddenly crashed, smashing into the dense forest below and killing all aboard. In normal circumstances this would have been tragic. Considering that one of the passengers in the plane was the de facto leader of Panama, Omar Torrijos, the accident was a national catastrophe. After a dozen years of relatively stable leadership, Panama found itself again amid a domestic crisis.[75] The ensuing power vacuum created tremendous domestic conflict in Panama as military and governmental authorities sought

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[74] American Embassy. "Economic Trends Report for Panama," July 1990, USNA, RG 185, Collection UD UP 114, Box 1: Folder: Panama Controversy Economic Recovery, pg. 3.
[75] Michael Conniff*, Panama, and the United States: The Forced Alliance*, (University of Georgia Press, 2001), pg. 101.

to assert themselves as the center of power in the small nation. For four years these machinations unwound behind closed doors, safely out of sight of much of the world.

The rise of General Manuel Noriega, who later was accused of orchestrating Torrijos' death, thrust the political infighting into the open. Noriega aligned himself with both Torrijos and the U.S. government in the 1960s and reaped the benefits of his partnerships, rising through the ranks of the Panamanian National Guard. By August of 1983, he had become commander of the Panamanian National Guard and arguably the most powerful figure in Panamanian politics.[76] Leveraging his military power, Noriega intimidated and brutally murdered his rivals, establishing himself as the strongman behind the Panamanian government. While the US was content to grant Noriega a long leash in the 1970s, the dictator's increasingly blatant use of violence and growing relationship with Cuba led Americans to become hostile to his regime by 1987.[77] Noriega was entropy embodied, a rogue element whose eccentric behavior and compulsive violence destabilized American and Panamanian relations. The stability imposed by the Carter-Torrijos Treaties eroded under the new regime and the next two years were overshadowed by the looming threat of military conflict. The age of oil was coming to an end in Panama.

Noriega's increasingly erratic decisions sowed concern amongst global energy companies, particularly those involved in the ANS trade. While Noriega had established himself as the de facto leader of the country, the American government and dissident elements within Panama worked to withhold the $150,000,000 dollars generated directly and indirectly by the oil trade from Noriega's forces. The funds were held in a trust that would be returned to Panama as

[76] Conniff, *Panama, and the United States: The Forced Alliance*, pg. 107.
[77] *Ibid*, pg. 111.

soon as a legitimate government was installed.[78] While this arrangement may have eased the consciences of American government officials who had helped Noriega rise to power, it concerned business leaders who were worried that Noriega might order the Panamanian Defense Forces to seize the pipeline. John McDonald, the President of Standard Oil of Ohio, a subsidiary of BP that directed the company's operations in Alaska, wrote to Congress in March of 1988 to express his anxieties. McDonald argued that, should the pipeline be closed, it would be next to impossible for BP to continue shipments of ANS oil. McDonald suggested that the already strained Canal would be incapable of maintaining the flow of roughly 700,000 to 800,000 barrels that were going through the pipeline daily. Ultimately, McDonald concluded "it will not be possible to maintain full Alaskan production if the pipeline is closed and the canal has to be used. Producers would be forced, both physically and economically, to leave the incremental 400 MBD of oil in the ground in Alaska unless waivers are obtained for either the use of CDS/foreign flag VLCC's around South America or for barrel-for-barrel exchange of ANS for oil delivered in the U.S. Gulf Coast from other parts of the world."[79] Noriega was not only a threat to Panama but a threat to American energy security. Given that America had suffered energy shortages in 1973 and again in 1979 the threat of another crisis was taken seriously.

At the crux of McDonald's argument was the old question of obsolescence. McDonald suggested that "Canal congestion is the most serious problem in maintaining the ANS flow."[80] In his mind, the primary issue stemmed from the fact that if it used the Canal, BP would be forced to use smaller tankers of up to 90,000 dwts which could only carry roughly 450,000 barrels of

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[78] Juan Sosa, "Letter from Panamanian Ambassador to the US Juan Sosa to Secretary of State George P. Schultz, March 21, 1988," March 21, 1988. USNA, RG 185, Collection UD UP 114, Box 1: Folder: Panama Controversy- ANS Oil, pg. 1.
[79] John McDonald, "Letter to Congress from Sohio (BP) Oil Company President John G. McDonald on March 18, 1988," USNA, RG 185, Collection UD UP 114, Box 1: Folder: Panama Controversy- ANS Oil, pg. 3.
[80] *Ibid*, pg. 2.

oil. This limitation necessitated a minimum to two additional Canal transits per day to meet demand. This created substantial financial burdens for BP. The company would have to transfer oil from large 200,000 dwt tankers to smaller vessels, a time consuming and expensive means of transporting oil, although admittedly one that had been common practice just a few years earlier. Even though these smaller vessels could fit through the Canal they were also forced to do so as clear-cut daylight only transits. McDonald argued that the addition of two or three more transits per day of this type would significantly slow traffic throughout the Canal. Finally, McDonald identified the Jones Act as a hardship. McDonald argued that there simply were not enough American tankers of adequate size to handle traffic if it were rerouted through the Canal.[81] Ultimately, McDonald echoed sentiments that had been harassing the Canal for half a century. The waterway was incapable of meeting the needs of modern maritime commerce, particularly the booming ANS oil trade.

Others were not convinced by McDonald's apocalyptic proclamations. Panamanian Foreign Minister Juan Sosa argued that the Canal was more than up to the task of dealing with ANS shipments in the unlikely event that the pipeline should close. Indeed, he argued that McDonald's claims were nothing more than an attempt to cut BP's costs and would ultimately "undermine the economic future of the Republic of Panama."[82] Michael Rhode, the Secretary of the Panama Canal Commission, argued that McDonald was gravely overstating the shortcomings of the Canal. Rhode pointed to the fact that Canal traffic had averaged 34-38 vessels per day during 1988 and that the Commission was confident the waterway could accommodate 40

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[81] McDonald, "Letter to Congress from Sohio (BP) Oil Company President John G. McDonald on March 18, 1988," pg. 1-2.
[82] Sosa, "Letter from Panamanian Ambassador to the US Juan Sosa to Secretary of State George P. Schultz, March 21, 1988," pg. 1.

vessels per day without delay, including sixteen to seventeen large vessels. With these figures, Rhode assured Congress that the Canal could handle up to four additional tankers carrying ANS oil.[83] Perhaps the most scathing criticism of McDonald and BP came not from Panama or the Canal Commission, but rather American shippers. Ernest Corrada, the President of the American Institute of Merchant Shipping, accused BP of merely trying to cut costs by getting waivers for the Jones Act. Corrada suggested "It does appear from the letter that British Petroleum (BP, America Inc.) is using the unfortunate situation in Panama as a cover to suggest Jones Act waivers and Alaskan oil exports and exchanges it could not ordinarily hope to get through Congress."[84] Indeed those two provisions were exactly what McDonald suggested to alleviate the impending energy transportation crisis. Although potentially unscrupulous, McDonald's methods pointed to the complexity of the energy trade. While useful, the Panama Canal was not well suited to the transportation of large quantities of oil. In the ANS trade, where bulk directly correlated with economy, the limitations imposed by the Canal were a considerable liability and led oil companies to view the Panama route with reluctance, particularly as oil fields in the Middle East continued to boom.

Despite this, the Canal remained important to American interests, both practically and ideologically. And it was not only oil interests that were assessing the Canal's continued utility. As the Noriega crisis unfolded, the United States continued to assert the value of the Canal in hopes that they could use it as a justification to oust the dictator. American officials continued the age-old trend of oscillating in their assessments of the Canal's importance, emphasizing its

[83] Rhode, "Memo from Michael Rhode to the U.S. Congress, March 23, 1988," March 23, 1988. USNA, RG 185, Collection: UD UP 114: Treaty Implementation Records Relating to the Panama Canal, Box 1: Folder: Panama Controversy- ANS Oil, pg. 1.
[84] Ernest Corrada, "Letter to Representative Gary Ackerman from American Institute of Merchant Shipping President Ernest Corrada, March 24, 1988," USNA, RG 185, Collection UD UP 114, Box 1: Folder: Panama Controversy- ANS Oil, pg. 1.

significance, or lack thereof, to justify domestic and foreign policy agendas. Unlike Bunker's and Kissinger's arguments during the treaty negotiations of the 1970s, politicians in the late 1980s were asserting the indisputable importance of the Canal as justification for the removal of Noriega.

The desire to oust Noriega led to a hearing on the strategic and commercial importance of the Canal in November of 1989. At the hearing, Canal proponents pointed to the sheer growth in the volume of goods that made use of the Canal, a figure that had expanded from 30 million tons in 1950 to 152 million in 1988.[85] Administrator Dennis McAuliffe stated that "Although use of the Canal has changed over the years, I would argue that its overall value continues to be significant and that it will still be playing an important role in world transportation in the next century."[86] These arguments carried a tremendous amount of weight and many politicians found themselves advocating for action in Panama, with some, such as Congressman Phillip Crane, going so far as to suggest that Noriega's actions rendered the Carter-Torrijos Treaties null and void.[87] Interestingly, however, the nature of assessing the Canal's value changed. While politicians still considered the waterway's importance to American interests, they were also increasingly tying its value to global markets. This marked a departure from the primarily domestic assessments that had shaped earlier discussions and perhaps reflected a growing willingness to acknowledge that the Canal's value transcended its utility to America.

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[85] R.P. Laverty, "Memo from R.P Laverty to Michael Rhode Jr. with Proposed Answers to Questions for Administrator McAuliffe's Testimony before Congress," USNA, RG 185, Collection UD UP 114, Box 3: Folder: Panama-Strategic Value, pg. 2.

[86] McAuliffe, "Statement of Dennis McAuliffe before the Panama Canal Subcommittee," November 2, 1989. USNA, RG 185, Collection UD UP 114, Box 3: Folder: 11/2/89 Hearing: Strategic Importance and Commercial Value of the Panama Canal, pg. 2.

[87] Philip Crane, "Remarks of Congressman Philip Crane," November 2, 1989. USNA, RG 185, Collection UD UP 114, Box 3: Folder: 11/2/89 Hearing: Strategic and Commercial Value of the Panama Canal, pg. 5.

Even as Noriega tried to resurrect the narrative of the Canal as a colonial construct, he shrewdly avoided closing down the Canal or the PTP during his authoritarian rule, recognizing that doing either would likely result in his immediate removal from power.[88] Despite his measured approach to the Canal, as time went on the United States became increasingly intolerant of his rule. President George H.W. Bush finally found his justification for the removal of Noriega on December 16, 1989, when an American soldier was shot and killed outside PDF headquarters. Four days later, 24,000 American troops invaded the country and while Noriega briefly found refuge in the Apostolic Nunciature of the Holy See, he finally surrendered to U.S. authorities on January 3, 1990.[89]

By the time Noriega's regime fell in January of 1990, it had done irreparable damage to Panama's position as an oil crossroads. The combination of inept economic management and substantial American sanctions undermined much of the economic vibrancy of the country, but nowhere were these effects felt as acutely as in the oil industry. The PTP's contributions to GDP fell by nearly half between 1985 when it peaked at 7.8% and 1989 when it contributed only 4.8% to a much smaller economy thanks to economic sanctions and a decline in ANS shipments. When measured in barrels the difference was much more precipitous. Flowthrough dropped from roughly 218 million barrels in 1987 to 116 million barrels in 1989. Revenue from the pipeline dropped from $122.6 million in 1988 to $78.6 million in 1989 before falling even further to roughly $59.4 million in 1990.[90] The pipeline, which had seemed a central component of the burgeoning Panamanian economy just a few short years earlier, was on the verge of irrelevance.

[88] Michael Kozak, "Statement by Michael Kozak, Deputy Assistant Secretary of State for Inter-American Affairs at the Hearing of the Strategic Value of the Panama Canal," November 2, 1989. USNA, RG 185, Collection UD UP 114, Box 3: Folder: 11/2/89 Hearing: Strategic and Commercial Value of the Panama Canal.
[89] Conniff, *Panama and the United States: The Forced Alliance*, pg. 117.
[90] American Embassy. "Economic Trends Report for Panama," July 1990, pg. 2-3.

The Canal, meanwhile, was only minimally impacted by the Noriega crisis. Its earnings dropped by about $5 million dollars in 1989 but recovered quickly.[91] The joint American-Panamanian Canal Commission continued to operate the waterway with remarkable efficiency in the aftermath of the Noriega crisis and on April 30th, 1990, President Bush nominated Gilberto Guardia Fabrega to be the first Panamanian to serve as Administrator of the Panama Canal Commission.[92] While the Canal weathered the storm it too was impacted by the shifts in the global energy trade. Canal traffic decreased during 1988 thanks in large part to a 5.9% drop in petroleum and petroleum products. While tankers still made use of the waterway, the significant role petroleum products had played in the make-up of cargo was being usurped by manufactured products such as automobiles and agricultural bulk items including corn and wheat. Meanwhile ANS shipments were increasingly being sent to developing West Coast ports and harbors.[93] The Canal recovered, but it seemed unlikely that oil would play as large a role as it had in the previous decades

Booms and Busts

Between the end of WWII and 1990 few commodities shaped the Panamanian Transit Zone as much as oil, particularly ANS crude oil. Petroleum had long been a mainstay of Canal traffic, so much so that even before the discovery of the Prudhoe Bay field, speculators clamored at the opportunity to create a pipeline across the Isthmus. As Alaskan oil moved from a speculative endeavor to a very real source of tremendous wealth, Panama became a center in the transportation of ANS oil. Massive 200,000 dwt tankers carried hundreds of thousands of barrels

[91] American Embassy. "Economic Trends Report for Panama," pg. 2.
[92] George Bush, "Nomination of Gilberto Guardia Fabrega To Be Administrator of the Panama Canal Commission April 30, 1990," Federal Register Division. National Archives and Records Service, Public Papers of the Presidents of the United States, George Bush, 1989 (Washington, D.C.: Government Printing Office, 1956-), p. 589
[93] American Embassy. "Economic Trends Report for Panama," July 1990, pg. 3.

of oil to Panama daily where it was transferred to smaller vessels capable of transiting the Isthmus. Peaking in the 1982, this trade pushed the capacity of the Canal to its limit. No one complained. Millions of dollars' worth of revenue poured in, generating wealth for Panama and providing America with the energy security it craved. The creation of the PTP in 1982 created even more opportunities for economic growth and soon the energy trade formed a crucial part of Panama's economy.

And yet the energy trade was highly volatile by its very nature. "Surprises" came from a variety of sources. Initial searches for Alaskan oil proved relatively ineffective as the Navy, Geological Survey, and Arctic Contractors struggled to find the oil fields that were allegedly abundant in northern Alaska. When oil finally was discovered a new set of challenges arose. The size of the Prudhoe Bay field was meaningless without the capacity to remove the oil and get it to market. While the world was confident this would be feasible, the near decade long process of negotiating and constructing TAPS muted enthusiasm for the creation of a transisthmian pipeline across Panama. As if that weren't enough, the ongoing tensions between Panama and the United States threatened to undermine the Transit Zone's promise as a site for energy transportation. When treaties were finally negotiated, the Panama Canal had to reckon with capacity and the potential ecological devastation that could accompany an oil spill. While the creation of the PTP seemed to alleviate these concerns, even the pipeline could not withstand the entropy unleashed by the rise of Manuel Noriega. The energy trade in Panama, while productive, was incessantly haunted by the specter of missed potential. An energy boom always seemed just out of reach, and even when ANS oil movements peaked in the mid-1980s, domestic and foreign policy concerns ensured that the lucrative trade proved short-lived.

Panama recovered from the havoc wreaked by the Noriega regime, and while petroleum products returned to the region, it was the financial and service industry sectors, as well as the Canal, that came to define Panama's economic rejuvenation. Thanks to the explosion of West Coast refineries and consumption, and domestic transportation of oil through American pipelines, ANS oil simply didn't need to utilize the PTP or Canal to the extent that it had in the 1980s. The energy trade then was chimera of sorts to the Panamanian economy and American energy interests. Panama had been able to capitalize on global energy trade and finally take advantage of its position as the crossroads of the world. Oil companies, while not thrilled with the limitations placed on the trade by the Canal's size and the Jones Act, were able to ship oil from Alaska to mainland America at considerably cheaper costs than they would if they were required to journey around South America. Conversely, however, the oil trade never quite delivered on the long-term economic growth it promised. The erratic nature of the energy trade and the looming threat of political and diplomatic entropy kept it from fully reaching its potential and becoming the centerpiece of the Panamanian economy.

The Noriega Crisis and the ensuing decline in the ANS oil movement across Panama heralded the end of American energy in Panama. By 1990, the Canal's Administrator and the bulk of its workforce were Panamanian, a trend that would continue as the end of the millennium approached and Panama took over control of the Canal once and for all. For a century and a half Americans had attempted to use Panama's unique geographic position to facilitate travel around the world. In doing so they bound themselves to a variety of energy sources including human and animal muscle, fossil fuels, and even nuclear fission and fusion. And yet in doing so they often encountered limits to their ability to control the environment. Whether it was slides that undermined attempts to establish permanence on the environment, strikes from disgruntled workers, or even the international crises that squandered the potential of the ANS oil trade, control over Panama and the energy sources Americans brought to the Isthmus were never absolute. Entropy whether physical, diplomatic, or economic, always lingered, unrelentingly asserting the limits of control.

Epilogue: Energy, Entropy, and the 21st Century

On December 14th, 1999, former President Jimmy Carter led a delegation of Americans to the Miraflores locks for the ceremony celebrating the transfer of the Canal to Panamanian control. While the formal transfer didn't take place until December 31st, the ceremony was held early amidst fears that the Y2K bug might make international travel dangerous on the official date. Potential technological apocalypses aside, the moment failed to garner the pageantry many thought it deserved. Carter celebrated the moment as "perhaps one of the most significant that has ever occurred in this hemisphere." The Panamanian delegation, however, didn't share Carter's enthusiasm. Amidst concerns that Republicans would leverage domestic hostility towards the Canal transfer in the 2000 presidential election, both Bill Clinton and Al Gore stayed away from Panama. Secretary of State Madeleine Albright was scheduled to go but backed out citing issues in the Middle East. Roberto Eisenmann, a senior advisor to Panamanian President Mireya Moscoso, voiced the anger of many Panamanians, claiming "It possibly shows a lack of class, a lack of political courage. It's caving to the extremes in your domestic politics."[1] While Republican anxieties about the Canal transfer didn't undermine the ceremony, they did point to the continued centrality of the Canal in American politics. Despite these challenges, the transfer went on as planned. As the new millennium dawned on January 1st, 2000, it did so on a Canal that was now entirely under the administration of Panama.

In many ways, Panamanians proved more adept at managing the Canal than their American counterparts had. There were no major issues in the years following the transfer. On

[1] Todd Robberson, "Ceremony Marks U.S. Transfer of Canal's Control to Panama." Dallas Morning News. December 14, 1999. https://eds.b.ebscohost.com/eds/detail/detail?vid=8&sid=82717098-8873-41e0-831c-e226f3288f26%40sessionmgr104&bdata=JnNpdGU9ZWRzLWxpdmU%3d#AN=4N04232152761929&db=nfh.

the contrary, a little less than eighty years after it had first been proposed, the third locks project was finally completed, although not in the way American engineers had expected. On June 26, 2016, the Chinese vessel *Costco Shipping Panama*, a container ship roughly 1000 feet in length with a 158-foot beam became the first ship to transit the new locks of the Panama Canal. This ended a ten-year, $5 billion-dollar project. The new locks, constructed adjacent to the existing locks at both the Atlantic and Pacific terminals, consisted of chambers 1400 feet long by 180 feet wide with a depth of 60 feet and were designed specifically to accommodate the newest neo-Panamax vessels on the seas.[2] The Panamanian public overwhelmingly supported the expansion of the locks, hoping that larger facilities would make the Panama route more enticing to large bulk carriers and allow the country to reassert the value of the Isthmus to global shipping.[3] Unlike previous eras of Panamanian history, there was no foreign power to usurp the prosperity that came with interoceanic travel.

And yet even the new locks were not exempt from the mandates of energy. In the original locks, boats were towed through by electric locomotives, but ships entering the new locks were guided entirely by tugboats. Pilots expressed their concern over the safety of this new arrangement as soon as it was announced.[4] Shifting away from the fixed tracks of the locomotives increased the unpredictability of ship movements and could result in more accidents. assuming that these accidents would involve massive vessels powered by tremendous amounts of energy, the potential damages could be substantial. These worries proved well-

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[2] Steve Mufson, "An Expanded Panama Canal Opens for Giant Ships." Washington Post, June 26, 2016. https://www.washingtonpost.com/world/the_americas/an-expanded-panama-canal-opens-for-giant-ships/2016/06/26/11a93574-37d1-11e6-af02-1df55f0c77ff_story.html.

[3] Karolina Zielinski, "The Panama Canal Expansion Project: A Historical Review and Lessons Learned." Journal of Information Technology & Economic Development 9, no. 2 (October 2018): 1–11, 4.

[4] Carrie Kahn, "The $5 Billion Panama Canal Expansion Opens Sunday, Amidst Shipping Concerns." NPR, June 25, 2016. https://www.npr.org/2016/06/25/483523910/the-5-billion-panama-canal-expansion-opens-sunday-amidst-shipping-concerns.

founded. In April of 2017, a tugboat helping vessels navigate the Canal collided with the US Coast Guard Vessel *Tampa*. The crash occurred when the tugboat captain fell asleep at the helm after working a twelve-hour shift. To accommodate the increased volume of shipping and manage costs, the Panama Canal Authority forced captains to work twelve to fourteen-hour shifts and many simply could not handle the demanding schedule.[5]

In December of 2018, the International Transportation Workers Federation (ITF) and its affiliate representing tugboat captains in the Panama Canal, the Union de Capitanes y Oficiales de Cubierta (UCOC), released a study alleging that due to the excessive hours pilots were working they were incapable of meeting safety standards.[6] They worried that because of the crucial role pilots played in transiting the new locks there was a significant potential that an accident of catastrophic proportions could occur unless a more reasonable schedule was adopted. Human energy, or lack thereof, still had the potential to undermine Isthmian transit over a century and a half after George Muirson Totten first set foot in Panama in hopes of constructing the Panama Railroad. While the landscape of the Transit Zone had been intricately altered to maximize Isthmian transit, uncontrollable energetic variables remained that challenged assertions of control over the natural world.

This reality defined the experience of Americans in Panama. Americans' faith in their own infallibility came close to undermining numerous projects, and even when the Canal opened it was beset by claims of obsolescence. This is not to say that the Canal was a failure. Indeed, the waterway has generated billions of dollars in global revenue and played a crucial role in

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[5] Elida Moreno, "Tired Tugboat Captains Flag Accident Risk at Panama Canal." Reuters, December 20, 2018. https://www.reuters.com/article/us-panama-canal-accidents-idUSKCN1OJ2P4.

[6] Professional Mariner, "Union: Fatigue of Panama Canal Tug Captains 'a Disaster Waiting to Happen,'" December 7, 2018. http://www.professionalmariner.com/Web-Bulletin-2018/Union-Fatigue-of-Panama-Canal-tug-captains-a-disaster-waiting-to-happen/.

establishing America as a global superpower in the 20th century. However, it is worth noting that transit networks in Panama never operated as seamlessly as was hoped. Canal projects, both envisioned and realized, forced American engineers, and today force Panama Canal administrators, to recognize the limits of their control as much as the extent of it.

For much of the 20th century, American engineers reacted to this reality with an unflinching hubris. Americans had created the transcontinental railroad, they had built the Canal, they had developed the bomb. In each era of Panama's energy history, American engineers in Panama justified massive infrastructural projects through self-righteous assertions that there was nothing that they could not accomplish with ingenuity and elbow grease. What they hadn't counted on was the unrelenting persistence of entropy to undermine these efforts. Panama's environment challenged Americans' expectations at every turn. Its shifting soils and drenching rains eroded constructed landscapes and threatened to undermine the railroad and Canal projects entirely. In hopes of establishing and maintaining order in this landscape, Americans obtained and deployed tremendous amounts of energy, betting that this brutalist method would finally help them overcome Isthmian entropy. It did, but also deepened their dependence on even more powerful sources of energy: a Faustian bargain accompanied by unforeseen consequences.

The cyclical relationship between Panamanian transportation networks, entropy, and energy consumption came to a head in the 1960s with the discussion of a nuclear canal. This debate was remarkable, breaking the chain of energy escalation that defined American transportation networks in Panama for a century. For the first time, Americans decided not to deploy a new source of energy. The hazards that accompanied nuclear detonations, as well as the technical infeasibility of the technology, were too extreme to be ignored. It took a decade of study to arrive at this conclusion but doing so suggested that American engineers, policymakers, and bureaucrats were finally beginning to understand their lack of control and the limits of brute force solutions to great problems.

Nuclear power proved the exception to the rule however, and, in the decades following the nuclear canal discussions, Americans found themselves once again enamored with expanding energy sources and networks, this time in the form of Alaska North Slope oil. While the trade never quite reached the scale that energy speculators may have hoped, the billions of barrels of oil that moved through the Isthmus indicated that Americans were doubling down on their energy consumption. The dangers of nuclear energy were unambiguous and consequently could not be overlooked. Fossil fuels were accompanied by smoke and pollution, but the consequences of their deployment seemed to pale next to nuclear energy, appearing almost benign by comparison. And yet as Americans' energy consumption ballooned the pervasive fallout of burning billions of tons of coal and oil were laid bare. While Panama is not solely to blame for these challenges, it serves as a microcosm for their development.

Panama is only one of the countless places where entropy and energy impacted human attempts to alter landscapes. The decline of America's domestic transportation network in the early decades of the 21st century forms an interesting parallel. While the Eisenhower Interstate Highway Act created a remarkable transportation infrastructure in the United States, it also created a landscape susceptible to seemingly marginal sources of entropy such as sinkholes, frost heaves, and erosion. These relatively minor occurrences, when taken collectively, require the investment of billions of dollars to hold at bay, and the crumbling bridges and potholed highways that crisscross the American countryside suggest that we may be losing this front in the war against entropy.

The electrical landscape of the United States also warrants examination. Our current centralized power grid, while it provides electricity to millions of people, also finds itself under threat from a variety of sources. Inclement weather has long wreaked havoc with power transmission as snow storms, high winds, and earthquakes are all easily capable of severing power lines. Increasingly, these natural sources of entropy are being joined by artificial threats. EMP bursts and cyber-attacks also have the potential to undermine these systems, allowing hostile entities to capitalize on the centralization of America's energy network. A more diffused system of energy production may be able to mitigate these concerns, but fundamentally restructuring America's electrical distribution would require a massive investment of capital and energy.

Perhaps the most pervasive and damning source of entropy threatening not just the United States, but the world, stems from our commitment to fossil fuels. Coal and oil, those seemingly benign sources of progress that powered construction of the Canal and enriched the nation, are today creating the most pressing environmental crisis in human history. Global climate change, the product of our insatiable energy demand, is reshaping the global environment. Human hubris, an unquenchable thirst for wealth, and an overconfident infatuation with technological solutions to grand challenges have prevented society from taking meaningful steps to address this challenge. Instead, we once again are placing blind faith in the assumption that we can overcome any obstacles placed in our path. In the quest to establish control over the environment and bend it to our will we have merely unleashed entropy on an unprecedented, global scale.

Finding a way to deal with climate change (or not) will be the defining accomplishment of the 21st century. There are no easy solutions to this crisis. Mitigating climate change will require remarkable investments of energy and significant alterations of the natural world, and a willingness to accept the role that our insatiable appetite for energy has played in raising our vulnerability to entropy. As individuals we seek solace in our anonymity, assuming that our personal consumptions of energy are so minuscule as to be invisible. The collective impact of this belief catalyzes the constant increase in the energy appetite of the nation and consequently revitalized the positive feedback loop between energy and entropy that has defined the 20th and seemingly the 21st centuries.

What society needs is a sort of energetic détente; a willingness to cut personal energy consumption by exploring more energy efficient technologies and making behavioral changes in energy usage. This process will ideally be accompanied by the adoption of decentralized and localized energy infrastructures, shifting the burden of energy production away from massive centralized networks reliant on fossil fuels and embracing the flexibility that comes with smaller systems that can be adapted to meet the needs of localized energy consumption. The relationship between energy and entropy suggests that the adoption of smaller, more localized solutions to entropic challenges mitigates the growth of entropy, containing it to manageable levels. If society can realize this objective it may be possible to minimize the impacts of climate change.

The relationship between energy and entropy mediated the relationship between Americans and Panamanians for a century and a half. The "control" that came from the consumption and deployment of unprecedented amounts of energy was an illusion, a siren luring unwary idealists towards an even more unstable environment. Our inability to resist the seduction of mass energy consumption has led us to the edge of a societal cliff. On October 8, 2018, The Intergovernmental Panel on Climate Change released a special report arguing that to avoid the most severe consequences of climate change, it is imperative that human society limit warming to 1.5 degrees Celsius.[7] The key to accomplishing this task is a substantial change in the way society thinks about energy. Consumption of energy is not an action free of consequences. And yet we have blindly accepted the fallout of our expanding energy palate without question, thanks to comforts it has conveyed. To paraphrase the world's greatest fictional mathematician, Dr. Ian Malcolm, "we were so preoccupied with whether or not we could consume more energy that we didn't stop to think if we should." Unless we stop to think if we should consume more energy, and the way in which we should consume it, we stand doomed to reap what we sow, a world of increasing entropy in which stability is history.

[7] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

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