RICE UNIVERSITY

American Extreme:
An Ethnography of Astronautical Visions and Ecologies

By

Valerie A. Olson

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

Doctor of Philosophy

APPROVED, THESIS COMMITTEE:

James D. Faubion, Professor
Anthropology

Amy Ninetto, Assistant Professor
Anthropology

Cyrus C. M. Mody, Assistant Professor
History

HOUSTON, TEXAS
MAY 2010

Abstract

American Extreme:
An Ethnography of Astronautical Visions and Ecologies

by

Valerie A. Olson

This dissertation is a coordinated ethnographic case study of environmental science, medicine, technology, and design in an American human spaceflight program. Its goal is to investigate how astronautics contributes to shaping "the environment" as an extensive contemporary category of knowledge, politics, and social action. Based on fieldwork conducted primarily at the National Aeronautics and Space Administration (NASA)'s Johnson Space Center in Houston Texas from 2005 – 2008, the study argues that, in practical and meaningful ways, ecology and cosmology are co-constituting in American astronautics. Using participant observation and archival data, the study evaluates how astronautics practitioners know and work with "the human environment" on a scope that includes vehicle habitats and the heliosphere and on scales ranging from the molecular to the cosmic. In this work, people shore up and break down unusual human/environment boundaries, making sense of what it means to do so in technoscientific as well as sociopolitical, symbolic, and transcendental terms. The four cases analyzed are: (1) how space analogue missions operate as simulations but also make arguments that extreme environments foster progress through confrontation with adversity, (2) how space biomedical subjecthood is fundamentally environmental rather than biological, (3) how "habitability" works as a key elaborating concept among space architects so that they can connect extraterrestrial and terrestrial habitation problems and solutions, and (4) how Near Earth comets and asteroids have moved from being obscure astronomical objects to objects of environmental policymaking that extends into the heliosphere and into the far future. The study's analysis brings social theory about the spatial politics of knowledge into dialogue with conceptual frameworks from the social studies of science, technology, and environment. As an ethnography of outer space as extreme environment rather than territorial frontier, the study highlights astronautics' connections to broader domains of environmental science and technology, and by discursive and practical extension, to a spectrum of American environmentalisms and engagements with extremity. In doing so, the study elaborates astronautics' role in making ecological knowledge, and attendant concepts like adaptation and evolution, cosmologically scalable.

Acknowledgements

To the many kind and generous people who made this dissertation project possible, I am gratefully and permanently indebted.

I entered JSC and the NASA institutional network through inviting encounters with Mark Craig, Dr. Judy Robinson, and Eileen Hawley. Edna Fiedler believed in and helped to develop this project. The National Space Biomedical Research Center and its senior managers, Dr. Jeffrey Sutton and Dr. Jeanne Becker, gamely and kindheartedly agreed to hire me as a research intern and gave me the encouragement as well the requisite tokens of permission I needed to come and go at NASA centers. Pam Baskin was my friend and constant NASA guide, helping and sometimes even pushing me, with caring and wit, to go where I needed to. The staff, participants, collaborators, and institutional networks of the NEEMO program accepted me (and my incessant questions) with grace and good humor, and they let me dive. Wendell Mendell, John Charles, Rob Landis, and the NEOphiles gave more than "one or two" interviews and brought me into their orbits, and I hope I had something to offer in return. The "Exploration Faithful" accepted me in as an observer and exploropologist; these pages are shaped in part by their debates, insights, humor, and hopes.

People within the National Space Biomedical Research Center, Johnson Space Center, Ames Research Center, National Undersea Research Center, NASA Headquarters, and Space Frontier Society who gave of their time, thoughts and dreams, chairs at tables, office space, documents, dive gear, and lunch money are legion. I would list them individually but being named herein may or may not be a welcome tribute, so I will simply say: thank you, so very much, with all of my heart. I will acknowledge them in terms of the teams I came to respect for their astonishing persistence and coordinated productivity in the face of constant uncertainties: the Life Sciences Directorate, the JSC Astronaut Corps, the Habitability and Environmental Factors Division, the Lunar Habitat Design brainstorm team, the Habitability Design Center, the JSC archive team, the Public Affairs Office, Ames Research Center, the Astromaterials Research and Exploration Science Office, the NASA History Office, and the JSC Oral History project team. In addition, I wish to thank the European Space Agency for allowing me to work as a staigiare at the Noordwijk Technical Center in the Netherlands and for accepting my visits at the European Astronaut Center in Köln, Germany. My time there gave me a vital comparative perspective on astronautical theories, discourse, and practice.

Rice University the Anthropology Department accepted me as a non-traditional student and encouraged an unusual project; I will always reflect on this with great gratitude and lingering incredulity. Among the Anthropology department professors, George Marcus brought me face to face with the joy and challenge of designing an anthropological project and hovered always there even when far away; James Faubion remodeled my mind and provided the rich analytic frameworks on which to base good questions; Hannah Landecker pushed me to move beyond my writing and intellectual habits; Christopher Kelty gave me thoughts, courage, and words when I lost them; Julie Taylor kindly brought the ethnography up out of me; Amy Ninetto steered me toward the historical roots of my inquiries. Committee member and historian Cyrus Mody provided guidelines for engaging with other disciplines. I will never forget formative moments and helpful encouragement in consultation with these Rice professors: Nia Georges, Stephen Tyler, Libby Vann, Jeff Fleischer, Dominic Boyer, Phil Kortum, Stanley Reiser, and

Jeffrey Kripal. I thank the Anthropology Department's administrative staff, Carole Speranza and Joanne Carpenter, for their help.

I was fortunate to acquire a team of outside readers and advisors, generous professors to whom I will always be grateful: Stefan Helmreich provided the careful reading and rereading and practiced guidance that made all the difference at critical moments; Debbora Battaglia buoyed heart and mind above and beyond; David Valentine helped me to see the really big picture and invited me on board as a colleague for his own space project. In addition, I'm grateful to Steven Pyne, David Nye, Joe Masco, Deanna Weibel, Cynthia Selin, and Patrick McCray for encouragement, mentoring, and new ideas.

Graduate students build networks that keep us "together," not just as a group but as individuals. Senior students in and outside the department, most now far along down their professional pathways in the world, were reassuring, provocative, and grounding. My deep gratitude and acknowledgements that "you were right" to: Andrea Frolic, Brian Riedel, Jae Chung, Kristin Peterson, and Michael Powell. During my first year in the Anthropology Proseminar at Rice I met the cohort that would be a constant source of impetus and critical feedback: Ebru Kalyaap, Anthony Potocniak, and Elitza Ranova. Among my contemporaries with whom I worked out ideas and problems that are now written deep into these pages are Nahal Naficy who transported me back the poetics, Matthew Wolf-Meyer who generously and compassionately pulled me into the most productive projects and networks, Elise McCarthy who was there at the first interview and co-designed this project, Michael Adair-Kriz who opened up spaces to be/think/rethink with renewed enthusiasm, Lisa Messeri who shared the field with me and read my early efforts with unrelenting kindness, Terri Laws who shared her wisdom and grace during our salons dedicated to the self and the real, and Maria Vidart, Cap Bendixsen, Dan White, and Nikki Payne with whom I shared great times and talks. I thank the HRC Dissertation 2009 – 2010 Fellows: Lina Dib, Philip Robichaud, David Getman, Cory Ledoux, and Catherine Fitzgerald Wyatt for the dynamic and thought-provoking meetings. Also, my thanks go to Sven Mesinovic, Michael Mooradian Lupro, Tiffany Romain, and Matthew Hersch for scholarly companionship in the cosmos. I'm also grateful to the students in the 2008 Proseminar and 2009 Advanced Topics in Medical Anthropology course for teaching me to be a better teacher, and for sharing your excellent ideas and inspiring work: Laura Resendez, Trevor Durbin, Janice Orlando, Tim Chryssikos, Sarai Conway, Erin McLaughlin, Stacey Pereira, Christine Bohne, Fiona Adams, Alicia Buck, and Sarita Panchang. To student colleagues coming up through the program, I extend my thanks and best wishes for the years ahead.

Without the generosity of a number of funders and supporting experiences, I could not have pursued this project. From Rice University, I was so very grateful to receive Anthropology department funding, a Lodieska Stockbridge Vaughan scholarship and fellowship, and a Wagoner Foreign Studies Scholarship. The Rice Space Institute provided start-up seed money; my thanks to Patricia Reiff, Umbe Cantu, and the Institute board for their support and for taking a chance on a social scientist. The Rice Univesity Humanities Research Center gave me the opportunity to participate in the extraordinary Mellon seminar lead by James Faubion, and supported the writing of this dissertation with its incomparable Dissertation Fellowship; to Hank Hancock and the HRC boards, staff, and funders, I offer heartfelt thanks. The National Science Foundation provided the deeply appreciated and much needed Dissertation Improvement Grant (#06020442). I want also to thank the M. D. Anderson Cancer Center Bioethics Center for giving me an internship and an inside view of research ethics in action.

Beyond the walls of the academy are my friends and family, who provide my life's foundations and for whom words of gratitude will always be inadequate. To Regan Overholt, Mary Bradsberry, and Erinn Gonzalez -- you have no idea how thoroughly your friendship and long-distance comedy sustained me. Ann Barbarow has seen me through every major event in my adult life, and I am grateful for her sisterhood and encouragement. To David Lombardi, Liz Ehrhart, and their girls Josephine and Juliet, thank you so much for being our Houston family. Thanks also to Ronald Kline and the girls (Ava, Tasmania, Priscilla, and Mocha) for their constant friendship. To Felisa Heft, *un montón de amor y gracias* for steadfast loving encouragement and the generosity of a guardian angel. My parents, Gail Olson and Dr. Bruce Olson, I thank for putting me in the avocado-colored butterfly chair in 1969 to watch Apollo 11 and for providing love matched with the belief that this all could and would happen. Also, in loving memory of my brave little cat Groucha, constant companion through the writing.

Finally, and ever firstly, I am deeply grateful to my wonderful partner John and amazing daughter Morrigan. They were the bright and steady stars by which I navigated through this whole adventure, and on whom I could always depend for the deeply sustaining warmth of their love, support, and good humor. This is dedicated to you.

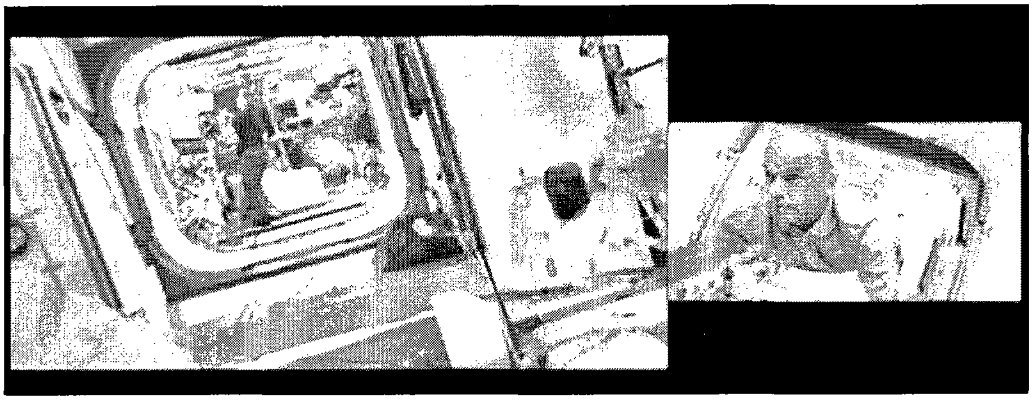
Table of Contents

Introduction:

Space as environment

We are in the epoch of simultaneity: we are in the epoch of juxtaposition, the epoch of the near and far, of the side-by-side, of the dispersed...Our epoch is one in which space takes for us the form of relations among sites.

- Michel Foucault *Of Other Spaces*[1]



Video clip: "In this Orbital Outpost...We Are the Experiment" / courtesy NASA

In February 2010, an American astronaut living in the International Space Station mounted two high definition video cameras back to back, turned them on, and began to fly. Jeff Williams, an Air Force colonel and devout Christian who had recently completed a photography book, *The Work of His Hands: a View of God's Creation From Space*,[2] was crafting a simultaneously juxtaposed video portrait of the station's interior and himself. One camera faces forward to catch scenes as he floats through the station's zigzagging modules, encountering racks of equipment and people on computers communicating with Earth; the other camera looks back on his face and the receding spaces he had just flown through. The finished video file featuring the footage from both cameras merged side-by-side is available on the National Aeronautics and Space Administration (NASA's) multimedia website. It is entitled "In This Orbital Outpost...We Are the Experiment" and tag-lined "an interesting perspective."[3]

One thing most astronauts like to do is to document perspectives on their position in outer space. These amount to highly technical and deeply humanistic contemplations of spaces, places, and their interconnections. Americans get up to the Station via a NASA Space Shuttle orbiter or a Russian Soyuz capsule. On the Station, an average complement of six people shares the extremely limited habitable volume within modules jam-packed with life support technologies, science experiments, tools, and gear. The Station is constantly in motion, flying around Earth at an average height of 320 kilometers and at a speed of 8 kilometers per second. In an interview with CBS news,[4] Williams describes his self-conscious experience of "living in a bubble" on the Station, a common astronaut reference to their social and technical conditions. The "bubble in space" metaphor also parallels current scientific designations of the whole solar system as a heliospheric "bubble," within which obtain other spaces with interactive atomic boundaries -- such as Earth and its atmosphere, a space station, or an organismal body. Williams' annotated Earth photography and forward/backward video "fly through" of his space bubble are concerned with creating relational perspectives on the scale, scope, and meaning of it all. But the video's title, "We are the Experiment," also reminds the viewer that astronautics, the practice of extending things and people into outer space, is *inclusively* experimental. In the "human exploration" (versus "robotic science") arm of astronautical practice, the basic processes of human life and habitation become exigent and contingent. The cosmos becomes a matter of environmental order, conditions, and interrelations.

This dissertation is an ethnography of space as an environment, and shows how, in practical and meaningful ways, ecology and cosmology are co-constituting in American astronautics. Between 2005 and 2008, I conducted fieldwork centered at the

Johnson Space Center in Houston, Texas, during which I followed people at work on the inaugural stage of a National Aeronautics and Space Administration (NASA) interplanetary human space exploration program called "Constellation." In 2004, President George W. Bush mandated a "Vision for Space Exploration," announced nearly a year after the Columbia space Shuttle disaster and as a reprise of his father's short lived early nineties "Space Exploration Initiative." Congressionally authorized by the 2005 Space Act, Constellation was intended to be the successor to the Space Shuttle and Space Station programs. At the time of this writing, Constellation is being canceled by the Obama administration, amid a complex domain of political opposition to the loss of American space supremacy and tens of thousands of jobs. It appears that it will never fulfill its mandate to go back to the Moon by 2012 and on to "Mars, and Beyond." While its human space exploration programs come and go, NASA continues its Cold War-initiated cosmological program of making "the American position in space" vital for national security and prestige and for producing authoritative knowledge on the astronomical cosmos and the human condition. Data about Earth collected in space and from NASA's space living experiments also contribute to the production of public environmental and ecological knowledge, and toward the making of everyday "human" life imagined and ordered not in terms of global nature but of a planetary ecosphere. In this way, American astronautics influences the contemporary experience of living on planet Earth, which has come to be, anthropologist Bruno Latour notes, a "time of simultaneities," during which "the question of co-habitation became fundamental."[5] What post-Cold War astronautics is as a venture today has a lot to do with the play of tensions between ideas of space and environment and the exigencies of simultaneity and the future understood as readiness, progress, and providence.

The dissertation traces my journey into NASA workspaces where what counts as "the human environment" has a scope ranging from vehicle habitats to the heliosphere. At NASA, environmental technoscientific practices are focused on both the constraints and unrestraint of human habitation processes, and people aim to know and manage human/environment interactions on their most extreme scales – molecular and cosmic. As my review of literature within the following chapters demonstrates, this dissertation differs from scholarship on space programs that focuses on their organizational sociology or their institutional roles in remaking the geopolitics of territoriality;[6] it is also not centered on rocketry or existing space vehicles such as the Space Shuttle or International Space Station. It is also different from the mostly non-ethnographic body of social scientific and cultural studies literature concerned primarily with the technological and frontier sublimes.

While I do not claim that there is a clear discursive or practical line separating space-as-frontier from space-as-environment, this dissertation aims to redress a deficit in research by pursuing the latter topic. In doing so, I show how American astronautics connects to a larger historical genealogy of environmental science, medicine, and technology, and by discursive and practical extension, to a spectrum of American "environmentalisms." In that sense, the dissertation offers something to juxtapose with the American astronaut-photographed whole Earth image and with Commander Williams' videography. It offers an ethnographic portrayal of institutional astronautics at work on environmental assemblages and of the politics, ethics, affect, and aesthetics inhering in astronautical visions and ecologies. I also want to provide an ethnographic foundation for evaluating how astronautics is implicated in broader American understandings of "environment" and "ecology" and attendant concepts like adaptation and evolution, particularly how those understandings are elaborated at terrestrial/extraterrestrial intersections. It is clear that the social movements that make up American environmentalism did not begin with the Apollo-era astronaut photographs of the whole Earth that are now emblems for those movements, even if such photographs and visionary space art continue to reflect American recognitions of environments as interconnected and vulnerable.[7] However, I hope to show how and what astronautical technosciences, people, things, concepts, and cosmological constructs contribute, in authoritative and dissenting ways, to shaping "the environmental" as an American category of controversy, shared concern, and social action.

Early on in my fieldwork, I learned that the term "environment" organizes astronautics' multidisciplinary work from the engineering of vehicles to the development of healthcare protocols, based on the commonly held idea that successful space missions hinge on the capacity to create and thoroughly manage environmental interrelations of people, things, and processes. A young engineer responsible for "environmental integration" on Commander Williams' space station bubble world, namely for the interaction of American and Russian water recycling systems, summed it up for me: "Our thought process is....environment, environment, environment...everything interacts with everything!"

A result of twentieth century technology-supported exploration and macro-scientific disciplines like climate science is that outer space is now categorized as one among a group of "extreme environments" that present new platforms for testing technologies and people and producing more commanding and comprehensive scientific knowledge about life and ecological processes. Consequently, "environment" and "extreme environment" operate meaningfully in astronautical workspaces in ways that the territorially-inflected idea of "frontier" does not, as terms invested with particular kinds of epistemological and ontological considerations of truth and order. Despite the fact that space exploration is not an active research topic within environmental history and social science,[8] astronautics does, on the practical and philosophical level, respond to a core historical and anthropological assumption: that groups of people distinguish themselves through their environmental engagements, integrations, and capacities.[9]

While NASA's official policies orient its work outward into outer space with the companion purpose to "expand human knowledge of Earth" for national security and technoscientific supremacy purposes,[10] disputes over the agency's relevance to life-on-Earth are foundational to the ongoing generational and interdisciplinary "astropolitics" of NASA. Critical to those politics, in the past and increasingly so now, are people's interpretations of NASA's value and purpose with respect to what Sheila Jasanoff and Marybeth Long Martello label the "Earthly politics" of environmental governance.[11] This dissertation's investigation into the astronautical politics of environment is not pitched at the level of national or international policy, but seeks instead, following work by anthropologists in other Cold War institutional settings,[12] to focus on politics and ethics happening "on the ground," in laboratories, in the field, and in other spaces where NASA and astronautics workers pursue projects related to but not limited to their NASA work. As ethnographers of nuclear weapons science and medical research show,[13] the work and politics of "big science" is a matter of broad collective negotiations, contests, resistances, and accommodations of interests and agendas that move in and out of institutions. At NASA, American astronautics' environmental work is simultaneously caught up with American debates, work, and concerns focused on the future of humans restricted to Earthly environments.[14] In this political ecology, official policies interact with other kinds of politics sustained by the people who work to legitimate NASA and produce its materials and processes. These are the politics I explore here, in relation to NASA's distinctiveness as an institutional architect not just of big technical projects but of ways to make connections across vast spaces. Although NASA is a baroque wonderland of technical and scientific terminology, its discourse and conceptualizations have always been animated by less-than-technical tropes and themes, like "frontier," that consolidate worldviews and sentiments and invest acts of truth-making with vitality and cultural resonance.

Based on my fieldwork encounters with "the extreme" everywhere I went, this dissertation highlights it as a thematic bridge. In referring to space as an "extreme environment," interlocutors were not only signaling its categorical status as a limit-case, but also the extent to which "the extreme" is regarded as a vital site (a place or condition) in which essential truths and proofs emerge. Historians and social scientists have long been interested in the extreme and its manifestations -- as violence, the sublime, extraordinariness, deviance, exceptionality, and states of emergency -- and have also recently embarked on other engagements with the politics and ethics of extreme embodiment.[15] But "extreme," expressed sometimes simply with the evocative prefix "X," is also used now in American popular culture to signify "ultimate" generative, liberatory, alternative, and transcendental states of being; there are extreme sports, extreme foods, and extreme makeovers.

Surrounded by references to the extreme within NASA, I became interested in how astronautics works with American historical and popular valorizations of extreme environmental confrontation and contest, and also in how the astronautical extreme sheds light on how American ecological ideas and practices are bound up with utopian projects of "extreme" embodiment and millenial anticipations. The ways certain astronautics groups and advocates used the more general descriptor "extreme" (and its broad entailments) over the more specific "outer space" illuminate these practitioners' struggles to legitimate their activities, their aging bureaucratic organization and its technologies, and to make beyond-rational emotional appeal for their work in a contemporary context. As Steven Shapin has described in his analysis of scientists struggling to re-enchant their organization-based jobs and inventions with vocational meaning and the innovative spirit, many of the people and groups featured in this dissertation see themselves as guardians of astronautics' – and of NASA's and America's – virtuous truth-producing potentials. In contested and uncontested ways, "the extreme" is being mobilized in that struggle.[16] The "extreme" can be scientific but it can also be aesthetic, charismatically edgy, and ecologically moral; it invokes futurism but not necessarily the played-out futurism of a failed space age.

The ubiquitous use of "extreme" also points to the presence of social contradiction and paradox. For example, at the level of NASA space center practice, work with the "extreme" brings promotions of astronautics' sexy-cool riskiness together with efforts to utterly eliminate risk from experiences of working and living. People designing far-out forms of totally integrated extreme environment habitability see their work as a way to open up new ways to live yet also to normatively systematize habitation processes. In addition, at the level of national environmental debate, astronautics has a long record of contributing to extremely polluted "space age" landscapes, and, despite official and non-governmental "green" technology development work by NASA-affiliated personnel, publics of all kinds scoff at the idea that human space exploration's enormously expensive and arguably unjustifiable extreme ventures can or will do anything to directly improve environmental technologies or knowledge. However, the astronautical "extreme," in practice and in science fiction, has also provided environmental theorists with ways to situate grand epiphanies and visions, these often depicted as if they are being had from a vantage point in the spatial or temporal extremes of space or the future. Contemporary American ecologists imagine the future of life on Earth in astronautical terms as a kind of "return" to an original planet, such as ex-NASA contractor James Lovelock's "Gaia,"[17] or as an arrival to an utterly hostile one, such as Peter Ward's vengeful "Medea."[18] There is also Bill McKibben's "Eaarth," the title of his book predicting the human need to adjust to the permanent transformation of our planet. The book was released with jacket image featuring a small whole Earth rising – or setting – behind a giant black "X."[19] The astronautical "extreme" is therefore invested with hopes for an enlightened environmental future, but also fears of a cosmological spatial flip-flop in which Earth becomes as uninhabitable as outer space. In American astronautical thought and practice can be found both the romance and terror of the temporal and spatial extreme, where terrestrial and extraterrestrial and familiar and alien ecologies exist side by side, available for comparison.

Billboard, NASA Road 1

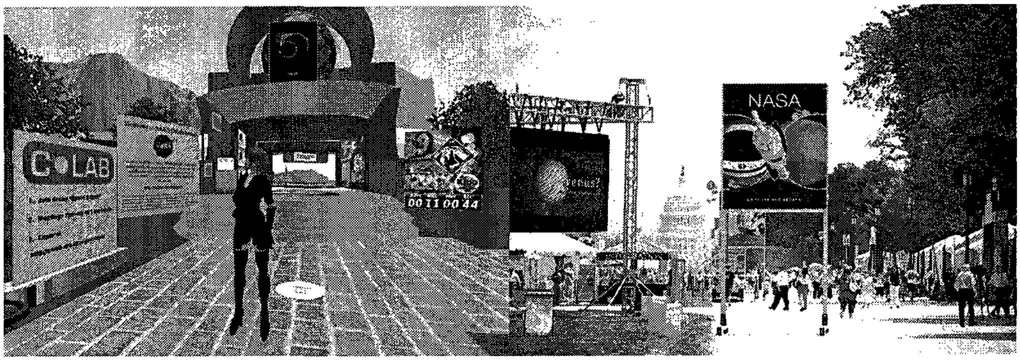
In and of NASA: fieldwork site and methods

I conducted most of this research onsite at Johnson Space Center (JSC) in Houston Texas between April 2005 and December 2007, although my work there also took me to other NASA centers and into other kinds of astronautics institutions and networks. Built on lands leased from Rice University and officially contained within the Houston metropolitan area, JSC opened in 1963 as the "Manned Spacecraft Center." It became one of NASA's ten far-flung centers of American governmental astronautics projects and funding. Politically situated as much to modernize the American South as to open up outer space, JSC, like other Cold War R&D centers, nurtured the growth of local space industries and their political and economic infrastructures. These infrastructures were critical to what Stephen Collier describes as ongoing regimes of Cold War era preparation in which enacting processes of "getting ready" for the future and its new spaces are as important as the actual staging of programs.[20] After the Apollo program achieved President Kennedy's mandate to send a man to the moon and return him safely to Earth, JSC continued to follow presidential mandates aiming American technologies, people, and policy ever outward, from orbital foreign policy/science laboratories like the

Apollo-Soyuz test program, to the military/technology/science multi-use Shuttle and Space Station programs, to the Constellation program's objective to establish American control over an "extending human presence into the solar system." This program's proposed vehicle "architecture" of human-rated and heavy-lift vehicles, which NASA Administrator Mike Griffin referred to notoriously as "Apollo on steroids," was intended to replace the Shuttle transportation system, enable the construction of a lunar base, and, with modification, take humans to Mars. When I began this work, internal documents that could explain the Vision for Space Exploration's genesis as a policy were still unreleased to the public (or marked with the Bush-era invention "sensitive but not classified") and are only now becoming available. As a result, the body of the dissertation preserves and reflects the processes by which I, often with my NASA interlocutors, sought to make sense of how and why this program came about, politically and historically.

JSC spreads across 1,600 square acres in what is called the Clear Lake area of the Texas Gulf Coast, surrounded by the military and aerospace company complex it supports, including Ellington Field Air Force Base and offices for aerospace and defense company giants such as Boeing, Lockheed Martin, Jacobs Engineering, and SAIC. Next to JSC is Space Center Houston, JSC's education and visitor's center, which serves as a kind of museum and low-key indoor theme park offering tram rides onto the JSC campus to visit designated tourist spaces like the historic mission control center, the park that houses the Apollo-era Saturn V rocket, and the huge hanger that contains full-sized Space Shuttle and Space Station astronaut training mockups. JSC made Houston into America's "Space City," and Houston proper as well as the little towns that grew up around these industries display the persistent, if now well-weathered, array of outer space references that used to add dazzle to aspects of Houston's daily life: "Apollo Car Repair," Saturn Boulevard, "NASA Flowers," the Astros baseball team, the Rockets basketball team, and the Astrodome attest to fifty years of astronautical space on Earth. American astronauts are still required to settle in the Clear Lake area, where streets are named after them, and memorials to their fallen start at JSC's memorial grove and spread outward across the country in the form of elementary school names and space learning centers. The religious life of the JSC area is vibrant, and although many of my interlocutors avoided direct discussions of their religious practices, most evidenced belief or spoke of their membership in one of the area's local congregations, including the large Grace community mega-church that held two JSC employee funerals I knew of when I was doing fieldwork, two Unitarian congregations that often sponsored talks linking spirituality with science and technology, and a Houston synagogue whose rabbi spoke with me about its collection of "Space Judaica" items used in space. In general, the aerospace industry in Houston is in a social, economic, and political holding pattern at best and at worst a steady decline, increasingly interpreted by historians, journalists, and cultural studies analysts as disappointing or long-overdue evidence of the end of the promised "space age."[21] But also visible today are signs of the industry's new small scale and tenuous entrepreneurialism. "New Space" technology and tourism start up companies, such as Bigelow Aerospace and Ad Astra, have offices in the area and are eagerly awaiting promised Obama administration funding.

JSC people I met with often asked me to guess NASA's yearly funding appropriation, confident that I, like other people they spoke with, would be surprised at its paltriness: during my fieldwork period NASA's funding hovered at $16 billion a year and .7% of the federal budget.[22] During Apollo, the NASA took about 4% of the national budget, a figure that my interlocutors sometimes used as a benchmark for how much civil astronautics could be counted to matter to American taxpayers. NASA funds are distributed not just to NASA centers and their home states but also around the country through other systems of grants and awards. Within NASA centers, one of the biggest sources of controversy and disputation how funding for "science" (robotic and remote sensing) and "human spaceflight" funding is allocated; although the numbers were often disputed, 2007 budget numbers indicate that it is possible to argue, as I heard scientists claim, that "science" funding was "half" that of "human spaceflight." Overall, people perceived these numbers and their cyclical changes to reflect electoral politics that affect the political and economic power of their centers, something I noticed when I found a hand-written calculation of these differences complete with hand-drawn map entitled "NASA's political geography" tucked into an archived technical report. When I arrived at JSC, the Vision for Space Exploration had shifted NASA funding toward applied technology research and development and away from basic science research, a shift that meant that JSC would achieve significant project funding allocation control for what became the $4 -7 billion per year Constellation program. With the cancellation of Constellation in 2010 interlocutors predicted a significant shift in funds back to NASA's basic research centers, such as Ames Research Center and JPL in California, and possibly outward to the NewSpace entrepreneurs.



(l) NASA Second Life Co-lab with NASA 50th anniversary banner 2008
(r) Smithsonian Folklife Festival 2008 / courtesy NASA

The problem of NASA's age as an institution, the legitimacy of its claims as a future-maker, and questions about the future of human spaceflight were a particularly hot topic during my fieldwork at JSC. From the time I arrived, people at JSC already thinking about NASA's upcoming 50th anniversary as an agency and 40th anniversaries of human spaceflight milestones, including the 2009 anniversary of the Apollo 11 lunar landing. As I describe in Chapter 1, twenty-first century NASA has been simultaneously trying to revamp its image and capitalize on its established identity as an American icon. In 2008 it became the second government agency to be featured in the Smithsonian Folk Life festival, where it set up booths next to the year's other featured "folk" cultures, "Texas" and "Bhutan." At the same time, at NASA Ames Research Center in the Silicon Valley of California, young social networking entrepreneurs hired by the Center's director were building a vast virtual NASA agency-world, complete with virtual space technology–design and cosmos exploration spaces, on the computerized commercial virtual world environment platform, Second Life. Heralded as a way to re-enchant the public with NASA work and hook them into programs like Constellation, this work could also be ironically disturbing to NASA's human space exploration programs, as virtual technologies to turn robotic and remote sensing data into public experiences of space provide justifications for a retreat from human spaceflight. The work of the Constellation program was therefore also an engagement within NASA with its own social and cultural environments, particularly its internal intergenerational environment -- poignantly evidenced by the nostalgic folkiness of its human spaceflight history juxtaposed with the futuristicness of its virtual environmental potential. I saw this at JSC, where the campus seemed, as data on its engineer and scientist workforce indicates, to be made up largely of (self-termed) "geezers" and much younger interns and "fresh-outs" (of university).

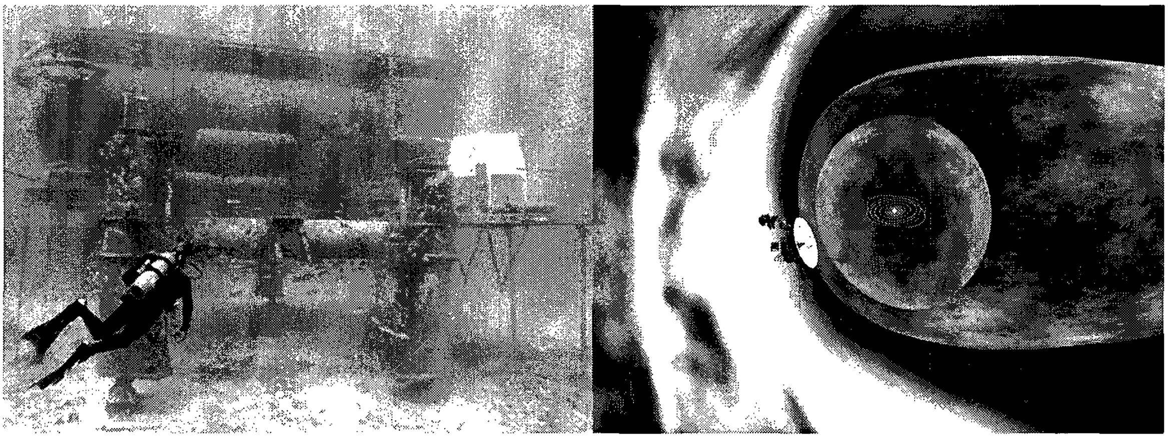
In 2007, the National Research Council released a workforce report confirming what I observed during my fieldwork and what was a constant topic of conversation at JSC: NASA's scientists and engineers are still by and large white and male, younger on average than other aerospace workplaces but aging relative to the rest of U.S. worksites, and represent a shrinking employment sector.[23] NASA currently employs 18,000 civil servant workers at its ten field centers and supports the work of 40,000 contractors and awardees. JSC is home to over 3,000 civil servants and supports 12,000 contractors. Government civil service demographics records show that JSC's civil servant population is half male (64%), white (74%), and classified as "engineers" (93%).[24] Two thirds of civil servant men are classified as scientists or engineers as opposed to about half of women, and earn on average $7,000/year more than women (males earn an average of $122,000/year). Men of all race/ethnicity groups are equally likely to be classified in the "scientists and engineers" category and to have comparable salaries. Although the classification "engineer" also includes people trained in other fields, its dominance as a category and practice at NASA, particularly at technology-focused centers like JSC, validates the prevailing native description of the agency that I heard often: "this is an organization by and for engineers." However, the batches of young people I saw at JSC represented the continuance (although reportedly slowing) of NASA's historical "co-op" program, in which students take work-study and post-graduate positions. JSC managers told me that this program used to be a way in to a NASA civil service position, but that it has now become a revolving-door training program, with most young people choosing higher paying technical jobs in the private sector.

I gained access to JSC and its surrounding commercial contractor companies as a government-badged (if quite a bit older than average) intern. I was hired in 2005 to work for the National Space Biomedical Research Institute (NSBRI), NASA's funding administrative organization for extramural life sciences research headquarted in Houston's Texas Medical Center. Obtaining my first badge took over three months to complete and was handled by a NASA security contractor; to receive a badge I was photographed and fingerprinted. By the time I left JSC, managers reported that badges were becoming more difficult to obtain for temporary workers and I heard that RFID tracking technologies would soon replace manual badge checks by security personnel at the gate. During my NSBRI internship I shared office space at the Wyle Laboratories buildings down the street from JSC, where I was assigned to work with a project manager there. My internship took me beyond Texas, including stints at the National Undersea Research Center site in Key Largo Florida, where, as I describe in Chapter 1, I worked as a research assistant for three "NEEMO" (NASA Extreme Environment Mission Operations) underwater space analogue missions in April 2006 (NEEMO 9), May 2007 (NEEMO 12), and August 2007 (NEEMO 13). I also followed JSC space analogue, space biomedicine, and space human factors networks to Ames Research Center in

Mountain View, California, where I conducted interviews and attended three conferences (two lunar science conferences and one "New Space" commercial space conference) in 2007 and 2009. In addition, I conducted archival research and a set of interviews at NASA Headquarters. Conferences were also important sources of ethnographic information. I attended two American Astronautical Society conferences (Houston, Texas) and one International Astronautics and Aeronautics Association conference (San Jose, California). From October 2006 through January 2007, I did three months of fieldwork at the European Space Agency, where I worked as a staigiare (intern) at ESTEC technical center in the Netherlands. I conducted a limited pilot version of the project I was conducting at NASA; these data provided an experientially comparative background for my NASA study but are not incorporated into this dissertation.

I recruited sixty-eight interlocutors for my dissertation project study using non-systematic ethnographic methods that have become time-honored means for moving within fields and among social groups. My NSBRI internship gave me access to NASA space biomedicine and analogue circles, where many of my regular interlocutors were working colleagues. As an intern, I also interacted with a variety of people whom I did not formally recruit for interviews. Because of the disciplinarily and institutionally integrated nature of NASA projects, it was possible to meet and interact with interlocutors through a kind of rhizomatic[25] search and sampling schema. I blended different kinds of recruitment and research methods in order to traverse, in appropriate ways, social domains usually separated by categories such as friendship, collegial association, supervisory relations, formal interactions, and circumstantial association. This flexible schema was important as I moved through a government institution that requires security clearance and which has a history of becoming increasingly inaccessible to publics without tokens of access or to members of the media or others seeking "inside" views. My rhizomatic approach did not prohibit me from deploying informal criterion and purposive sampling strategies[26] that allowed me to approach potential participants based on professional and demographic characteristics, and my interlocutor pool of civil servants, contractors, and out-of-NASA networked people (formally recruited and informally associative) is comparable to JSC's general civil servant demographic profile.[27] One of the key venues for this hybrid rhizomatic/purposive sampling strategy was my weekly participation in informal Thursday morning "Exploration Faithful" (aka "Explorogroup) meetings moderated by Assistant Director for Exploration for the Astromaterials Research office, lunar scientist Wendell W. Mendell. On the whole, most individuals I approached generously agreed to participate and help me with my project.

In the dissertation, I use a combination of real names and pseudonyms for places as well as people. The majority of the people I worked with, recruited for my study, and got to know within NASA and astronautics networks consented to the use of their real names. However, to go the extra mile to protect personal and professional privacy, I use a variety of identity protection techniques. Following ethnographic precedent, I use pseudonyms when possible but also real names when referring to people's publicly documented appearances, roles, statements, or published work. Therefore, a few people are "split" individuals in this document. In addition, I deploy other means to hide identities if necessary, including modifying demographic or biographical information. Also, I sometimes obscure the true designations of locations, such as buildings, even though I was not required to do so. I may have gone overboard in taking such precautions and some individuals may have preferred to be identified directly, but it is my intention to communicate, analyze, and respect, in the best possible ways, the extraordinary experience I had among NASA's people.



Aquarius underwater habitat / courtesy NOAA
Heliosphere and spacecraft / courtesy NASA

Habitat to Heliosphere

The following chapters lay out four ethnographic spaces in which I encountered the making of astronautical visions and ecologies, from habitats to the heliosphere, and followed the thematic thread of "the extreme." Chapter 1 is about my experience as an intern working on the NEEMO 9 extreme environment analogue program, in which astronauts and technicians enact space-like missions in an underwater habitat. I argue that the analogue serves as both a simulation of and an argument for human spaceflight. As the analogue mission operates, it connects acts of reasoning *about* extending into extreme environments with rationales *for* why and what it means to do so, specifically by interrelating the mission's training, exploration, science, technology testing, and promotional activities. By showing how the NEEMO program emerged within a domain of argument and justification that it also contributes to, I show how American astronautical practices proceed to make claims about the kinds of human progress possible through contentions with extreme environments. NEEMO enacts an argument that "extreme environments" in general are inherently generative for bodies, societies, and technologies, and that they provide also some "ultimate" premises for truth claims about a cosmological *telos* for human environmental experience. As such, NEEMO missions evince an American astronautical *and* environmental narrative that extending human presence into the solar system advances against the specter of human ecological limitation and social collapse.

Chapter 2 moves into the extreme medical world of space biomedicine and argues that, in an inversion of the usual clinical model, astronaut medical subjecthood is fundamentally environmental rather than biological. In extreme environments like outer space, the concept of environment cannot be bracketed out from life processes; as a result, investments of power and knowledge shift from life itself to milieus: sites of interface among living things, technologies, and environments. To illustrate what this means on the ground, I describe space biomedicine as form of environmental medicine that seeks to optimize and manage technically-enabled human ecologies where life and environment are dually problematized. I provide examples of what I term its "ecobiopolitical" strategies enabled by the exigencies and contingencies of extreme living: creating a new "space normal" physiological category, situating humans as at-risk elements within integrated biological/technological/environmental systems, and the development of space suits that are not just explorations in how to blend biology and technology, but are explicitly aimed at improving the scope and scale of capacities to shore up or break down human/environment boundaries and limits.

A return to habitats grounds Chapter 3, in which I spend time among space architects and industrial designers trying to design lunar habitats and to better define the elusive but critical concept of "habitability." The chapter examines in-formation ideas and practices centered on the technical and creative formalization of what counts as "habitable" space, and the connections between thinking and enacting that this work fosters. It focuses in particular on how and why space architects work to make extremity habitable, and how through this work they articulate generalizable truths about human/environment interaction and offer solutions for technical, political, and ethical problems of contemporary terrestrial human habitation. JSC is where the chiefly conceptual work of spacecraft and habitat building is centered, and as a result, "habitability" becomes an "elaborating concept" that doesn't just organize space-work but allows space architects and designers to give shape to their expectations that "humanizing" extreme environment habitation can innovatively "environmentalize" un-extreme living, evincing the politics, ethics, and aesthetics of kind of technical environmentalism. I examine how NASA habitability concept work intersects with burgeoning American architectural and design interest in post-catastrophe, low-resource, recycling-intensive, autonomous, and semi-closed loop living designs, including following habitability work out of JSC, where it takes the Americana-esque form of a prototype camper-trailer built by a JSC architect-consultant.

Finally, Chapter 4 documents the heliospheric imaginary and politics of American asteroid deflection and exploration activism. By entering an informal "rebel" multidisciplinary JSC working group which tries to advocate for crewed missions to Near Earth Objects (NEOs; comets and asteroids with nearby or Earth-crossing orbits), I track how NEOs have moved from being obscure astronomical objects at the edges of the solar system to key objects in an intersection of astronautical and environmental policy. Viewing NEOs as threats, sources of raw materials, and sources of information on the primitive solar system, the JSC "NEOphiles," as they call themselves, are connected to a broader network of scientists and engineers trying to advocate for comprehensive national and international programs to deflect NEOs headed for Earth, and, in doing so, to formalize politics and ethics for cosmic "planetary defense." As such, NEOs are not only the cosmological but also the ecological "boundary objectifiers" of a heliosphere that matters for Earthly life, as astronautics activists link the future of space exploration and management to the future of the human species.

In presenting an ethnography of space as environment, I attempt to bring ethnographic specificity to American astronautical claims that we earthlings live in a cosmic ecology, and how people at NASA act on that idea, imaginatively and technically. I focus on the simultaneous work and thought involved in making that spatial and environmental claim, within and across different institutional and disciplinary spaces, primarily at Johnson Space Center but also beyond it. By choosing to look at this process in the domain of human spaceflight, rather than in robotic and remote-sensing science, I attempt to show how central and yet how troubling the environmental "human" is for astronautics practitioners, as experts and as citizens, working in NASA programs. Robotic and remote-sensing astronautical science is less overtly controversial and as such I found it a less compelling entrée into the meaningful question of space as environment. Human space exploration has been a contentious national investment for fifty years, and as someone who grew up with this controversy, I took on the attempt to examine its practices as well as its political and ethical ambiguities and anxieties. As such, this study attempts to present how American astronautics practitioners work with the sometimes irreconcilable multifaceted "human" of that controversy. Facets include the powerfully symbolic "American human spacefarer" of United States' military-economic security and expansionist policy, the astronauts of Johnson Space Center, and the cosmically transcendent and trans-environmental human of an imagined limitless and environmentally integrated future. Part of the work of justifying and making a place for this multi-faceted human in America, as I found out, is not just to build rockets but a cosmic ecology for it, making it possible to relate little spaces of survival and habitation to larger ones of dreams and destinies, to know and manage extreme constraints and undo extreme limits, and try to prove that there is something essentially American about doing so.

------//------

---

[1] From a text by Michel Foucault (translated by Jay Miskowiec) that was published as the article, "Des Espace Autres," in Architecture /Mouvement/ Continuité in October 1984 (issue 5, pp 46-49); accessed at: http://foucault.info/documents/heteroTopia/foucault.heteroTopia.en.html.

[2] Williams (2010).

[3] Accessed at: http://anon.nasa-global.edgesuite.net/HD_downloads/exp22_flythrough_1080p.wmv

[4] Accessed at: http://www.cbsnews.com/stories/2010/02/15/assignment_america/main6210779.shtml

[5] Latour (2005: 211).

[6] I cite some of this literature in the body of the dissertation; other literature not cited is also foundational to the public understanding of NASA history. A circle of historians and policy analysts with unusual access to NASA continue to produce most of the scholarship on the American space program, explaining its cultural changes according to the influence of three general historical and political factors: the relationship between American political leaders and NASA's upper administrators (cf Logsdon 1986, Launius and McCurdy 1997, Handberg 2003), the program's "natural" decline from a strong technical culture which promoted a frontier mindset of acceptable risk to a "weakened" bureaucracy (cf McCurdy 1993), or ever-widening disconnects between the popular culture of space-age expectations, space policy concerns, and government agendas (cf McCurdy 1997, Launius 1999), including the "robots versus humans" policy debate (Launius and McCurdy 2008). W. Henry Lambright is known for his application of concepts gleaned from science and technology studies so that he can explain the ways NASA technologies such as the shuttle and space station are socially shaped (Lambright 1994, Lambright and Schaefer 2004). Other writers have produced notable books on NASA work culture such as New York Times space columnist Henry S. F. Cooper's *Before Lift-off* (1987), *Managing Martians* (Shirley and Morton 1998), a manager's memoir and retrospective description of NASA's scientific and managerial systems to coordinate robotic rover missions between earth and Mars, and investigative journalist Bryan Burrough's extensive reconstruction of American experiences in the Shuttle Mir program (Burrough 1998).

[7] Henry and Taylor (2009) analyze past and current space photography and art as on a trajectory to representing space traveled environments as worthy of protection as extensions of the Earth's environment.

[8] Some notable but limited exceptions to this are environmental theorists like Ingold (2000) (see Chapter 4 note 38) and Berleant (1992; on the way the aesthetics and perception of extraterrestrial environments suggests the need for a recomprehension of "environment"), also work by environmental historians on extraterrestrial environmental ethics (1986), and work like that of Kohler (2002) and Robinson (2006) that bridge environmental history and the history of science.
[9] See environmental anthropologists Dove and Carpenter (2008: 1 - 85) on the genealogy of "environment" as a topic of philosophical and later social scientific inquiry.
[10] NASA Space Act (as amended) Section 102.d.1: http://www.nasa.gov/offices/ogc/about/space_act1.html
[11] Jasanoff and Martello (2004).
[12] See Gusterson (1996), Masco (2006), and Zabrusky (1995).
[13] See note 11 and Epstein (1996).
[14] Although it is beyond the scope of this dissertation to prove, the former "space race" mandate to demonstrate national technological capability may in some ways be in the process of being replaced by mandates to prove "environmental capability," from remote sensing to habitation technologies.
[15] Along with citations for work on medical enhancement, extreme sports and tourism, body modification, extreme organisms ("extremophiles") provided in Chapter 1 note 15, see also theoretical work by Foucault (1995), Agamben (1998).
[16] Shapin (2008) crafts a compelling discussion of scientific future-making as a process in which scientists negotiate their own values and visions of innovation with those of organizations and funders.
[17] Lovelock (2000).
[18] Ward (2009); see also Lovelock (2006).
[19] McKibben (2010).
[20] Collier (2008).
[21] From the late nineteen-eighties forward, there has been a growing sub-genre of "end of the space age" literature. The son of a Cape Canaveral engineer, American literature scholar William Atwill writes *Fire and Power, the American space program as postmodern narrative* (1994) to show how the uneasy civic conscience of the space program is expressed by its literary contemporaries who chronicle the termination of its early heroic vision and expose its "noble" "misdirected" and "wasteful" attempts to change society through rocketry. In *Rocket Dreams, how the space age shaped a vision of a world beyond* (2003), journalist Marina Benjamin searches for the survival of the utopian communal goals of the early space age by attending astronaut autograph conventions, talking with Roswell hitchhikers, playing in internet space gaming sites, and touring the SETI institute. She concludes that the space age that was based on NASA's model of rocket-propelled human space exploration is exhausting itself, but that it has colonized our minds by enriching our inherent urge to technologically expand our cosmic sense of place from our "earthly confinement" (Benjamin 2003: 216). Journalist Andrew Smith's *Moondust, in search of the men who fell to earth* (2006) is a collective ethnobiography. He interviews six of his childhood heroes, the remaining Apollo astronauts, in their home locations in order to characterize their adjustments to life after the moon and, by doing so, he assesses the character of the "mature" space age. Replicating the persistent thematic link of human development to the human experience in space, Smith claims that the legacy of the dying space age is not to be found in new technologies, but in a new way to see and experience life as an earth-bound human, a journey that each of these aging astronauts eventually pursued. Another notable requiem for the space age is popular literature scholar David Lavery's *Late for the Sky, the mentality of the space age* (1992). Lavery interweaves literary and mass media examples to show that this "mentality," and the modern cosmology that has grown with it, is actually made up of a dialectical struggle between "the real 'two cultures,' " one which is earth-focused and the other which is space- focused. He moves for abandoning the literal mode of space exploration, to explore the more legitimate earthly human domain of inner space. Greg Klerkx's *Lost in Space* (2004) is an attempt to find the contemporary social venues that will sustain the space age. He relies mostly on texts and media for his analysis but also sought firsthand experience with the Mars Society by camping out on remote Devon Island to observe one of their mission simulations. Although Klerkx's book is mostly a topical analysis of what he sees as the loci of space age inertia (NASA) and enthusiasm (for the Mars Society, the Space Frontier Foundation, SETI), he provides an insightful theoretical contribution in the form of space development perspectives typology.
[22] Unless otherwise indicated, budgetary figures are retrieved from http://www.nasa.gov/pdf/202960main_NASA_FY07_Financial_Report.pdf. Other estimates place NASA's percent of the federal budget as low as .5%. As a point of comparison, a Congressional Research

---

Service analysis claims that the U.S. total Department of Defense-allocated budget for space operation is $22.5 billion for FY06 (accessed at the Federation of American Scientists' website: http://www.fas.org/sgp/crs/space/RL33601.pdf).

[23] National Research Council (2007).

[24] I derived these statistics (current as of 2/2010) by manipulating data cubes on available from the NASA Shared Services Center: http://nasapeople.nasa.gov/workforce/data/WICNCurrent.htm

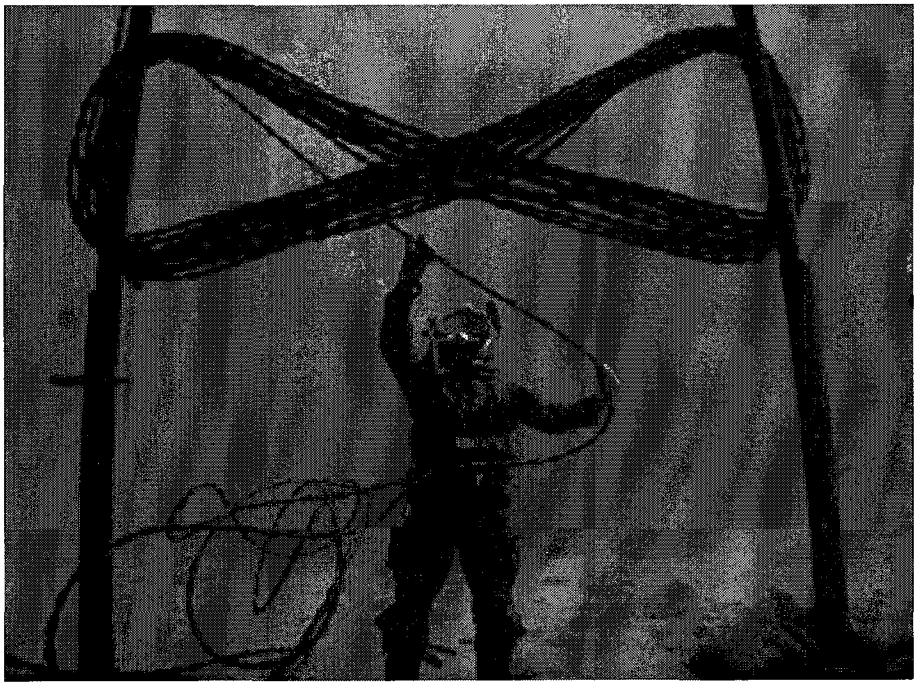
[25] During his dissertation defense in May 2005, Rice anthropology doctoral candidate Brian Riedel deployed Gilles Deleuze and Félix Guattari's (1987) conceptual image of the "rhizome" to describe this "horizontal" method based on the daily living circumstances and research experience-seeking that constitutes ethnographic fieldwork, especially in contexts in which concerns about trust and secrecy are important.

[26] Bernard (1998) and Schensul *et al* (1999).

[27] Comprehensive demographic information on contractor pools is not available as it is for civil servants.

Chapter 1
Per Aspera

Per aspera, ad astra.
[Through adversity, to the stars]
-- Latin motto used by NASA and space advocacy groups[1]



NEEMO 13 aquanaut manages his air hose "umbilical" / Courtesy NASA

The view of durable buildings and grassy swales from Curt Mansfield's office window is calm and orderly, belying the veteran engineer's endless engagement with adverse environments and dicey futures. It's October 2004, nine months after President Bush mandated the new Vision for Space Exploration. About to retire from Johnson Space Center, Curt has taken on a non-technical job with the hope of finding ways to "control" the public relations "environment" so that human extensions into the solar system will be accepted as vital to the future.[2] What is at stake is NASA's claim on the future an American -- and by discursive extension "human" -- environment. Also in the balance are dreams and lifetimes of labor. Curt has worked on all of its post-Apollo engineering programs since he was nineteen, and witnessed three decades of attempts to justify human space exploration in documented commissions, panels, polls, and consultant reports, some of which he gestures toward while he talks. I am in his office interviewing him with a Rice University classmate because we made a fieldwork course project out of our curiosity about how NASA, our institutional neighbor down the I-45 freeway, promotes human space exploration. Surrounded by spacecraft models and marketing books, Curt bluntly sums up the root cause of what he calls a "strategic positioning" problem:

> …[NASA engineers] didn't use [the end of the space race] as an opportunity then to move beyond the technical to figure out why, *why* should this country really send people into space? Even on the rare occasions when we did, it was just in rhetoric. Well, 'we should because destiny of the species, yada yada yada, yada yada yada.' It was fodder for speech. It never took root in building a structure that actually shaped what we did around what we concluded was the reason to do it.

He goes on to make analogies between different kinds of exploring, and to illustrate how exploration inspires progress. But his critique of "just rhetoric" justifications and also of NASA's entrenchment in "the technical" harbors a perspective on what good human space exploration justifications should be and do: justifications should be built into processes and things that evince them.

New American human spaceflight programs intensify acts of justification and exploration, and this chapter examines how and why astronautics groups bridge those activities. Human space exploration is still not securely "black boxed" as a given technical or social fact of American life, plaguing its advocates with the unending challenge of how to simultaneously argue for and build human spaceflight programs in uncertain contexts. Soft-power logics of prestige and high-ground strategic advantage provide only one dimension of this justification arena, which extends into pre-space program astronautical arguments about what it means to overcome, inhabit, evolve, and transcend. As a result, there is a half-century of entangled lines of reasoning about why humans should extend into the solar system, what NASA should build and do, and how to connect reasons with actions. Curt's practiced critique of NASA's disconnected realms of saying and doing is one I often came across as I started my dissertation fieldwork at JSC. Verbal data such as Curt's interview would have been my basis for understanding how astronautics practitioners make arguments for human space exploration had I not been recruited, soon after my interview with Curt, to work as a paid intern for the undersea NASA Extreme Environment Mission Operations (NEEMO) "spaceflight analogue" program.[3] In fact, on the day I spoke with Curt, NEEMO "aquanauts" in Florida were "splashing up" from a mission to the seafloor, having merged exploration and justification, and having made a case for human engagements with adversity as a phenomenological mission within a mission.

A group of JSC technical experts with frustrations and goals like Curt's operated the first NEEMO mission in 2001, later giving it the charter "to advance NASA's ability to extend human presence across the solar system by the affordable and innovative use of spaceflight analogues." NEEMO is the most complex of NASA's past and present exploration analogue programs. Six crewmembers survive and work in an underwater habitat off the coast of Key Largo while being supported from land by a small mission control team set up in NOAA's National Undersea Research Center. By running as situationally and procedurally "analogous" to spaceflight, NEEMO missions combine astronaut training, science and technology activities, and public education and outreach. When I began working as a research intern for the NEEMO 9 mission in 2005, I noticed that it proceeded from start to finish like a tactical response to Curt's critique, by simultaneously building toward and contending for an environmentally extendible human future. This is even more pronounced because, unlike other space analogues that focus on the scientific analogousness of planetary geologies or biomedical conditions, NEEMO's environment is generalized as "extreme" and its objectives are catholic.

I found, in other words, that this analogue mission has more to do than simulate human space exploration -- it *is an argument* for it. What I mean by this is that as a NEEMO space analogue mission operates, it connects acts of reasoning *about* extending into extreme environments with rationales *for* why and what it means to do so. These connections take the form of explicit verbal justifications, but are also enacted implicitly via analogy and demonstrative interrelations of the mission's training, exploration, scientific, technological, and promotional activity strata.[4] While argumentation and space mission operations may seem to be two different kinds of activities, one rhetorical and one practical, NEEMO missions call attention to their commonality as procedural activities that have things to prove. To be sure, all space missions and other non-analogical space activities coordinate argument and operation but NEEMO missions are vivid cases in point. By showing how the NEEMO program emerged within domain of argument and justification that it also contributes to, I show how American astronautical practices proceed to make claims about the kinds of human progress possible through contentions with extreme environments. At the same time, I make a case for recognizing how technoscientific practices make arguments that are not exclusively verbal and in fact take other forms in order to be more convincing. In focusing not just on the analogue *per se* but how argument and the value of environmental struggle animate it, I aim to show how contention is a modality that bridges the social, practical, reasoning, and affective dimensions of American human space exploration.

Critical to the NEEMO argument, and a central concern of mine, is how "extreme environments" serve as premises for truth claims about a cosmological *telos* for human environmental experience. The category "extreme environment" is a modern grouping of natural and social spaces that threaten life and pressure human endeavor because they are unpredictable and "elud[e] normalization," whether biological, psychological, social, or technical.[5] Extreme environments are topical for the NEEMO analogue in a practical sense, but also in the sense of being strategic *topoi*, according to the classical rhetorical definition of *topos* as a place from which to argue.[6] The *in situ* argument proceeding from NEEMO missions is that extreme environments are not just threatening but also extremely productive in social, technological, and ecological terms. This case rests on the Darwinian-inflected supposition that extreme environments are inherently generative because they *are* abnormal, providing fruitfully agonistic spaces for some bodies, spirits, things, processes, and societies in ways that (in a kind of conditional Lamarckian corollary) can transform humans as a cosmic species. According to my interlocutors, extreme environments spatially "force" and temporally "accelerate" biological and technological innovation, a perspective not unique to the human side of astronautics but also shared by astrobiologists and robotics engineers.[7] When NEEMO missions analogize sea and space as these kinds of extreme environment, the U.S. human space exploration program strengthens a powerful authoritative narrative, which takes the form of a kind of macro-ecological project that can't be absolutely reduced to an exercise of military soft power or an expansion of national territory. As such, NEEMO missions evince an American astronautical *and* environmental narrative that extending human presence into the solar system advances against the specter of ecological limitation and social collapse.[8]

I make my bid for understanding a NEEMO mission as an argument by using Stephen Toulmin's (2003) model of argument as a practical and situated procedure of justification. In doing so, I follow a now common social scientific view that scientific, technical, and exploratory processes are narratives. But I also call attention to how argumentation can be built into and significantly shape such narratives.[9] In *The Uses of Argument*, Toulmin outlines how arguments, even if not formally logical, are coherently constituted through the integral steps of making grounds, warrants, backing, rebuttals, and qualifiers in order to substantiate claims.[10] I suggest that these elements are not just features by which arguments can be evaluated, which is a prime concern of Toulmin and other argumentation theorists. They are also -- for the purposes of social scientists interested in modern relationships between rhetoric, narrative, performance, and material culture -- criteria by which things and processes might be recognized to *be* arguments. Toulmin's formula breaks from a tradition of treating arguments as formally logical theory-making speech acts, maintaining instead that argumentation is more generally describable as the practical "procedure" by which people narrate and justify claims in social context.[11] Although Toulmin's concern is with ways of reasoning rather than rhetoric, his emphasis on "how" claiming and justification work invites deeper consideration of how artful persuasion may proceed in fields such as engineering and operations that revolve around procedural events and processes.[12] His model also indirectly backs social scientific scholarship on the situatedness of knowledge claims and how projects based on universal ideals are shaped by the social "frictions" that call their claims to account.[13] Consequently, Toulmin's model gestures toward a broader anthropology of argument, one in which a NEEMO mission can be understood to anchor what informal logician Peter Weddle terms an "argument ecology" of issues, reasoners, audiences, and points to be made.[14]

This introductory chapter outlines how NEEMO's argument about the inherent productivity of extreme environments is 1) embedded within a broad argument ecology and 2) operates procedurally; in doing so, the chapter also establishes some of my dissertation's key lines of argument. I hope to contribute to emerging ethnographic investigations into the ways people imagine and socially incorporate "the extreme" *per se* as a productive condition and space, a topic of study currently centered on the social construction of disability, aesthetics, body modification, medical enhancement, and extreme sports and tourism, with emerging but still limited attention to technoscientific projects.[15] Second, in this chapter I hope to add to analyses of expert arguments and the forms they take, particularly in practices like engineering, operations, and exploration, which may have distinctive processes and goals that are not reducible to those of science.[16] In addition, I want to examine human exploration's distinctive forms of demonstrative theorizing and argumentation on its own terms without foreclosing it as an inadequate and outmoded substitute for remote and robotic science.[17] As such, this chapter focuses less on the scientific and technological analogue reasoning that is concerned with comparing Earthly and space experiences, and more on the ways that controversies about what count as legitimate forms, spaces, and reasons for experimentation and testing are bound up with arguments about the "real" value of extreme exploration and today's American human space exploration program. By holding that NEEMO is as fundamentally "argumentative" as it is "technoscientific" I am not trying to divert attention from what NEEMO is: I am trying to foreground *how* arguments within and about human space exploration have a role in what human space exploration as a technoscientific practice has *become* – particularly, what it is doing on a deeply terrestrial and watery Florida seafloor.

In contributing ethnographic data to these lines of investigation, I support my dissertation's larger goal to outline how government-funded technoscientific engagements with extreme environments enrich powerful emerging discourses about human futures, evolutions, and ecologies. If, as historian of modern biology and medicine Georges Canguilhem notes, the "state of health" has come to be understood not just as conditions of non-illness and normality but as the capacity of "man" to "dominate the environment and organize it according to his values as a living being,"[18] then, as I argue overall in this dissertation, nation-building extensions into extreme environments have become more than colonial and military reterritorializations. They promise the endless revitalization of modern subjects and societies within experimentally improvable and flexibly scalable ecologies that appear profoundly and unarguably natural exactly because they are presented as environmentally cosmic in dimension and authenticity. I pursue this topic further in Chapter 2 when I examine the conceptual, practical, and lived notion of a space biomedical "milieu."

In what follows, I present first my conceptual and theoretical grounds for viewing NEEMO as a technoscientific argument-in-action.[19] Then, based on my participation in a total of three NEEMO missions, I use sentinel examples from the planning and execution of its flagship mission at the time, NEEMO 9, to illustrate how and why NEEMO operates and argues at the same time. I conclude with my own self-conscious immersion in the mission as an "honorary aquanaut," through which I call attention to the embodied experience of being enrolled in the argument for extreme exploration.

Histories and forms of astronautical justification: from analogical arguments to analogues that argue

> When asked to judge between competing arguments in which they have little or no expertise, people will fall back on the most compelling vision.
> --The Center for Cultural Studies and Analysis, *American Perception of Space Exploration*
> (on Curt Mansfield's desk, October 2004)[20]

In Curt Mansfield's claim that fifty years of human space exploration justification can be summed up as "destiny of the species, yada, yada, yada, yada yada yada," the "yadas" include analogy-making practices still at work in 2004. When NASA was authorized into existence in 1957, American human space exploration advocacy discourse moved from pre-War grassroots advocacy contexts[21] taking place at the edges of government, academia, and industry and into the center of coordinated Cold War nation-building where future directions for Americans and "humanity" were being developed in aeronautics and astronautics R & D centers. After Apollo, American presidents and NASA still convened blue ribbon panels of diverse advocates to make cases for human space exploration as a national and "human" priority, but, as Cold War support for space racing became dated and Reagan-era support for space militarization receded into well-funded but low-profile shadows, increasing numbers of critics began to label the space age and NASA as directionless and obsolete.[22] An ongoing "humans versus robots" exploration debate divided scientific and human exploration stakeholders, and opinion polling reported sliding support for human space exploration.[23]

When President Bush announced the Vision for Space Exploration in 2004, NASA had the challenge of justifying a human lunar exploration program without Cold War ideology and urgency. The Vision interleaves narratives about human environmental transcendence with lines of reasoning about how outer space extensions sustain and grow American technoscience, society, and economy. The NASA history department began to countermand a negative public relations environment by publishing an online essay series entitled "Why We Explore" to catalogue the interdisciplinary evidence for a human "primordial urge" to explore and endorse NASA's role as a "premier agent" for that urge.[24] However, NASA also invited employees as well as citizens to enter essay contests to answer this "why" question, as if creating avenues for justification strengthened NASA's justification discourse. NASA Administrator Mike Griffin justified the program nationally and internationally while U.S. "space coast" stakeholders lobbied hard for their established military-industrial and nascent commercial space industries. To lend credence for its "return to the moon" campaign, NASA expanded its arguments in websites like "Why the Moon?" and "NASA @ home and city" that informed taxpayers that "space" (a metonym for spaceflight- and human exploration-enabled spinoff technology) productively "exists in your environment" and is ever more evident "everywhere you look." NASA "participatory exploration" programs offered citizens a chance to act as "proxy" explorers of the solar system or visitors to virtual NASA worlds.[25] Bush science and technology advisor John Marburger characterized space as an environmental extension of America's "economic sphere."[26]

Although Cold War claims about the value of claiming territorial high-ground in space obtained in fears about a rapidly growing and secretive Chinese space program, martially-flavored justifications fell behind the making of arguments focused on space as a site of challenge that ensures evolutionary potential, access to capitalizable resources, and the thriving of modern social and political ecologies. By 2008, NASA officials were instructing people to replace the term "vision" with "program" in communications, signaling the materialization of the Constellation program; however, the making of human spaceflight justifications continued, a process centered in large part on the making of analogies.

In these twenty-first century argument arenas, analogies –discursive as well as material – continue to be a key technique for human space exploration justification. Despite the reputation of analogy as an inferior form of scientific reasoning, space scientists, engineers, and exploration advocates have come to depend on them for use in work with huge gaps in time and space and between knowns and unknowns – in both technoscientific and sociopolitical domains. Analogies made to verbally justify space exploration are not only simple one-to-one comparisons, they often interrelate several kinds of progressive processes: space exploration is evolutionarily analogous to prehistoric migrations and "voyages of discovery" which are analogous to how a child learns to walk, stand, reach out, leave home, mature.[27] Backing these contemporary analogies is astronaut Neil Armstrong's famously terse metaphor on the lunar surface in 1969, in which a man's "steps" are like social, technical, and environmental "leaps" forward in space and time.

Analogies that claim space exploration to be analogous to evolutionary and developmental processes set the stage for procedural activities like missions to demonstrate an argument-in-action. Using work by analogy and argument theorists, and complementary work within social scientific studies of science and technology, I hold that the "leap" needed to regard NEEMO as an argument is not a long one, and broadens possibilities for anthropological investigations of both analogy and argumentation.

Scholarly work on scientific analogizing and argumentation outnumber studies of analogizing in engineering and operations, but such work provides key general insights into how and why analogies are made and used in technoscientific practices.[28] As psychologists Holyoak and Thagard argue in their influential survey of analogical thinking across social domains, analogizing structures "leaps" or "steps" of reasoning from the known to the unknown so that scientists can learn (or evaluate what can be learned) through comparative bridging and extensions.[29] Holyoak and Thagard specifically describe analogy as the mental process of mapping a known "source" onto an unknown "target," which is the definition used by JSC in its centralized analogue program database.[30] Analogy and metaphor theorists suggest, as space advocates know, that philosophical and scientific analogies gain illustrative and persuasive power when they manage to mobilize "multiple analogies" made up of many analogous components rather than one-on-one analogies.[31] In addition, these theorists demonstrate that scientists will use non-scientific analogies in order to illustrate and promote their claims and theories within and beyond laboratory settings.[32]

Social scientists have pursued the significance of analogy making strategies beyond the laboratory, arguing that the use of scientific analogies to validate non-scientific processes give them an important social "life." Importantly, as Nancy Leys Stepan argues in her analysis of how analogy biologizes justifications for racism and sexism, that social life is not predicated on whether analogies are intrinsically right or wrong.[33] In such analogical schemes of claim- and truth-making, analogous things themselves come to represent the collective "steps" of social and scientific reasoning. Comparative fact-making about race and gender come to reside in evolving skulls and bodies,[34] models of life processes built on analogical reasoning represent and "perform" essential truths about life, [35] and comparatively extreme environments like "ocean" and "space" evoke analogical comparisons, such as a shared "alienness" or "primitive vitality," that animate and justify technoscientific investigation and activity.[36] The analogue components of analogies, therefore, are things that represent complex social processes of argumentation and justification.

Scholars of science and technology routinely explore the dynamic relationship between the scientific and technological processes and rhetorical strategies such as analogizing, storytelling, and arguing -- but come just short of describing discrete assemblages of things and activities, analogous or otherwise, as arguments. Studying controversy and its epistemological manifestations and entailments is a mainstay in the social studies of science, a pursuit that originated with a focus on cycles of contestation and resolution as the mechanism by which theories and "paradigms" change, [37] the processes by which contests over fact-making methods and facts themselves become stabilized and epistemic,[38] technologies and processes become new material "platforms" for theory and work, and "core sets" of scientists mobilize scientific and non-scientific knowledge as tactics to promote their arguments.[39] Such foundational literature focuses on how technologies are shaped by the controversies they are designed to solve or render moot,[40] a move that opens the door to examining how processes like experimentation might be or work as arguments. In this scholarship, technology design controversies and arguments represent conflicts of interest among networked associations of living and non-living "actors" and also as contests of power and ideas that shape project successes and failures.[41] Diane Vaughan, in her thorough recapitulation of the ill-fated Challenger shuttle launch decision,[42] tracks the role of argumentation in determining how engineers decide to adhere to or deviate from established procedures, revealing entanglements of technical, economic, political, and institutional activities that are in her words, the "solidification of argument."[43]

Theorists of science and technology have come to blur the distinction between discrete "things" and the processes of association, activity and discourse that assemble and disassemble them, calling attention to how such "assemblages" "perform" not just the functions for which they were built but others required by the different social domains to which they matter. This makes it possible to leap to understand how such assemblages can perform argumentatively or, indeed, how procedures of making things or events proceed to argue.[44] It's possible to say that space shuttle crashes are also engineering decisions and justifications in the process of failing,[45] or that patients enrolled in using digital health care ID cards put the arguments for the cards' use into action,[46] or that the Moon has a history as place of argument, first for "reflexive" social critiques[47] and later for comparative planetary science (see Chapter 4). These studies consider arguments historically and forensically, but invite ethnographic attention to processes of argument in action. The NEEMO habitat, like a space shuttle, shows through its extended material and associative network of "operations" the unbounded nature of technoscientific arguments in general, and how they are extend beyond their formal verbal articulations.

Stephen Toulmin portrays arguments as acts of justification that rely on "logically practical" procedures that have internal validity to arguers and audiences, even if they do not follow the "analytically ideal" rules of argument. Arguments are, in his words, engaged in "the actual business of arguing."[48] As an astronautical analogue in the service of extreme environment exploration as well as space exploration promotion, NEEMO is on a mission to argue from the seafloor. Mirroring Stepan's interest in how analogies work in a larger context, Toulmin advocates "seeing and describing the arguments in each field as they are, recognizing how they work, not setting one's self up to explain why or demonstrate that they necessarily must work."[49] A widely engaged scholar whose work straddles philosophy and social science, Toulmin promotes analyses of argumentation using "considerations" that are historical, empirical, and, he ventures tentatively, "even – in a sense – anthropological."[50]

Toulmin specifies that all arguments have have features geared toward securing the "practical" advantages of well-justified claims, something that analogue missions are certainly doing. In Toulmin's model, argument claims become "grounded" when people marshal evidentiary "warrants" they confirm through legitimate "backing." "Backing" is a situational practice in which claimants marshal evidence, demonstrations, and data that will work in their "field." Warrants can come from different domains to support the argument-in-process; they can be historical, aesthetic, moral, ethical, psychological, legal, disciplinary, and theological according to the field in which the argument is being made. That field is what informal logician Perry Weddle calls an "argument ecology" made up of associative and dynamic environments of issues and audiences.[51] In Toulmin's and Weddle's perspectives, the "grounds" of an argument are not just conceptual but environmental in the broadest sense. Arguments have spatial and temporal dimensions, including situated claimant-audience relationships in which place and conditions matter and ongoing processes of "rebuttal" and response by audiences and publics. In this model, arguments, like missions, *happen.*

With my foundational argument for viewing NEEMO missions as arguments-in-action now out of the way, I begin my ethnographic analysis. First I describe how my internship introduced me to the scientific and political argument ecology in which NEEMO is situated and in which extreme environments are portrayed as inherently productive, spatially and temporally. When I got into JSC, I found out how and where NEEMO is located within the history of spaceflight's analogical contentions and argumentative undertakings. Then, using my experience working on NEEMO, I provide examples of how NEEMO works as an argument through enacted procedures, and the effects of that process on me as a brief inhabitant of – and potential claimant in favor of – that argument.

The futuristic argument ecology of mission programs and planning

While I could have pursued access to the planning and execution of "actual" International Space Station missions, I fell into an opportunity to work on NEEMO. These analogue missions represented a larger set of interrelated things I wanted to understand further: astronautical analogies, the general category of extreme environments, and ways of instantiating the future. The NEEMO mission planning I became involved with right away was occurring in support of the new Constellation program's aim to replace the Shuttle and Station programs with activities geared toward getting out of low Earth orbit. As a result, NEEMO pre-mission planning defines a broader historical, spatial, and institutional argument ecology, highlighting foundational claims being made about the social value of extending into extremes. I entered this ecology as an intern for the National Space Biomedical Ressearch Institute (NSBRI) helping to align, via a choreography of mission procedures, the complementary exploratory and self-justificatory goals of the NSBRI, NASA, and the NEEMO program. If I expressed this as an analogy, it might look something like this: `Preparing for NEEMO 9 : extreme environments :: preparing for the future : bridges across space/time gaps.` That analogy contends that space "is" time, and that extreme space "is" the future. This contention grounds the claims, analogies, backings, and warrant-making activities that constitute NEEMO 9's futuristic argument ecology through procedure.

I entered NEEMO's argument ecology and its institutional network at the same time. After speaking with Curt Mansfield in October 2005, my Rice colleague and I interviewed one of his colleagues, a high-level life scientist manager who eloquently mixed terms from American political theory and biology claiming that NASA was facilitating the "human" "manifest destiny" to "evolve" in space. At my request to find a way "in" to how this was happening, the manager put me in touch with Dr. Sara Rengler, a charismatic and experienced psychologist at the NSBRI. Rengler invited me to assist on the NEEMO 9 mission, which was to have the same biomedical focus as the NEEMO 7 mission that was ending on the day I met Curt Mansfield. She was in need of an experienced research intern for a multi-faceted space behavioral health "feasibility study," and, intrigued by our common interest in science and technology history and also by my former career as a research manager, she offered me an NSBRI internship. The NSBRI is NASA's centralized extramural medical research funding organization and is tucked within a neuroscience center in Houston's enormous Texas Medical Center.

Within the NSBRI's world of extramural space biomedical research coordination, NEEMO is one site within an extending geography of research sites, from sleep labs to submarines, which are bridging spatial and temporal extremes. Dr. Rengler explained the "human" bridge that NEEMO crews make for NASA and NSBRI science and technology researchers. As they move just a few miles off shore and only a few dozen meters down into the sea, crews become extremely isolated and confined in an "alien" place that physiologically "saturates" them – a process in which their acclimation to an unearthly ambient pressure of 2.5 atmospheres pushes bodily gases into tissues, rendering crewmembers unable to return to land without eighteen hours of decompression. They are as "far" away as space station astronauts.

These conditions and the relative frequency and accessibility of NEEMO missions make it a promising testbed not just for long-duration space mission problem-solving, but also for building up NASA's claims that spaceflight and Earthly research are linked. In such bridge-making, the "distance" between an environmental normative center and environmental extremes is understood to be essentially temporal,[52] representing a gap between known and unknown but also between better ways of living improved by the exigencies of exploratory extensions and innovations. As Peter Redfield argues in his comparison of the "ecology of modern expertise" involved in the co-architecting of colonial and global outer spatial governance regimes in French Guiana's modern prison and space agency launch sites, "high technology" is compelled to redefine the limits of the "inherently cosmopolitan and active environment" within which modern subjects and modern governmental systems are imagined to be comprehensively advancing -- socially, spatially, and temporally.[53] According to the logic that supports such an ecology of modern expertise, the extreme risk and cost of spaceflight and its innovations are justifiable on the grounds that environmental and social advancements are linked together as processes in transition. Space analogues and space/terrestrial research collaborations have long sought to justify that claim.

Analogue space

More analogue space exploration missions "launch" each year than flights into outer space, representing a new extremely situated iteration of lab-based experimental goals to make humans and things survive space. The original NASA "space analogue" was not an analogous mission but rather an analogue *body*, a computerized "biocybernetic" simulation of the "human system" proposed in 1963 by contractors in the short-lived Cyborg Program as a way to model options for "engineering" space-adapted humans.[54] By the 1970s, however, the term "space analogue" came to refer to configurations of human/machine/environment interactions that could be scientifically investigated in artificial or controlled conditions. NASA and extramural researchers concerned with long-duration space habitation risks began to analyze medical and psychological data collected in living conditions that they determined to be space-analogous —in isolation chambers, underwater vehicles or stations, and polar outposts.[55]

In the late 1990s, NASA developed space analogue missions that combined elements of laboratory-controlled simulations, astronaut survival training, and field-testing in far out "space-on-Earth" worksites. Unlike formal simulations or workaday training exercises, space analogue missions are conducted in the field for days or weeks at a time and are narrated by participants as comprehensive and risky space-like situations. As a result, analogue missions, like space missions, require the technological and social means to innovatively solve problems by managing life and work functions together under extreme limit-testing stresses. These are what Stephen Collier calls "enactments" of risk through an "event model" (the analogue mission) that assesses future risks but also creates knowledge about "collective life" faced with future dangers; however, as I will show, astronautics enactments *in situ* are considered the vehicles through which *improved* collective futures emerge, bolstering a "politics of truth" about mechanisms of progress and evolution.[56] Space analogue missions become, with space missions, events for knowing and controlling as well as optimizing human life. Although my NASA interlocutors were involved or following only six "space analogue" programs being conducted hospital research wards, isolation chambers, meteorite craters, arctic deserts, and at sea during my fieldwork among them, JSC also hosted in 2007 an "analogue summit" that produced a database with 58 historical and contemporary "projects," "facilities," and "sites" counted as part of an analogue data-collection field.[57]

As a space analogue that requires life-support technology, NEEMO is a descendent of late 20th century government and private undertakings to make closed loop experimental ecologies: micro-environments that demonstrate and justify ways to better understand ecological processes by building and operating them as technologies. Although it is not technically a closed loop system, NEEMO is the latest in a series of what became known in the 1980s as "controlled ecological life-support systems" (CELSS). Also called "bioregenerative controlled ecological life-support systems" and advanced life support systems, these were government military dual-use projects like the Tektite and Man in the Sea programs and privately funded projects like the controversial and only partly successful Biosphere II project to enclose humans within a self-regulating environment (the Earth is Biosphere I). These ventures flourished in the U.S. from early 1970s through the early 1990s, a period described by W. Patrick McCray as the height of "visioneering" projects undertaken in response to 1970s discourses about humanity's trajectory toward crises of spatial and resource limitation.[58] NOAA's *Aquarius* habitat, built in 1986 and interchangeably designated "the world's only underwater laboratory [or] habitat" represents an early proposal that NOAA would be a "wet NASA" to conduct Apollo-style underwater exploration missions.[59] As such, NEEMO missions further "visioneering" era understandings of Earth as just one among many possible biospheres. In 1990, NASA Administrator Thomas Paine multiply-analogized the shared claims of government and private experimental ecologies:

> In this historical context, I see Biosphere 2 as a shining beacon pointing the way to an expanding future for humanity. Closed ecology systems can free us from Malthusian limitations by making the Solar System our extended home. For the first time in the history of evolution, the human intellect can extend life beyond Earth's biosphere, following the lead of species that left the oceanic biosphere to inhabit dry land billions of years ago. In the 21st Century, a network of bases throughout the Inner Solar System, interconnected by space transportation and communication infrastructure, can sustain vigorous high-tech civilizations evolving on three worlds.[60]

In the tradition begun by Presidents Kennedy and Reagan, undergirded by utopianism and romanticism, Paine likens American exploratory trajectories as the way to the "shining city on the hill" that would be watched by "the eyes of all people" as described by American colonist John Winthrop in his 1630 ocean crossing. Paine also situates space programs on an upward reaching branch of a social Darwinist model of civilization in which transcendent evolutionary adaptations can be recognized not by biological or social structures but by technical infrastructures. I heard such colonial-style justifications later, after NEEMO 9, when I continued to interview NEEMO participants. One white space physician couched his acknowledgement of American colonial genocide and greed between truth-claims, steeped in analogies, about a "human" ecology of progress:

> The common themes that people always talk about is, but they're still true, in that you have to have a vehicle or reason to improve.... And many times that's economic, or exploration, or political, or perhaps even greed or any of those bad things, those are all human things, but if you look back on history, some of those things actually had a lot of good that came out of them. Now it wasn't so good for the American Indians, but by Spain and Portugal and other people wanting to explore, they increased trade, then they were able to find a new location to do that, and they were able to develop the United States, and other than the American Indians who should be celebrated for what they are and we did it wrong how we did it, but I think any American who's living in the United States can look directly back and should look directly back at Portugal and Spain and France and England for them being who they are. The rest of the world, we have to develop a location like the Americas to be able to interact and trade [...] So, until you're able to go and explore, then you're not gonna benefit. And if the Queen of Spain and the King of England and whoever was in charge of Portugal, they had lots of human problems, they had lots of public health issues, and a lot of poor people, and they took that seed money and they invested it, and we're able to make, and probably every other scientist says the same thing, but that's the truth.

Space represents an unmarked site for human "improvement" for an unmarked but privileged "you," where money is biologized as seed.

In supporting this vision of human ecological mastery in transition, NEEMO provides NASA and its funded network of researchers with raw material for a justified cosmic-level ecology. NEEMO serves, in ways imagined by Administrator Paine and the space physician, as a "world" in which to build technological capacity as well as to claim that extreme environment research agendas are logically interrelated and transcend "transitory" social specificities. In the NEEMO literature I read as I began to work for Dr. Rengler, JSC organizers describe NEEMO as the only analogue extant that is both "operationally" and "environmentally" analogous to future deep space exploration missions. "Operational" means that the analogue's procedures are as close to actual spaceflight as possible. Although there are disputes among government and non-government space analogue practitioners, such as between NASA and the Mars Society space advocacy organization, about which analogue settings best represent space exploration missions, NEEMO organizers paint a picture of a politicized environmental hierarchy of more or less operational analogues, more or less aligned with dominant trends in Earthly and astronautical progress. They also make it clear that the best analogue missions can coordinate the worlds of expeditionary operations, cutting edge science and technology, and effective public outreach. At NEEMO, that outreach comes from the *Aquarius* habitat as if it already exists elsewhere than Earth, reminding people that they are on an ecological trajectory that is moving forward in space and time. NEEMO's capacity to do all of this is what made it interesting to Rengler's NSBRI colleagues. Like NEEMO 7, NEEMO 9 was centered on a telemedicine project conducted by a Canadian telemedicine research institute affiliated with the Canadian Space Agency, the Hamilton University's Center for Minimal Access Surgery (CMAS), and supported by the U.S. Army's Telemedicine & Advanced Technology Research Center (TATRC). In spring 2005, I began working with Dr. Rengler's project manager, Sue Devitt, to pull together the suite of NSBRI tests and experiments for in the upcoming eighteen-day NEEMO 9 mission slated for September 2005.

Extending space research and research space

The NSBRI presents itself, like NEEMO, as a sentinel bridger of extreme spaces and times and as such, provides backing for NASA claims to benefit Americans and humans in general. The NSBRI's stated aim is to fund extramural researchers to "provide medical monitoring, diagnosis and treatment in the extreme environments of the moon and Mars" and then "transfer" those innovations to Earth for patients "suffering from similar conditions" to astronauts, such as "osteoporosis, muscle wasting, shift-related sleep disorders, balance disorders and cardiovascular system problems."[61] A plethora of research papers and outreach bulletins tout the NSBRI's mission to hasten biomedical futures, claiming that both astronauts and long-distance truckers will be able to use self-testing technologies to prevent fatigue-related accidents, that treatments for radiation-induced osteoporosis will help endangered astronauts on Mars as well as cancer patients, that "futuristic" non-invasive "Star Trek"-like monitoring technologies can measure metabolic rates for spacewalking astronauts and earthbound cardiovascular patients, and that telesurgery will extend expertise into socially peripheral environments like the Moon and remote Earthly communities.[62]

In NSBRI research projects, "extreme environments" are sites in which current and future problems can be solved at the same time. A warrant for this approach comes in part from the assumption that in extreme spatial edges, all people, from elite astronauts to remotely disadvantaged communities, are clinically marginalized and at risk. Remoteness in this model is a function of distance, overshadowing remoteness as a function of sheer lack of access. "Gaps" are spatially operationalized and imagined as collapsible through clinical technologies that are extendible and mobile, thereby enrolling humans at the "edges" of modernity – whether Earthly or extraterrestrial – as clinical progress pioneers. Such claims are grounded by the idea that the space between centers and extremes is temporal in two ways: it is a problem space for synchronizing the deployment of expert interventions, and it is a productive space in which both modernity and technology are forced to improve through modes like miniaturization, portability, and remote monitoring. The category "extreme environments" include Earthly and cosmic "outer spaces," incorporating them as zones that manifest progress through adversity.

The NSBRI suite of experiments and procedures that Dr. Rengler assembled and that Sue and I started to coordinate in spring 2005 came from six groups of NSBRI affiliated researchers across the nation who had had experience with research in space, but for whom this space-analogous sea mission represented new and potentially more accessible extreme site in which to investigate sleep/wake cycles, fatigue, perceptual vigilance, stress, and teamwork. The NSBRI Principal Investigator overseeing the substudies, sleep expert Dr. David Dinges of the University of Pennsylvania, had had some of his research and equipment "flown" on space shuttle missions but classified the whole NSBRI NEEMO 9 payload suite as a "feasibility study" to acknowledge that the equipment, tests, and surveys are being extended beyond their original environmental operating parameters, from space and Earth to the sea. The NSBRI experiments on the psychology of extreme environment experience would be made to fit in with as many extreme activities as possible, particularly those of CMAS. CMAS was planning to collect neurological and experiential data on telemedical task performance simulated in computer programs or in a surgical set-up in which an operator works on a foam body-analogue with simulated flesh and blood while receiving long-distance mentoring from CMAS surgeons. The habitat would also house a small telesurgical robot in its tiny bunkroom, to be controlled by CMAS principal investigator Dr. Mehran Anvari from a strange throne-like chair I saw while visiting his Center in Canada. A big demonstrative goal for CMAS: to tie the first telesurgical knot under water. As with all NEEMO missions, other long-time NASA collaborators paid to be involved, such as SRI International, which planned to test "next generation" robotic "assistants" planned for military as well as industrial and astronautical applications.

Although I knew that the Army was involved, my experience of the military as a background presence in NEEMO illustrates how the military pursues its interests in extreme environments and in defining the meaning of the extreme. As one young engineer told me, it was very infrequent to come across anyone with military clearance; and, NASA work was subject to ITAR review but people didn't refer to their products as "classified." I learned that NEEMO aquanauts would be using recently declassified NAVY dive equipment, and that TATRC was going to simulate extreme battlefield stress during the aquanaut telesurgical experiments, but these details and the people involved in them floated in and out of my direct experience, as did my exposure to military interests during meetings and through the circulation of information, which was fragmented and vague. Nevertheless, during the NEEMO mission prep process, I heard pro- and anti-military sentiments from some of my NASA-based interlocutors who often described military involvement as a means to an imagined peaceful astronautical end. In a "multi-use" context in which extremes are enrolled into claims about the future of national progress and security, the military is a key element of the NEEMO practice and argument ecology. As Joseph Masco shows in his ethnography of the sublimely threatening but shadowy presence of "the bomb" as the structuring element of Cold War cultural logics, [63] the military secrecy and objectives were a shadowy presence in NEEMO 9, evident in its capacity to make military telemedicine part of the "civil" space program's aim to co-constitute territorial and extreme environmental nation-building.

As the summer approached, Sue and I worked with other NEEMO-bound technology and science research teams, as well as JSC's Public Affairs and Educational Outreach offices, to integrate and interrelate the NSBRI experiments and tests into the NEEMO 9 mission timeline, and by extension, into the future of normative human life processes improved by knowing their limits. This merges medical and environmental monitoring in the extreme. The crew's sleep/wake cycles would be tracked by "actiwatches" worn to register light changes and motion and through sleep-quality questionnaires. Before most of the CMAS telemedicine tasks and NASA exploration dive activities during the mission, the crew would complete questionnaires supplied by social psychologists from the NASA Ames Research Center to record their perceptions of physical and mental demands. They would also turn video cameras on their own faces for researchers developing optical character recognition software to detect micro-expressions of stress, anger, and fatigue, but which I also heard described as contributing to terrorism-prediction research. After tasks, the aquanauts would collect spit and send it to us on land so that Dr. Dinge's sleep lab can measure their cortisol levels as an indicator of stress. The aquanauts would also take a computer test designed to provide them with cognitive fitness feedback, which was analogized as a kind of basic "life sign" by being referred to as a "blood pressure cuff for the mind."[64] During periods of time during the mission, two aquanauts at a time would wear a complex body-suit full of physiological monitoring sensors invented by investigators at Ames Research Center. At the end of the day, each crewmember will do a round of "perceptual vigilance testing" using handheld testing devices from Dr. Dinges's lab. In addition, all the internet video and onsite video made during the mission would be analyzed by researchers who study social proxemics to determine team cohesion.

My role as a data collector reflected a new and strategic direction in the psychological understanding of extreme environments -- not as pathological but mentally and emotionally enhancing.[65] I would administer some standard and novel surveys developed by social psychologists located within the NASA Ames research center that would determine the stressful but also adaptive features of team behavior. This research protocol included a timed "creativity test" that would measure whether or not extremes foster innovative thinking. Within this web of interconnected research goals and spaces, extreme environments appear not as social or environmental exceptions but as the limits of an extended human ecology through which, through useful technology spin-offs, a fully normalizable and optimized future emerges.

As the mission date approached, Sue and I also began to pre-incorporate ourselves into the NEEMO operational environment and to be seen as invested team members, by traveling and by starting to get physically immersed. In order to understand the environment we were adapting our study suite to, and because we wanted to fit into the NEEMO social world and be invited to dive down to observe the habitat, Sue and I also learned to SCUBA dive. During the year, we threw ourselves into swimming pools and muddy south Texas lakes learning to dive, determined be able to think and speak as "NEEMO divers" as well as researchers. My *in situ* introduction to the NEEMO argument environment came as I started to hang out onsite at JSC with NEEMO organizers, learning about the institutional dimensions of NEEMO's argument ecology.

NASA in the extreme

Able to come and go from JSC as a badged intern, I spent time with NEEMO's organizers and learned more about the program's contentious history to justify itself as a logical dimension of NASA's mission "to explore," not just space, but an analogically connected archipelago of extreme sites. NEEMO occupies a precarious position as a controversial new program focused on extreme environment exploration within a threatened U.S. program dedicated to outer space. The ways NEEMO organizers justify their ocean-based analogue to a space agency calls attention to the larger argument ecology of contemporary exploration advocacy. Like historical artic and space exploration advocacy, NEEMO's organizers celebrate facing risk *in extremis* on behalf of the U.S. as a nation, but unlike those ventures that were bound up in the staking-out of territory in specifically national terms, NEEMO organizers advocate for "the extreme" as a social-ecological space. Their arguments in favor of the generative extreme make use of persuasive analogies and generalities that create universalizing slippages not just between now and the future, as we have seen, but also between territory and environment, bodies and spirits, science and exploration, technologically enabled survival and evolution, and Americans and humans.

To get into JSC, I would drive off I-45 freeway, pass the Webster city gate that declares itself "gateway to the future," turn onto Saturn Boulevard and drive up to the front gate. There, employees and visitors are greeted with an analogy: a little herd of Texas longhorns grazes next to a stand of rockets. Brought to JSC in 1997 as an homage to its ranchland past and boost student involvement at the center, the scatter of impassive cattle adds a whiff of living history to the air blowing around the stark black and white rocket cylinders. This scene juxtaposes and analogizes two American ages, two kinds of energetic power, two kinds of modern space, one territorial and one environmental. As material symbols of territorial expansion and adaptability, cattle and rockets signal that spaces that become habitable, from ranches to air-conditioned buildings to pressurized space capsules, can become useful.[66] It also acts to refute the late 19th century "Turner hypothesis" (authored by historian Frederick Jackson Turner) that the American frontier is closed by indicating that "frontier" has multiple meanings.[67] It reminds JSC visitors that the Cold War cosmology NASA helped to create was based both on securing territory and making uninhabitable spaces productive through environmental engineering. With "extreme environment operations" in its name, the NEEMO program exemplifies one dimension of that shift.

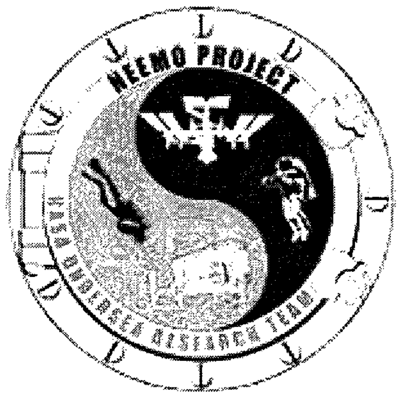
As I headed for the tiny NEEMO office "bunker," I traveled through Building 4's "Mission Operations Directorate" that oversees the Shuttle and Station programs and into hallways bedecked with U.S. space mission emblems, posters, and big brilliant photographs taken from Earth orbit. To enter the NEEMO bunker after this walk is like going into a little transcendental nautical bubble within outer space. The narrow bunker is a converted two-room storage area festooned with trans-national and trans-historical representations of underwater exploration history and popular cultural references that make up the symbolic and technical paraphernalia of a program working hard to justify itself. Occupying the NEEMO bunker when I began to visit for meetings were the two people who argued NEEMO into existence through years of negotiation with JSC administrators. Bill Todd is a 20-year veteran astronaut trainer who grew up in Mercury astronaut Scott Carpenter's neighborhood in Clear Lake, fascinated by his neighbor's saturation dive experiments in the 1960s. Marc Reagan is an engineer, space station trainer, and former aspiring astronaut who also serves as a flight controller. Behind Todd's desk is an artifact from British polar exploration history, Anglo-Irish explorer Ernest Shackleton's recruitment poster for his vaunted Antarctic expedition on the wooden ship *Endurance*:

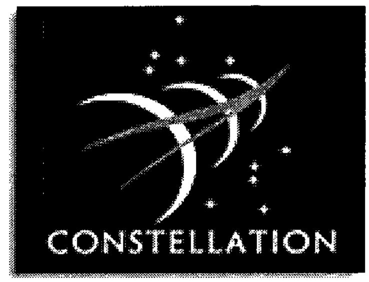
> Men wanted for hazardous journey. Small wages. Bitter cold. Long months of complete darkness. Constant danger. Safe return doubtful. Honour and recognition in case of success.

This "men wanted" advert draws attention to the masculine and distinction-based social worlds of extreme environment exploration, and sense of being called as well as dared that are central tropes of NASA discourse.[68]

This advert also emblematizes Bill and Marc's struggle to make a robust argument ecology of socially-backed and warranted claims for their vision of what NEEMO and NASA should be known for. The NASA they envision is not just expanding a nation into space, but is committed to understanding and incorporating all manner of extreme environments as sites that can keep NASA, Americans, and human beings in general moving into new survivable spaces as a way to ensure evolution, transcendence, and ethical and practical authenticity.

NEEMO symbolism also depicts arguments about the value of the categorical and environmental extreme. As with space programs and missions, NEEMO has a program logo and each mission crew designs their own patch, keeping some symbolic elements continuous. The logos and patches featured on the bunker's walls and on the program's materials, digital displays, and archives are as much unique program emblems as they are a way to re-frame NASA's identity as an "extreme environment" agency.[69] The program's general logo renders two human extreme environmental scenes into a ying/yang symbol framed by a nautical porthole, adding further meaning to *Aquarius*'s identity as a station to access "inner space." It is as if those environments, and the people geared up to go into them, are ecologically and technically complementary, sharing a





journey of enhancement and even enlightenment. NEEMO mission patches from 2004 onward feature the Constellation program's optimistically vectored topology of progressive destinations, but add the sea to the "Moon, Mars, and beyond" trajectory, indicating that the ocean is an originating site for the human ecological and evolutionary journey. In this schema, the "extreme" is a constellation of terrestrial and extraterrestrial sites, knowledge, and experience that is analogous. As one NEEMO participant explained to me, *all* astronautical missions should be regarded as analogues for subsequent missions: "that's why we call ISS [the International Space Station] an analogue… we have [also] used the term "Mars forward"…a Mars forward objective is any objective that utilizes the Moon as an analog for Mars." Given these symbolic and rhetorical features, the NEEMO program's logos, patches, and charter act as enthymemes: rhetorical statements with assumed or syllogistic elements. Namely, that humans have, can and therefore should extend themselves into extremes, and that extreme exploration is a part of human nature.

The idea that human nature and destiny lies in contending with and mastering a succession of progressively extreme sites exemplifies what David Nye has called the American "second creation" foundation narrative, in which new sites of occupation and technological development are imagined not as final and unique destinations but as springboards from which to engage and normalize the next productive site.[70] In its rhetorical abstraction, the "extreme environment" is imaginable as the ever-receding spatial and temporal edge of a known ecological cosmos that now extends, via human capacities and machines that are both understood to be "evolving," into the most uninhabitable environments imaginable. In the NEEMO bunker, a poster commemorates the early saturation dive projects that aligned the progress of technology, the endurance of bodies, and a new perception of what counts as human ecological space. The first French aquanaut Robert Stenuit expressed the cosmological perspective of those projects: to open up a "second universe" in which "the improbable is normal" and in which new environmental resources, material and spiritual, provide a "guarantee of the future."[71]

Part of NEEMO's bid to situate itself and take positions on the future, includes, as with the NSBRI, the claim that it bridges gaps. For NEEMO organizers, those gaps are not just technological, temporal, and spatial but indicative of NASA's, America's, and by extension humanity's, capacity to keep or lose a commitment to improvement through extreme risk-taking. Such gaps are also understood, as if borrowing from ecological anthropologist Roy Rappaport's argument in *Pigs for the Ancestors*, as a difference between practices associated with a "cognized" versus "operational" environment.[72]

Todd and Reagan started NEEMO as way to solve training and perceptual gaps caused by the "flip the switch mentality" of workaday environmental simulations that gloss over the need to cultivate other kinds of practices to survive an actual operational environment.[73] However, at the same time, they understand themselves to be countering gaps in NASA's stated commitment to engage with extremes and the actual amount of time the organization spends doing it. They see analogue missions as an integrated experience of pre-adapting technologies and people to representative environmental conditions in order to "drive technology by the appropriate end users," where end-use is situated use. To "get relevant data" that increases the use-value of new technologies, Todd told me, "you've got to do it in this [extreme] environment," otherwise "you could do it in a lab."

As historian of biology Robert Kohler and exploration historian Michael Robinson both argue, fieldwork and exploration practices have a history of disrupting the controls and social conduct ideals that have come to characterize the legitimate practice of "science."[74] Todd and Reagan and other NEEMO supporters are passionate advocates for "science" as a general category of practice, but they advocate for ways to legitimize science and technology testing done in the field. In this way, they advocate building what Kohler calls a "boundary" worksite, part laboratory and part fieldsite, that contextualizes science as one dimension of a larger argumentative narrative about the social and biotechnological value of exploration.

Defending NEEMO

Within JSC, a skeptical cadre of laboratory-centered scientists and engineers actively opposes NEEMO. NEEMO's advocates portray it as a "real" mission program that builds the capacity for science and technical innovation to be done in uncontrolled settings while engaging the public, but detractors label it as a thrill-seeking "boondoggle."[75] One life scientist complained to me that NEEMO experiments to test planetary surface equipment prototypes on the seafloor are expensively redundant. "They coulda done that in the [Neutral Buoyancy Laboratory] pool here," he told me, "not go to the Bahamas [sic]....the deal is: they needed things to justify their presence." A senior planetary scientist also complained that there were little in the way of peer-reviewed articles coming from NEEMO, just enthusiasm for it as a popular adventure and a lot of unused data. Ironically, these objections to NEEMO mirror arguments against human spaceflight within a broader argument ecology. In the contemporary national debate, those who defend exploration as a proving ground full of intangible benefits like "inspiration" and tangible benefits of technology "spinoffs" are locked in disagreement with those who claim that exploration projects justify experiential spectacles that are only tangentially beneficial to society. This is the social environment in which NEEMO contends for itself.

To make their case, NEEMO supporters agree that NEEMO is not a substitute for controlled scientific work, but argue that exploration-situated science is an act of inspiring demonstration that has the power to restore a sense of social evolutionary progress. Such situated science and testing is not necessarily bad science or bad technology, especially when it acts as a way to mediate separate scientific and non-scientific worlds. One long-time NEEMO technician dismissed critiques of NEEMO's current spotty scientific publishing record by telling me that NEEMO missions strike a balance between producing the "academic science" that "the public doesn't understand" and getting "down to a level that everybody can understand" through live, explained demonstration. "Everybody" in this argument means publics and legislators who watch and listen -- everyone who can be persuaded that exploration, like a laboratory, is a space of valuable emergence. This is a future-nostalgic form of persuasion. Supporters emphasize the value of NEEMO to inspire children in particular, and portray NEEMO as a kind of adventure novel in action, comparable to the works of Jules Verne (visible in the NEEMO acronym) or television shows like *Sea Hunt* that they read as children. The concern with the imagination and inspiration of American children, or the child within American adults, was an oft-cited "intangible" justification for spaceflight. This concern is grounded in biblical tradition and technoromantic[76] but not transmaterialist. It expresses a worry over the social loss of what historian M. H. Abrams has called the "freshness of sensation and the disordering of the senses"[77] that enables redemption, through embodied experience, including science and technical practice, from stagnation, hopelessness, and failure to recognize ways to create a "new earth."

Responding to my question about what exploration does for a society that is different from laboratory-based science or technology development, one chief NEEMO organizer responded with an analogy and an analysis of embodied exploration as exercise to prevent individual and social dissolution on the material and immaterial levels. Darwin, in his estimation, is a NEEMO aquanaut precursor:

> For me it's very broad, it's very global, and you don't even have to get into the specifics, or sell exploration or Shuttle or [the International Space] Station, it's a lot simpler than that. It's the intrinsic need in all of us to learn and think about the unknown and what's out there, and when I say what's out there I don't mean Mars or the next solar system necessarily, I mean when Charles Darwin set off on the Beagle, why did he do that? Why did he decide 'I need to go around the world for five years and collect biological samples from all of these places that nobody's been,' Why? .. everybody said 'you're a fool.' Because he knew there was so many things that are unknown. And we're in the exact same position on a bigger scale. And if we don't listen to our inner self, wondering, then where do we go?

> We can't stay -- I don't mean physically, I mean spiritually, and physically, and psychologically, where do we go from here? ....Well, we're gonna lose our inner desire, our inner wonder, our inner spirit, because that, you're born with some of that, but you're a product of your environment, and the more and more of our society that relies on short term goals and short term fixes, we're gonna start to lose that spirit, that so much of our society used to have, our heroes were explorers and astronauts, and when I say explorers I mean people in medicine and chemistry and psychology, people on the frontier of whatever they're doing, not just mountain climbers. But the society now, we used to say "kids, they don't know" but even adults, to where even adults don't know who the frontier, who are the pioneers of the fields. We will crumble, if we're not based on something.

In this way, its advocates give NEEMO multi-purpose value as a restorative cure for NASA and America. Such justifications invoke what Lawrence Buell calls the American "environmental imagination" found in the works of both privileged and disaffected American writers who portray direct engagements with nature and wilderness as way to restore a personal and national sense of purpose, authenticity, and identity.[78] One trope commonly used within NEEMO and exploration advocacy in general evinces this argument clearly: "realness." Acts of reasoning, embodied experience, and affect are deeply intertwined in this argumentative notion.

When NEEMO supporters argue the analogue's value to newbies like me or to JSC administrators, they consistently emphasize NEEMO's "realness" in institutional and broader social terms is a quality that ultimately trumps its scientific shortcomings. Todd explains that NEEMO's "real" value to NASA as an institution bears out over time: every astronaut candidate that completes a NEEMO mission qualifies as ready for a flight assignment. An Ames colleague of Todd's, NASA cognitive scientist and longtime desert analogue participant and ethnographer Bill Clancey, told me that analogues foster the "authentic work" of allowing people to pre-determine and even "make arguments" in the field about the nature of an unknown target "context" or "environment." He suggests, like analogy theorists, that the analogy-making is what links all human activities together, including spaceflight: "all of life, all of our new enterprises have an analog that we refer back to… so it's not new to space that we do this." A NEEMO 9 support technician summed it up for me: "this is a real mission and real shit happens."

For NEEMO supporters I spoke with, analogue missions do not just benefit human space exploration goals, they are public and embodied acts of "realness" that counter what they imagine as a degradation of certain kinds of American authenticity. In their estimation, the fates of such acts directly affect the survival of particular "American" qualities. One of these qualities is cooperation. NEEMO advocates tout its incorporation of foreign aquanauts from space agency partners such as the Canadian, Japanese, and Russian space agencies not just because their participation is operationally "real" but because it exemplifies, as one technician told me, American values about "working with others." Another of these "real" qualities is the intrinsic authenticity of exploratory behavior as compared with other kinds of behavior. One NEEMO engineer-organizer summed up this argument during the stressful waiting time before a NEEMO mission launch. Eyes bruised with fatigue, his mood cantankerous, he connected uncertainties about the future of the American space program with the future of American society, from the perspective of someone who grew up, as I did, in the age of spaceflight "firsts" and emotional discourses about the "raising" of political and environmental consciousness:

> It scares me to think that what we are leaving a legacy of is loud music, foul language, love of inanimate objects, desire and need for inanimate objects of every possible kind, and not having the intrinsic desire for exploration, being a pioneer, in our culture. And that desire has been, you can trace where we are now, you can trace why we got here was because those cultures before us had that desire. I mean look at how many people sacrificed everything and you know,

> what are we gonna do in the next fifty years if we give up on the world's only undersea habitat. Say OK we don't need to be manned anymore. All the dreams that every kid had at some point in his life...and then now we jeopardize our space program, say OK, it's too expensive to do that too. The only thing that we can afford to do is fight everybody in the world, just have wars. That's what we're gonna do. We're gonna be a warring country that just fights all the time.

His words belie the stereotype of the "unemotional" engineer. Exploration, in his view, offers the corrective of "real" language, love, desire, sacrifice, embodied pioneering, and, even and especially dreams, as against their inauthentic shadows. His view illuminates how discourses of "authenticity" of practice and belief that stimulated 1960s and 1970s counter-culture explorations have transferred to what Erik Cohen describes as the "quest for extreme authentic otherness" that motivates ecotourism and extreme or exploration tourism and the ethical escape from the "contrived."[79] Following this logic, NEEMO becomes a way to enact personal and professional claims about the value of American human space exploration, where "claiming" is an action that Steven Toulmin describes as first and foremost an "assertion" that makes "a claim on our attention and a claim on our belief."[80]

NEEMO advocates are clear that taking personal and professional positions in favor of NEEMO and human extreme environmental exploration are evolutionarily adaptive, ethical, and attention-getting acts. The online aquanaut diaries are testimonials about the experience of gaining what they call "expeditionary behavior" but also convey personal experiences of ecological epiphany and conservation advocacy. One veteran NEEMO aquastronaut I at lunch at a JSC cafeteria during the pre-mission planning phase explained to me that the NEEMO "expeditionary behavior" being cultivated was an "analytical process" in which crews accumulate a "technical history" of exploration that a "next generation" can improve upon. In his model, expeditionary *behavior* is a kind of cultivatable habitus but the *desire* to explore is an evolutionary trait – an exercise of genetic potential that I describe in more detail in Chapter 2. In addition, the term "expeditionary" (International Space Station missions are called "expeditions") more definitively sets out a discursive space in which to argue that embodied human exploration does something different for human beings than remote or robotic exploration. It also suggests that controlled experiential exploration has a virtue and value equivalent to controlled experimentation, although the virtues exceed the spatial boundaries of laboratory production.[81] Another NEEMO veteran told me that what distinguishes the American exploration experience from that of other nations is "our" penchant for being adaptively "open:" "[in] America we don't have any kind of deep rooted need to do it one way or another, maybe it's the flexibility, that gives us the open mindedness." American human extreme explorations, in this view, foster national characteristics of open mindedness and mobile flexibility that enable evolution, broadly understood. As a result, most NEEMO organizers and participants I met were also committed to protecting earthly extreme environments in ways that recognize them as fragile and threatened, and also threatening the loss of spaces in which to exercise the exploration trait through controlled embodied experience. This confusion of notions about evolution is a characteristic of exploration discourse and its politics of progress.

The program's acronym homage to Jules Verne's fictive "Captain Nemo" indicates its tacit support for the protection of extreme environments as distinctive and generative spaces. Pieces of NEEMO equipment in the bunker in particular exemplify analogies connecting exploratory ecological ethics with utopian ideals. On a table are *Aquarius* habitat laptops, used in a site that NEEMO organizers are pleased to mention (in homage to Jules Verne's novel title) is located approximately "20,000 millimeters under the sea." The habitat computers are named "Arronax" and "NedLand" after Captain Nemo's captive but eventually sympathetic "guests" on his proto-submarine, Nautilus, which engages in antagonistic attacks against shipping interests that would today be called ecoterrorism.[82] During missions NEEMO participants listed NEEMO's contribution to ecological understandings: how NEEMO operates in the spirit of oceanographic ecological work, how aquanauts recognize the seafloor as a fragile neighborhood that is worth protecting, and how they consider their institutional reputation as rebel-innovators to be coupled with their personal history as adventure and nature enthusiasts. NEEMO participants were also likely to make reference to Disney films *Finding Nemo* and *The Little Mermaid*, indicating through puns, jokes, and enthusiastic analogies their emotional affinity for the ocean as another world equivalent in ethical and meaningful stature to the human surface world but also deeply threatened by it. Although NEEMO is not a marine science mission, some NEEMO missions undertake to assist NURC scientists with research activities, a capability that NEEMO organizers used to promote the multipurpose value of their exploration platform. In his examination of environmentalist discourse in "extreme surfing" in Cornwall, sociologist Patrick la Violette[83] details how engagements with a sublime world of extreme waves threatened by pollution turns surfboards into authoritative platforms for making ethical claims about the future of the Cornwall identity, portraying the threat to environment and identity as coeval. As I observed, the NEEMO program takes a stand against environmental threat and loss that also aims to boost NASA's identity as a sentinel producer environmentally-grounded views of American and human futures.

In my future loomed the fall of 2005 and the planned October mission date. Sue, the NSBRI study coordinator and I began to spend more time with the three NASA and one TATRC-sponsored crewmembers slated to be the NEEMO 9 "aquanaut" crew. NEEMO crews have a consistent social composition. The commander is usually a NEEMO veteran and flown astronaut – making him or her an "aquastronaut" in NEEMO parlance. This mission's commander was Canadian Space Agency astronaut and physician Dr. Daffydd "Dave" Williams, a veteran of NEEMO 1. Under his command were two mission specialists: Dr. Tim Broderick, a thoracic surgeon and astronaut hopeful from Cincinnati, and two unflown NASA astronauts from Houston, Air Force Colonel and aerospace engineer Ron Garan and structural engineer Nicole Stott, both in the last phase of their astronaut training and waiting assignment on a Shuttle or Station mission. In order to qualify for a NEEMO mission, all four had to pass an Air Force Class 3 physical, become SCUBA certified, and have logged 25 dives. The final two members of all *Aquarius* aquanaut crews that Sue and I would meet in Florida were the NURC habitat technicians, a young technical diver named Max and former NAVY diver named Pete. The habtechs are are experts on the operation of the hab and are viewed as members of the NEEMO crew although they are only incorporated sporadically into mission activities. Under the official rubric of managing the exigencies of extreme survival, this hierarchical and task-based social differentiation imports a recognizable social system of inequality to the sea floor and foreshadows the space social future. During the NASA pre-mission media outreach blitz that put the aquanauts on NASA TV and in news spots around the country; the habtechs took backstage as interchangeable members of a category of diver-laborer, not destined for space.

Right before the mission, we were reminded about the environmental "extremes" we were contending with. Hurricane Rita swept into the Keys and nearly knocked *Aquarius* off its seafloor moorings, bumping the mission from September 2005 to spring 2006. As the new Mission Day 1, April 3, approached, NEEMO organizers began to invite people to "follow" this "real mission" over the Internet and in the news. Now I ask the reader to follow the NEEMO 9 argument-in-action. This argument emerges strategically within the 18-day choreography of sites, activities, demonstrations, and communications -- including my own immersion in the space of argument.

Mission Day 1: taking positions

From here on, NEEMO's argument happens *in situ*, via procedures that interrelate doing, saying, and inhabiting. The physical space that includes NEEMO mission control and the *Aquarius* habitat site becomes a zone in which claims gain discursive and demonstrative backing and warrants and claimants are put in touch with audiences, exemplifying what Toulmin calls the practical and contextual procedure of argument. In this section, I show how the mission timeline makes NEEMO's argument ecology render an argument. I do this by accounting for how three sentinel days build and enact that argument. Mission Days 1 and 2 argue in favor of extreme environment productivity in the form of data collection, demonstrations, and associations, and the making of justifications in the form of animated testimonials and eventful kinds of visual and interactive media. On Mission Day 15, I participate in this argument ecology by following procedures and becoming an embodied case-making element of the argument, in ways that were both predictable and surprising.

NEEMO 13 "launch"

0800 to 2300 hours: reorientation

I'm still trying to get my ethnographic bearings, which, despite a year's training and preparation, are still shaky. My efforts to position myself inside human space exploration has turned me into a SCUBA diving intern in sunscreen and boardshorts living in the turquoise water edged world of the American Caribbean working on a program named after a fictional renegade submariner. Sue Devitt and my other NSBRI colleagues have been here for two weeks setting up our lab in a room under the main condo, so I am scrambling to get situated as a worker and ethnographer. Mission Day 1, I soon find out, *pace* Curt Mansfield, is an exercise in strategic positioning. As the day unfolds, I notice how acts of getting into position to operate the mission establishes NEEMO's capacity to *take* an authoritative position on the value of extreme environment explorations. Unlike my exposures to the symbolic and discursive value of "extremes" and "futures" during pre-mission planning, Mission Day 1 launches live-action strategic coordinations of time and space and of demonstration and communication.

The dense humid air of this April morning in Key Largo is tangy with brine and diesel as divers, astronauts, scientists, engineers, and technicians haul SCUBA gear and pile it onto the slick deck of a small, well-used NURC boat named *Research Diver*. When the boat is loaded, those of us are land-locked exchange damp hugs and some last laughs and ribbings with a crew about to start their space mission with a splash*down,* not a launch *up*. The sky is violently azure, the sunlight blazes, the air is hot and heavy. I'm dying to see video of the aquanaut crew from inside the habitat where they will adapt to their technologically experimental environment and proceed to "execute" the eighteen-day mission timeline. This timeline is so operationally and strategically critical to NEEMO's aims and its survival as a program that a former NEEMO aquanaut called it the "almighty timeline" back at JSC.

As the NURC captain starts up the little boat with a puff of exhaust, I watch the crew and their accompanying NURC and NASA "topside" staff jump in and cast off, right on time. Fishing and dive vessels full of boisterous tourists follow in *Research Diver's* wake, passing by the two unmarked NURC condos and all of us on the dock, not knowing that NURC's little boat is headed out to the *Aquarius* habitat dive site 4.5 kilometers offshore, marked only by a tall yellow life-support buoy surrounded by a ring of floaters that cordon off the small area as a restricted government site. While several of us wear NASA mission polo shirts with patches, none of us wear government badges in this open non-secure space, so to the casual observer the shirts might just look sporty or like company uniforms.

Next to me on the dock is a tanned, very lean, and profusely sweating veteran astronaut-engineer-diver. He is doing tests to improve the "centers of gravity" on future spacesuit environmental control backpacks. His team will put prototype backpack frames on aquanauts who will walk around in weighted boots on the rugged white coral sand bottom near the habitat, testing out what their encumbered bodies would feel and act like on planetary surfaces. Noticing my disorientation, he asks why I'm here. I answer that I'm an NSBRI research assistant, but am also here to study the "science and technology culture" of human space exploration. He corrects me kindly but with a furrowed brow that narrows his bright-eyed gaze, wrenching me out of my pre-mission preparation attitude: "Well, this is not a science or technology culture, it's an operations culture."

His statement reminds me that NEEMO is now "in operation." Scientific and technical activities are happening because people and technologies are being put into survival mode and at risk. This also puts them into position to say and show where human beings can and should go and why. This operational position eclipses the mental space of mission planning and puts into motion procedures, of all kinds, that are considered vital to mission success in more ways than one. The astronaut PI who corrected my understanding of where I was is also reminding me that I need to adopt what aeronautics and astronautics practitioners call the "situational awareness" of a risky environment: risky for the crew, risky for us as researchers, but also risky for the whole future of extreme environment exploration if the timeline doesn't unfold as planned. All spaceflight timelines are haunted by interruptions that create crises of justification: the Apollo 1 fire, the Apollo 13 accident, the Challenger and Columbia shuttle disasters. What is at stake now is to make these high-profile highly scripted operations produce data as well as meaningful and communicable experience. And, simply succeed. I head up into NURC's condo for visiting researchers, my now slightly damp mission timeline in hand, to check to see what planned set of events are slated to happen next. Everyone here will now, in NASA-speak, "work the timeline," and we will not be without it, physically or mentally, for 18 days.

Social scientists have been recently drawn to the time-keeping problems and technologies of robotic and human space exploration, a problem of historical interest to applied behavioral health researchers working with the military and space agencies.[84] Anthropologists and sociologists have focused on the design of interplanetary work spaces,[85] the analysis of how those work spaces become fraught by the clash between dominant timekeeping "zeitgeber" ("time giver") logics of industrial-age labor management and the embodied "agrarian"-time experience of being tied into another planet's solar-cycle-determined "day,"[86] and the ways that intricate procedural "checklists" became so vitally integral to human spaceflight missions that Apollo astronauts anthropomorphized them as additional "crewmembers."[87] In the mission situation I am involved in, the procedural logics of space/time management will perform an operational and promotional "syntax" that strings together now and future, sea and space, recognizable realities and realizable possibilities.

I leave the dock and walk upstairs to find out what's happening at NEEMO mission control. A Navy SEALS sticker on the condo sliding door teases me with the slogan "the only easy day was yesterday," which sums up the specific and general idea that extreme expedition manifest personal and social transformation through confrontations with hellish challenges. I walk immediately into the thick of what amounts to timeline control, where events, things, and messages are coordinated and disseminated to NASA and beyond its borders. The mission control/living room is crammed with NASA astronaut trainers, flight controllers and a couple of dive consultants. Also present are visiting NASA, CMAS, and Army payload VIPs, NASA public affairs and other non-NASA media technicians, and assorted "friends of NEEMO" gathered to witness today's splashdown. I see exhaustion in the tanned and sunburned faces around me, under spiky haloes of barely combed hair quickly rinsed of salt water from early morning diving runs out to the habitat to prepare for the crew's splashdown. The condo's kitchen counter is piled with scribbled-up timelines, notepads, telecom equipment, and bottles of neon-colored sports drinks. While many people here have just arrived, the small core operations and payload management teams have been here with the crew for two weeks, living together like camping buddies in the condo and completing final bouts of training and orientation.

I inch my way in behind a crowd of intently focused NASA managers and technicians. They are glued to a large laptop screen that displays the digital timeline. Based on what is going right and wrong right now, upcoming operations protocols are already being revised in order to be successful by a rail thin, unshaven Hawaiian-shirted NASA mission controller who looks like he's been awake for weeks, but whose eyes shine with alertness and whose hands move competently across his keyboard. Planned actions are in a constant state of pre-improvement, a technique of foresight that my interlocutors insist is a benefit of dealing with extreme spatial and temporal exigencies. Someone shouts out that our crew has dived down to the habitat site and is taking a diving tour of the area they will now call "home" and "the neighborhood."

Just as with space missions back at JSC, one area of the room is being set up to collect, manage, and distribute photographs and daily press releases back to NASA and directly to public audiences as fast as possible. The NEEMO 9 timeline is peppered with media interviews and "educational outreach" in which newscasters and children can talk "live" with the aquanauts over telecoms, and which also includes a scheduled visit by ABC's Miles O'Brien who will dive into the habitat, an unusual breach of aquanaut health-protection protocol made because it's a strategically valuable opportunity for NASA and NEEMO. Media outlets are being lined up for aquanaut interviews, from "Greener Magazine -- Green Solutions for American Homes and Families" to morning talk shows. The mission will also include what CBS news called the "most extreme phone call ever" between the *Aquarius* and the Space Station. Today, NEEMO staff begin the daily scramble to get aquanaut writings and pictures approved by NASA officials and onto the internet, where they begin to accumulate like unfolding episodes from a reality-TV show. On computers, live internet video feeds from *Aquarius* flicker and shimmer.

Like the NEEMO bunker back at JSC, the condo mission control room environment situates everyone's focus on operational time, but also on the contentious revolutions and hopeful evolutions of extreme environment exploration. On the longest wall of the room is a topological map of the *Aquarius* reef site, named the "Scott Carpenter Basin" to commemorate Carpenter's later foray into space analogue operations as commander of NASA's small submersible Scott Carpenter Space Analogue station that for a time operated within a few feet of the *Aquarius* in the late 1990s. Carpenter only flew one NASA mission, which became infamous because he fixated on a mysterious sparkly phenonmenon outside the capsule and was distracted from his timelined monitoring of fuel use and trajectory in a way that almost jeopardized his reentry. The sparkles turned out to be dumped urine crystals but his attention marked him as a kind of deviant but heroic astronaut. The habitat's name, "*Aquarius*," evokes the four-decade interconnected history of NASA/NOAA collaboration and negotiation of an overlapping environmental authority over sea, atmosphere, space research and operations that amplifies and further naturalizes a European cultural historical and now contemporary working understanding of space as sea-like and the sea as space-like.[88]

Next to the Carpenter Basin map is a sign Bill and Marc bring to each mission that asserts fractiously: "Science always wins over bullshit.– Dick Rutkowski." "Science" in this case refers not only to the general practice but also to NOAA aquanaut and technical dive expert Rutkowski's autoexperimental campaign to prove that air was not the best mix of gas for humans in deep diving. Across the room from the map and the Rutkowski quote is the now-traditional NEEMO pirate flag that flies over NEEMO operations on land and underwater. This is not the American flag that signals the "flags and footprints" territorial claiming for national prestige. Instead, the flag complements the outsider edginess of the NEEMO acronym, making an aesthetic assertion about what it means to break barriers, act outside norms, and love the extreme. Despite these assorted mementos of struggle and defiance, the mood in the room, although spiked with fatigue, is a mix of pleasure and nerve. This is not the second-order aesthetic observation of sublime nature, but is grounded in the embodied joy and wonder of *being* extreme.

At the end of the day, everyone in the condo and everyone in the habitat gather around telecom equipment for our day-end planning conference to review the day's successes and problems. I return to my nearby hotel room to write fieldnotes while watching an episode of the Discovery Channel's *Deadliest Catch.* It dramatizes the shockingly dangerous lives of Alaska crab fishermen in the watery frontier of the Bering Strait, their strict routines, long hours, and punishment by the elements. Watching crab fishermen being doused by impossibly cold waves while they laugh and curse, I study my timeline to prepare for the ambitious and foundational Mission Day 2.

Mission Day 2: argument by procedure

<u>0820 hours. coordinating space to experiment, explore, live, work, and justify</u>

I'm back at the NASA occupied NURC condo at 7:15 am on Mission Day 2, which, in its ambitious and exhaustive integration of key activities, may not be typical but is a flagship day for the NEEMO program. Today's activities will repeat each day in different combinations, but what is being established now is a baseline capacity to enact activities in similar hourly proportions throughout the mission. By my calculation, for every two hours of "science" or technical testing, there is an hour devoted to demonstrating and communicating about the mission.[89] The jam-packed day shows what NEEMO can achieve, and establishes a virtuoso performance of claiming, evidence-making, and demonstrated and interpretive justifications made with futuristic flair.

Today's timeline covers the possible repertoire that any NEEMO mission day can cover, priming Dave, Ron, Nicole, and Tim, and the hab techs Max and Pete for their upcoming16 hour a day regimens. The NEEMO mission control team and representatives from the payload teams crowd around the green condo's tiny kitchen table for the morning Daily Planning Conference call with timelines and mission event logbooks in hand, ready to take notes, troubleshoot problems, and revise activities and procedures.

Right after the planning telecon, the four NASA crew members will embark on their first round of CMAS telemedicine experiments and demonstrations, attendant bouts of NSBRI behavioral health measures, do some training on how to use the habitat's "hookah" system for excursions on the seafloor using long air hoses rather than tanks, and do a live hour-and-a half educational outreach broadcast to teachers and school children. Like always, cameras outside and in the galley area of the habitat stream silent but live internet video. A lot is riding on Mission Day 2. Steve, a NEEMO flight controller, dials the *Aquarius* habitat's phone number and acts as the spokesperson for the topside staff and payload participants gathered around the table, a role that is analogous to the NASA "capsule communicator" job during spaceflight missions. Besides being a way to exchange information, the conference calls are also conducted to maintain what the NSBRI social psychologists call the "social cohesion" between "ground" and "space" that enable extreme environment missions to appear socially integrated and productive, in other words, normal. The day's outreach activities extend this notion of social cohesion to NEEMO's publics: the topside and crew will be called on to represent the productive environmental integration of sea, space, and Earth. Marc closes by reminding the NASA crew that they will become fully-fledged aquanauts at 10:38am.

<u>0840 hours. the set up</u>

NEEMO 9's most high-profile payload gets underway: the CMAS science and associated outreach are vital to the mission's argument ecology because they proceed as much to generate data on telemedicine in extremes as to demonstrate the value of extremes to the everyday. Today's CMAS task is a telementoring scenario. Two NASA crewmembers complete a series of computerized surgical tasks remotely supervised by

Dr. Anvari from the CMAS offices in Canada. They wear an EEG sensor to capture brainwave activity, and will complete the NSBRI behavioral health measures, taking pre- and post-task computerized performance readiness feedback tests and spitting into saliva collection tubes that will be measured for cortisol levels as a proxy for stress. Such remote medical mentoring exercises have been conducted for years, but what makes this exercise novel is that it is occurring underwater and that it will make the telementees work with extreme temporal "latencies" of communication with the telementor that go beyond the bounds of Earthly signal delays. To simulate an Earth/moon telementoring incident, the communication will be delayed for up to 2 seconds. Dr. Broderick is the first subject, representing not a naive telementee but one with some training. The CMAS task descriptions I read with Sue back at JSC argue that although surgeons have been able to adapt to latencies, this test will determine what happens when the delay represents an extraterrestrial gap between surgeon and a lunar base astronaut operator-surgeon.

0905 hours. warrants, evidence, backing

The crew take photographs to memorialize Tim's experience as an extreme environment test subject: his head is covered by the weblike EEG net, face dripping with saline, hunched over laptop with a look of cheerful tolerance on his face. He sits in the habitat risking electrocution, "operating" in a non-medical setting in which both he and an imaginary patient are technically on life support, standing in, as NEEMO press releases and media presentations describe, for future astronauts far from home. Also deliberately made visible by the photos is the uncanny experimental context -- the eery, "alien green" sea-filtered sunlight streaming through the *Aquarius* porthole. The crew jokingly refers to Tim as "Ensign Broderick" -- a Star Trek reference to the characters in opening scenes that are often killed to the dangerousness of an alien situation. Tim's test foreshadows an upcoming task by Dr. Anvari who will tie a telesurgical knot, the first ever tied underwater. This CMAS demonstration is in keeping with the NSBRI's goals as well: to find ways to extend the expert reach of biomedicine despite any environmental constraints of time and space. Tim is in effect performing live a statement made by Bill Todd during a press interview before the previous telemedicine-focused NEEMO 7, in which he says that NEEMO telemedicine provides "the real stresses needed to validate telemedicine in an extreme environment" in ways that will "help chart a course for long-distance healing." But the EEG net and the lagtime setup don't work perfectly. Data from this and other experiments in the habitat will and will not yield what the investigators wanted, in part because of the uncontrollable habitat conditions, rescuing failed experiments by legitimating them as exploratory acts.

The CMAS "telemedicine experiments" in NEEMO, however, are not just telemedicine or experiments, but a timelined combination of experiment and testimonial, demonstration and public outreach through interpretation. Today, each aquanaut will spend as much time doing the experiment as explaining it to the public. In the condo mission control room, NASA staff have started to compose the day's internet ready "reports from topside" and "aquanaut diaries," in which the frustrations of working with "latency" in the extreme, and equipment that breaks down and data that doesn't get collected, are rescued from experimental failure and reframed as a wave of the future. "Latency" in this case is not just a space exploration risk, but a general challenge to the modern achievement of precision in spaces where the coordination of time breaks down, in which precision becomes belated, ineffective, or even possibly unextendible.[90] While this is an example of how, as Rachel Prentiss has argued,[91] surgeon's bodies and bodily "surgical sites" are mutually articulated through simulated practice, the NEEMO example extends this notion of mutual articulation into spaces. Through the bodies of telementor, telementee, and patient, centers and peripheries are mutually articulated in space and time. NEEMO enrolls another set of participant bodies in this articulation: teleaudiences.

1330 hours. making the case

Within 3.5 hours of Tim's CMAS 1 task comes the first round of live publicity in which the aquanauts, still in the end stages of their experiment, become educators through an uplink to the Catholic elementary school, St. Joseph's, that is connected to the hospital in which CMAS operates. Video of this event, archived on a Canadian science education website,[92] puts a frame around NEEMO 9's persuasive juxtapositions of normal and extreme, here and there, now and future. Dr. Anvari stands at a podium before an audience of schoolchildren, in front of a screen on which are two abutting video projections. The lefthand side is set up to show a series of illustrative videos, while the right side feeds live from inside *Aquarius*. The crew sits around the little galley table, the flickering green porthole behind them, Nicole keeping her EEG net on her head so she can explain what she has been doing.

Dr. Anvari begins by explaining that his goal is to make "surgery is possible at long distances" so that "we are connected" regardless of the magnitude of distance, from hundreds to thousands of kilometers, by a "network for surgical care." Anvari presents the students (via this education video being made for other audiences) with a spoken, visual, enacted mosaic of persuasive evidence. The live habitat feed anchors the argument in the sea, showing the sea-green lighted porthole behind the crew. Anvari begins his talk with scenes from previous telemedicine demonstrations, showing a clip from a news spot in which an announcer echoes Anvari's words by saying "now that the concept [telemedicine] has been proven as a viable option interest has grown." The announcer goes on to say that the Army and NASA are supporting Anvari's efforts to restructure the limits of social physicality: "Remote surgery suggests that the next chapter in the story of fiber optics may take us beyond what we think of as communication. In addition to talking, listening, and watching, we will be able to act at a distance." Anvari then shows a video of the first woman he operated on, saying: "She was the one to agree to be the first person in the world to have a surgeon operate on her from a distance, and to me she is a hero." A video of the patient pops up, juxtaposed next to the feed from *Aquarius* showing the aquanauts, all heroes. Anvari goes on to play a video clip in which Dr. Sanjay Gupta of CNN describes the NEEMO 7 experiments as making "*Star Trek* come true" as NASA astronauts are "being trained to act as doctors in extreme environments." After this clip, Anvari explains the virtual, merged physicality of telementoring by saying that he is "guiding an astronaut to act as my right and left hand, to perform the surgery…Someone with no knowledge of anatomy or surgical instruments, [the surgeon makes it] as simple as possible, to coach them through potentially life threatening situations." Anvari plays an echoing Dr. Gupta clip: "As doctors prepare to use their skills beyond the confines of hospitals like these, they may find in extreme situations [that] almost anyone can act as a surgeon." Anvari presents telemedicine's innovative capacity to collapse technical, environmental and social barriers, connecting this with the heroic presence of aquanauts in the extreme and with the child-audience's future as potential recipients of such technologies. This extends the notion of where it is possible to live safely and healthily. Anvari explains:

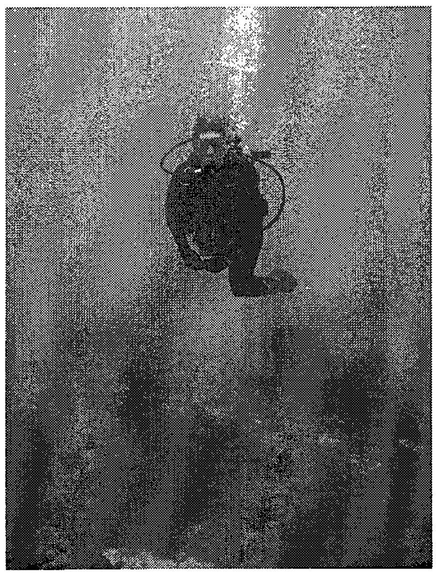
> We've been working to develop a new portable robot for extreme environment to provide emergency surgical care...You may remember an Antarctica doctor that got sick, had to risk lives to airlift the person out, well if they had our technology that person could have had the surgery. The same is true in many communities in Canada, there are communities which for two, two three weeks at a time when the bad weather, nobody can be airlifted in and out, and so if you get really sick basically you have no way of accessing healthcare. Where it's gonna go, I don't know. Could you have operations at home? Potentially, yes. But our goal right now is to develop systems that allows every Canadian irrespective of where they live to have access to the best medical and surgical care. And that same technology will help astronauts explore space, explore back to the moon, and hopefully in the near future, to Mars.

Anvari's lecture illustrates the co-production of medical and human exploratory extensions, presenting an argument in which the ontological position of both arguers and audience matters: this case is best made to an anduence not in an office, or in a text, but live and *in situ*. Commander Williams speaks to the audience as children, linking Anvari's and NASA's goals to the maturation of his childhood desires:

> ...a dream that I had as a young boy in Canada, growing up from the time that I was 7 years of age, that was in 1964, but in those days I dreamed of flying in space as an astronaut....then I dreamed of exploring underwater as an aquanaut... But the important message here is that if you have dreams to become an astronaut to become an aquanaut, work real hard, study hard, and follow your dreams and hopefully it'll all work out for you just like it did for us.

The crew then gives a virtual "tour" of the habitat to the students, comparing the likeness of spacecraft and *Aquarius*, and remarking on the way that fish have become like "neighbors." Although the argument being made is steeped in the valorization of power over environments and persuasion by show of that power, it also uses a tactic that feminist rhetoricians Foss and Griffin call "invitational rhetoric," in which persuasion takes the form of invitation.[93] According to astronautical historian Frank Winter, the tactic of inviting people to "ride along" in simulated experiences of spaceflight, for entertainment or educational purposes, created and sustained public support from the late nineteenth century.[94] Anvari and the aquanauts invite students inside extreme spaces, showing them that normal environments are simply spaces between extremes – between sea and space, between disadvantage and advantage, between evolving presents and improved futures. The aquanauts provide visceral evidence to reverse the assumption that innovation flows from normal to extreme, showing instead a flow of extreme to normal, portraying their "new home" as a place not of fearful threat and danger but of innovation. After the presentation, teachers leave feedback on the website: "Our grade 5 and 6 classes enjoyed the transmission very much. It was invaluable for them to learn some science facts and where science and medicine are heading." "The kids are excited at what they're seeing and learning... The tour of lab, relating of own personal experiences was fabulous."[95]

After the mission I obtained a DVD of the crew's many live education and outreach sessions; during these, the aquanauts sit around their tiny galley table, going from one live interview to another, re-creating *de novo* the performance of greetings and answering versions of the similar questions over and over, repeating their arguments for multiple audiences. Particular phrases, appear over and over, echoing the St. Joseph's broadcast: NEEMO is a "technology accelerator;" it is "extending the reach of surgeons and physicians beyond the walls of their hospitals" "into remote and isolated environments to serve underserved communities." In these *in situ* interview/arguments, the heroic charisma of "being there" embellishes what the aquanauts say and do with the liveliness of the scene, invoking what Aristotle in *Rhetoric* describes as "the graphic power of 'setting before the eyes'" that gives "metaphorical life to lifeless things" that is boosted by "a touch of surprise."[96] Ever-present is the promise that future extreme extensions will inevitably produce a value greater than what is now possible, a kind of argumentation that is not rooted in scientific deduction or induction through experiment, but what Stefan Helmreich notes as "abduction," the linking of predictive hope based on understandings of a rationally progressing future.[97] NEEMO in operation does not dispute that science can be done elsewhere, but makes the argument in doing it in the extreme enacts the necessary environmental adaptations for ever-extendible human life.



The author / NEEMO 9

Mission Day 16: immersed in the argument

> I like it better when we don't talk. It allows me to concentrate on the reef, its beauty, and the work....sometimes talking gets in the way of communicating and when you talk a lot, usually you are not doing anything else productive. In any rate, today we used hand signals, talked sparingly, and got a lot of work done -- we knew what we were doing.
> --Mike Gernhardt NEEMO 1 aquanaut[98]

> My life is my argument.
> --Albert Schweitzer[99]

<u>0845 hours: jumping in</u>

My chance to "dive on the hab" came as it does for many of those who are not trained NURC or NASA dive staff: as a highly contingent opportunity that comes with the rapid and implosive force of a sudden squall. At two days before the mission-end "splashup." I had almost given up on getting to dive. Sue shows up at my hotel room door: "Bill says you can dive, get your stuff, c'mon, c'mon, we gotta go *now*!" I hesitate. I will be joining a subset of the predominantly male and highly experienced veteran divers and NASA personnel group to which I have struggled to demonstrate at least an acceptable amount of operational competence for over a year. Sue coaxes me through my hesitation with a few well-articulated calls of encouragement and a reminder that the boat is going to shove off in 30 minutes. But fear of embarrassment by seasickness, the ultimate sign of an un-expert body turned inside-out in this context, has been mounting since I'd vomited miserably on a charter dive trip the following week. Rationalizing unreasonably that I should just practice some tactical redundancy, NASA style, I stick a tiny 1.5 milligram scopolamine patch below my left ear, gulp down 25 milligrams of meclizine hydrochloride between sips of Gatorade, and carefully position two pressure-point motion-sickness prevention bands on both wrists. With my body and mind already undergoing performance pre-adaptations for the extreme, I stuff my wetsuit into a duffle bag and run at top speed toward the NURC condos.

Now that I've downed Gatorade and drugs, it's hard not to feel I'm making an embodied commitment of some kind by jumping into the sporty, risky, macho, optimized "x"treme part of the pro-extreme-environment argument. I'm headed from experiential periphery to the phenomenological center of NEEMO's argument ecology, a shift that reminds me just how much this argument in favor of human extension and extendibility relies on acts that bring its epistemic and ontological "positions" together. As I arrive at the NURC deck to pick up my dive gear and haul two tanks of air onto *Research Diver*'s deck, I catch Bill Todd's eye and get one of his brilliant white grins. I am aware that I being gifted a privileged and exceptional but putatively "human" ecological experience meant to cause me to re-learn, re-imagine, and redefine my own limits and capacities as a highly adaptive being.

During this dive, I get inside the most material and the most immaterial dimensions of human space exploration justification. There is the case for gearing up cyborg-style to push beyond the envelopes of wellness[100] and safety; there is also the case for obtaining an "extreme" ecological and psychological perspective that can be shared. In other words, diving on the hab puts me wholly in the middle of the argument that the extreme experience is transformative and also transferable to others through extensions of witnessing, testimonial, and dedication to an exploration cause. As an anthropology student, I am also acutely aware that this argument echoes contentions that ethnography is valuable because it is a situated process of testing normative knowledge against the extended domain of human experience in order to redefine both. Such an argument is *not* supposed to be made only in and by minds, but through embodied ventures beyond assumed and relative states of the normative.

Technically, people allowed to dive on the hab are called "VIP" divers, which I translate as Very Important Participant. Bill and Marc and their staff are keenly aware that a key product of NEEMO is not just "expedition ready astronauts" and scientific and technical data, but a kind of person: veterans who can articulate the value of NEEMO specifically and extreme operations in general.[101] As one of their co-managers put it:

> There is a [networking] strategy, absolutely, but it's also something that we see or we nurture right up front, we tell them right up front, we tell them you're gonna get to do this cool thing, we're gonna ask one thing of you, or two: be safe and then at the end of the mission we hope you become advocates of what we're doing so other people can do it. We're pretty clear about that.

That expectation makes me think of being converted. There is convergence in the shared technical and religious meaning of "mission" as "to send out," indicating that people are not just sent to a NEEMO mission but sent out after it to continue its objectives.

On the boat out to the hab, I become aware that I am among human extremophiles, people who consider themselves to be exemplars of new, previously unimaginable ways to survive. There is an instant camaraderie among people who live a desultory extreme lifeway focused on moving from one environmental condition to another. NURC manager and dive master Don, skipper Peter, three NASA employees, an NSBRI technician, and a physician diver guest sit or stand amidst an orderly but impressive pile of dive gear on the little boat's narrow deck. They represent dozens of tropical and coldwater dives, cave dives, mountain climbs, survival training experiences in forest wildernesses, and one member who nearly made it through the as-ho (astronaut hopeful) application tests and trials for astronaut selection. Gear gets checked silently and adjusted with pulls and tugs, charging the scene with an almost erotic aura of technical proficiency. The physician diver on board is a minor celebrity: a microsurgeon and member of the Explorer's Club named Kenneth Kamler who authored *Surviving the extremes: a doctor's journey to the limits of human endurance*[102] (a book full of phrases like "skulls have disadvantages") written a year after visiting NEEMO and entering the habitat to stitch up the hand of a NEEMO aquanaut. When we get to the dive site, the yellow life-support bouy in sight, we stop: Ken is there to write an article on this experience for *Popular Mechanics* but he is also going to take a battery of NURC skills tests that will qualify him to dive down to the habitat during NEEMO dive excursion activities without a NURC chaperone, another extreme environmental rite of passage. He jumps in for the swim test.

Above me is an inverted bowl of blue sky stuck with cottony clouds, below are horizontal swaths of turquoise ocean that I look down into from the side of the boat: I can just make out the roof of the habitat and the nearby white gazebo where divers can refill their tanks with air pumped from above, and it looks like a world apart. As my eyes move from sky to ocean depths, I feel no sickness at all, happy that I won't be remembered as *Aquarius*'s first anthropologist visitor and also a barfing greenhorn who chummed the waters above the hab. Since we left the dock my field of vision has narrowed a bit and the tropical yellows, blues, and greens seem jaggedly bright with little tails of color, no doubt the psychedelic result of my adaptation redundancy strategy. It's easy to feel connected to spaceflight arguments in favor of looking down and perceiving something new about the narrow zone of the planet that we inhabit. This argument ties together a number of astronautical perceptual experiences: from Apollo astronaut and mystic Edgar Mitchell's "noetic" experience of cosmic unification, to the observational trope of "borderlessness" noted by spacetravelers of all backgrounds, to the oft-cited characterization of these experiences in space advocacy literature as "the overview effect." That is the title of a popular book by spaceflight advocate Frank White, who uses philosophical and emotive astronaut testimonials to support his claim that spaceflight is in the "embryonic" phases of "laying the foundation for a series of new civilizations that are the next logical steps in the evolution of human society and human consciousness...and serves as a vital function for the universe as a whole" as a way for the cosmos to know itself.[103] This argument claims that the capacity to displace human bodies beyond Earth creates the ultimate dissolution of idiosyncratic limitations, imagined as not just social but terrestrial. This claim makes space exploration into an extreme form of "aperspectival objectivity" that does not locate its universalism in technoscientific acts of purging of emotion and social specificity from observation, [104] but in a romantic and realist recognition of a cosmically-defined humanistic purpose in spacefaring technology. This perspective naturalizes technological inequalities, creating a human evolutionary and transcendental-experiential ladder with spacefaring societies on the top rung.

This extremely universalized argument is linked not just to dramatic claims by science popularizers like Carl Sagan but to psychological research associated with the NSBRI. When I was prepping for the mission, I met Peter Suedfeld, a University of British Columbia at Vancouver psychology professor who has collaborated with NSBRI researchers and pioneered a growing focus on the "salutogenic" (health-enhancing) effects of coping with stressful and non-place specific environmental and experiential engagements with "extremes" relative to their own normative ways of life. What animates his interest is not just the operational functionality of missions, but an overall understanding of the "impact of outer space on inner space," which he operationalizes as a set of research variables that can indicate a spacefarer's overall experience of "Transcendence (a combination of Spirituality and Universality)."[105] Within this research-based project, space and undersea habitats act as universally applicable cosmology-awareness-producing units. Before the mission I read a sci fi novel, *Starfish*,[106] in which people with extreme violence in their pasts are chosen to be cyborg-aquanaut laborers in a deep-ocean geothermal vent site because they are considered to be pre-adapted to environmental extremes; the vent site turns out be home to an alternately evolved lifeworld.

Marc lets us know: time to dive. As I take a giant stride off the end of the boat and submerse I feel like acting out what, after historian Gillian Beer's work on the effects of Darwin's prose on the Victorian literary imagination, a role in a "Darwinian plot" about struggle and overcoming.[107] Hoses that give me access to a portable atmosphere in a tank encircle my body, and I enter a quiet watery otherworld from which I now look up to see the bottom of the boat fading away – giving me what NEEMO organizers might call "the underview effect." Now that my lungs extend into tanks, every phase of breathing is noticeable and my vision opens up to another landscape in which I have to be aware of myself three dimensionally. My hands join my feet to become sources of motion control and ways to manage my new gear-defined existence, but also of ways to speak to my dive buddy, an NSBRI technician, in signals. As we descend toward the habitat, I kick my fins to balance the fall, and my ears pop frequently to adjust to a new atmospheric norm. I have never been so aware of the molecular details of my existence. This is one way in which, as aquanauts claim, one becomes aware of one's body as an evolutionary artifact of particularities like air, gravity, and atmospheric pressure, but also of the exhilaration of experimenting with these particularities. In physician John Phillips' history of how compressed air and beating "the bends" opened up vertical frontiers, he writes that "the ultimate limits of technological progress will be determined by the physiological limits of the humans who use them."[108] The extreme environment body operates under threat, but the exploration context can make sense of this, looking up from below or down from above, as progress, evolution, transcendence.

Swimming toward the habitat that looms before us like a soda can on legs encrusted with bright coral life and hugged by shimmering schools of fish, we came upon a timelined activity that calls on the mind to analogize and envision. Before us, Dave and Ron walk on the seafloor as if on the moon's surface, wearing weighted boots and helmets as if in spacesuits, building a spindly non-functional "lunar communications tower" out of thin white PVC, communicating with each other by comlink, unaware of us hovering to the side. Ron's work with PVC to evince the terrestrial uses of astronautical technology will continue after NEEMO as he continues work with Nicole on their Manna Foundation NGO that brings solar-powered water purification techniques used on the Space Station into communities in Africa and Mexico, work that came in part from his experience as an astronaut engineer and an epiphany he had while running, he told me, when he noticed the abundance of solar energy around him being absorbed into the asphalt, unused.

We swim by this analogue lunar scene and pop our heads up into the habitat's wet porch air/water boundary. The stench is impressive: accretions of bacteria, aromas from dive gear rinse buckets for experiments designed by Houston school children on environmentally-friendly bacteria-control methods. We chat with crewmembers, off quarantine now that it is the end of the mission. They are buoyant, elated, and completely comfortable. The loud grating and wheezing sound of the air pumping in and out of the habitat from above reminds me that we are in the extreme and still relying on life support, but the overall effect is not uncanny or sublime, but strangely homey, like being in someone's garage. Nicole snaps a picture of us.

Heading back out to glide around the hab my sociological self-consciousness is put on hold in favor of other kinds of consciousness: how much air do I have? Which way do I go? What happens next? I experience a temporary muting of ethnographic analytic loops about nation-building, military technology testing, the making of exploration as a valid activity, elite expenditures and privileges, avenues of technological chauvinism, universalizing slippages and erasures. I remember instead: poetic phrases from some of the online NEEMO aquanaut journals, and sensuous images:

> Transitioning to an Aquanaut was like staying out in the wilderness and actually becoming a part of the nature… The lightning flashes above us with a storm overhead remind me of another place that we had all but forgotten of during our stay as inhabitants of the reef.[109]
>
> … Floating in the terminator/ In the instant/Before sunset/In the moment/Before sunrise/In between/Night and day/Light and dark/Life and Death[110]
>
> *Image*: the surgical robot tying a knot in front of a window with fish swimming by.
>
> *Image*: Nicole on the NEEMO 9 night dive two days ago, kneeling on the sand in the midst of phosphorescing organisms, arms raised, imitating the Florida Keys' famous underwater "Christ of the Deep" statue.

As our VIP dive party begins our return to the surface, the regulator in my mouth whooshes out bubbles, reminding me of sound machines that imitate the womb experience. Sunlight gets brighter, the boat becomes visible. I surface, grinning, and am quiet on the boat ride back; Marc Reagan asks me how I liked the dive, I just smile and nod, which is acceptable in a group where actions are understood to communicate more precisely and righteously than words.

The mission finishes up uneventfully: the crew spend 17 hours decompressing in as their habitat bunkroom slowly changes to surface pressure; then they walk to the wet porch, hold their breaths and swim upward as fast as they can, having been re-adapted to life on land. There is a big "splashup" party on the patio-dock of a wealthy Key Largo couple who enjoy their association with NURC and NASA. The next days are spent packing and getting ready to go home. Sue and I find ourselves back at our usual Key Largo cantina hang-out. A local tow truck driver, Jake, amiable and happily drunk, chats with us, saying that he lives here for the sea, sand, and sun and asks us why we're here. We explain the mission, enthusiastically. He begins needling us: *what will you accomplish? What is the point?* I say, *To explore.* Sue, the daughter of a NASA engineer, says, like many of my interlocutors do, *To see what's over the next hill.* I find myself reciting justifications I had written in fieldnotes with exclamation points around them to highlight their unexamined assumptions; they fall out of my mouth and before I know it, I'm in a bargument defending NEEMO. Jake pops up from his chair in a huff: *That's a waste of your real lives.* Sue and I smile at each other and have another drink; we're going home tomorrow. In my suitcase is a plastic-sleeved certificate signed by NURC managers that proclaims me an "honorary aquanaut," with a new charge:

> Your journey to *Aquarius* at Conch Reef, in the Florida Keys National Marine Sanctuary, is part of our effort to excite and educate our friends about the wonders of our world's oceans and coral reefs. We challenge you to use this experience to teach others about what you saw and learned.

As I sit with Sue, I am uncomfortable about how I behaved like a NEEMO insider, but also impressed by the incorporability of its argument. From this point on, when I speak with other NEEMO participants and go to NEEMO reunions, experience and memories extend between us, like assumed agreements.

Conclusion: always arguing

> We choose...to do [these] things, not because they are easy, but because they are hard...
>
> John F. Kennedy quote, frontispiece, Review of Human Spaceflight Plans Committee, 2009[111]

In fall 2009, after I wrote this chapter, historian of arctic exploration Michael Robinson[112] posted in his exploration history blog "Time to Eat the Dogs" his interview with historian of British exploration culture Felix Driver.[113] Their topic was the state of exploration history as a discipline. Robinson has investigated how the twentieth century "Arctic fever" that still shapes American space program justification discourse was constituted when explorers gave a receptive American public a storyline about national vitality in which science and technology are embedded but not driving forces. Robinson and Driver discuss their sub-discipline's current move away from investigating how empire is and goes "everywhere" to emphasizing the particular contingencies and results of exploratory encounters among peoples (what Anna Tsing would call "frictions").[114] Driver points out that exploration was inherently fractious, to the point that argument and controversy shaped how expeditions proceeded as well as the ways that explorers interacted with publics and colonial powers and colonized peoples contended with each other in micro- and macro-arenas of confrontation and disputation:

> You can't work on exploration for long without realizing the strong emotional pull of the subject on explorers and their publics; and the fact quite simply that they were always arguing, either with 'armchair geographers' (those much maligned stay-at-homes) or with their peers. If these arguments were frequently staged if not orchestrated by others, that is part of the point: these controversies were more than simply the product of disputatious personalities, they were built in to the fabric of the culture which produced them.[115]

Both Driver and my NASA interlocutors are aware of the strategic value of conflicts and assertions to the production and reproduction of exploration as a technical and cultural act. By working on *and* in such a venture in a contemporary non-colonial setting, I've shown how environment is made into a vital proving ground minus the emphasis on the conquering of nationally defined territory, and I have also gone a step further to show how exploratory contentions are operationally and strategically "built in" to expeditionary things. I've argued that NEEMO missions are contentious to the core: contending for the interconnected social, evolutionary, and transcendental value of a broad categorical environmental overcoming.

As the space analogue acts out how and why to "extend humans" to the surfaces of other planets, it generates waves of *in situ* written, visual, and oral testimonials about the value of embodied exploration experience to "force" into being improved technologies and ways of living that by necessity must expand beyond "our fragile environment" on Earth. The space analogue on earth makes an accessibly naturalized case, before witnessing audiences, for the demonstrablility of astronautical epistemologies and ontologies, bringing the experientially possible, probable, and reasonable together. The mission treats "is" and "ought" like two PVC pipes in need of coupling in the analogue lunar communications tower corner, slipped together by bare aquanaut/astronaut hands to actualize a "human" goal of joining a now-ocean to a future-outer-space, bridging an ecologically limited human environment with an unlimited one. As I find out when I move from this experience into the realms of space life science, space architecture and design, and mission advocacy, the argument built into and coming from the NEEMO 9 mission refracts, contentiously and viscerally, through it all.

------//------

[1] Commonly attributed to Seneca the Younger's revision of a phrase from Virgil's Aeneid, "ad astra per aspera" is used in a launch site memorial plaque for the Apollo 1 astronauts killed during a launch test fire

["In memory of those who made the ultimate sacrifice so others could reach for the stars; Ad astra per aspera (a rough road leads to the stars) God speed to the crew of Apollo 1"]. "Ad aspera" is also, for example, the title of the National Space Society's journal.

[2] Soon after this interview, Mansfield retired from JSC to become president of an astronautics professional society and a director in a nearby NASA contracting firm where I visited him several times during my fieldwork.

[3] As I have explained in the introduction to this dissertation, this NASA project was not the project I came to Rice to pursue. Instead, the curiosity that led me to fall into a project centered at JSC happened precipitously, through an unexpected turn of events made possible by several key figures with extraordinarily distinctive personalities who provided me with access into some of the most restricted and fantastical spaces in the Rice University area, and, almost before I could catch a breath, onward to even stranger other spaces, even, with NEEMO, one that brought me into an environmentally "alien" world. And so, began a journey some of my Rice graduate student colleagues declared evocative of Victorian era *voyages extraordinaires*, particularly Verne's or Carroll's. This evocation acknowledges the position of the student ethnographer as inexpert naïf but in a throwback position, back to the very Victorian-era beginnings of anthropology. My colleague Nahal Naficy, who wrote a dissertation called *Persian minature writing* about her experience working in an office in Washington DC with Iranian democracy advocacy NGOs, reminded me often of my occupation of a kind of Wonderland and my Alice-ness along the way. Curt Mansfield' conspicuous and urgent engagement with time and its political appointments and space/time transitions at the time I met him was for me, an unmistakable White Rabbit encounter – an analogy I'm sure he'd react to with great good humor.

[4] Peter Galison has painstakingly detailed what he calls the differing institutional "intercalation" of instrument development, theorization, experimentation that create situations in which disciplines "trade" or collaborate across disciplinary boundaries in ways that enable new constellations of practice around shared discursive and material objects (Gallison 1997: 781-844). However, he does not include in those strata the bureaucratic or commercial functions of administration, promotion, fundraising, and social organization; this is an oversight remedied in complementary theorizations of how institutions coordinate and institutionalize different knowledge production techniques such as Keating and Cambrosio's "platforms" (Keating and Cambrosio: 2003) or ethnographies that more thoroughly map the social production of scientific and technical knowledge, such as Steven Epstein's *Impure Science* (1996) or Diane Vaughan's *Challenger Launch Decision* (1996).

[5] Kroll-Smith et al (1997: 3); see also de Certeau's essay ("Walking in the City" 1984: 91) on the modern American urban spatial "cosmos" of "coinciding" extremes, from oppositions of people to contrasts of deprivation and excess, that represent the act of "challenging the future."

[6] Aristotle [Kennedy] (2007).

[7] For example, microbiologist/geologist/astrobiologist Penelope Boston (1999) explains what "extreme environments" mean as an ecological relativist concept, claiming that extreme environments force organisms to modify themselves in ways that distinguish them morphologically from their ancestors, and that astrobiology is poised to find new environmental "norms," made imaginable by understanding Earth's biological extremes.

[8] I am suggesting in this dissertation that the environmental and ecological discourses and narratives I found within NASA communities of practice are in important ways pushing back against depersonalized and decontextualized forms of technocratic knowledge production. Arguments made within technocratic frameworks do not have to be inherently, as Jean-François Lyotard (1984) claims, anti-narrative, and in fact the argumentative narrative that unfolds in NEEMO is concerned with transmitting experience-based truths that are only partially connected to the production of scientific knowledge. NEEMO displays what Lyotard might describe as narrative defined by and immersed in "the pragmatics" of its own "transmission." (Lyotard 1984: 20).

[9] See Haraway (1991) and Robinson (2006).

[10] Toulmin (2003). As an ethnographic object, the "argumentative thing" also calls attention to the ways that anthropologists recognize and work with what George Marcus has called "critical forms" of fieldwork data" [McCarthy and Olson(2007:37)]. In this case, recognizing how "astronautical argument" escapes the standard data category of "discourse" became "critical" to how I understood particularities about astronautics as a technoscientific field, but this happened when I understood it to be inextricably bound up with "practice" data I collected during the analogue missions.

[11] Toulmin claims that arguments across different fields are comparable because they are procedural, and pursues his investigation by positing that shared procedural features (as seen in judicial processes), like the shared goal of justification, is what arguments have in common (Toulmin 2003: 14 – 19).
[12] As an ethnographic object, the "argumentative thing" also calls attention to the ways that anthropologists recognize and work with what George Marcus has called "critical forms" of fieldwork data." In this case, recognizing how "astronautical argument" escapes the standard data category of "discourse" became "critical" to how I understood particularities about astronautics as a technoscientific field, but this happened when I understood it to be inextricably bound up with "practice" data I collected during the analogue missions.
[13] Anna Tsing's work on global connections contends that they are not fluid motions but are defined by "frictions" made by the sticky vicissitudes of contentions and encounters, particularly clashes over "engaged" appeals to "universal" claims (Tsing: 2005). "Environments" are spaces of friction, fueled by competing claims about the nature and meaning of human/environment relationships and their futures. Her encouragement to social scientists to study how universals are made and unmade through in such nodes of friction contains an implicit invitation to study how arguments are instantiated. Space programs are ideal sites for such studies, considering how overcoded they are with conspicuously "universal" claims grounded in the very notion of the universe as a site for manifesting truths about humans, knowledge, life, and the future.
[14] Weddell (1978); see also Perelman (1982).
[15] See Thomson (1997), du Preez (2009), Hogle (2005), Kosut (forthcoming), La Violette (2006), Cohen (2004), Helmreich (2009), Olson (2010 forthcoming).
[16] Key work done to establish such differences can be found in Bijker *et al* (1987).
[17] Historians Robinson (2006) and MacDougall (1997) make comprehensive critiques of American human space exploration on these terms, see the Introduction for other citations. There is a deficit of comparative critiques of non-American human versus robotic spaceflight cases.
[18] Canguilhem 1989: 229.
[19] By calling NEEMO an argument in action, I am referencing Bruno Latour's (1987) classic admonition to study science in action with respect to the lengthening and strengthening of scientific networks through contestations about the making of facts and authoritative technologies.
[20] Center for Cultural Studies and Analysis (2004:2).
[21] Bainbridge (1983).
[22] See Introduction for detailed citation list.
[23] See Launius (2003) for an overview of pre-Vision for Space Exploration polling trends.
[24] http://www.nasa.gov/directorates/esmd/home/whyweexplore/why_we_explore_main.html
[25] http://www.nasa.gov/externalflash/nasacity/landing.htm , NASA Co-lab
[26] Marburger (2006).
[27] The source analogy for the idea of humans as children leaving an Earthly cradle is attributed, vaguely, to the 1911 letters of Russian cosmist and rocket equation theorist Konstantin Tsiolkovsky; a common translation, which appears on at least one NASA website, is "the Earth is the cradle of the mind, but we cannot live forever in a cradle." In 2003, the NASA Means Business student public service announcement competition winner reproduced this analogy as a child figuring out how to use a chair to reach a table on which a Mars globe sits in their video "Reach" (Art Center College of Design: 2003).
[28] See Hesse 1966; Beer 2000; Campbell (1999), Dunbar (1995), Hallyn 2000, Helmreich (2006) and (2009).
[29] Holyoak and Thagard (1995: 15); see also Kenneth Dunbar (1995), whose meticulous analysis of analogy-making in laboratory settings shows that scientists make "local, regional, and long distance" analogies, the latter two categories often used expressly for communicating with colleagues of other disciplines or publics.
[30] https://external.jsc.nasa.gov/analogs/index.cfm
[31] Shelley (2003).
[32] See Holyoak and Thagard (1995), Dunbar (1995).
[33] Stepan (1991).
[34] Stepan (1991).
[35] Helmreich (1998); Keller (2002), Greisemer (1990).
[36] Helmreich (2009). Myers (2009).

[37] Kuhn (1996), Latour (1987).
[38] See Rheinburger (1997) and also Shapin and Shaffer (1985), who specifically address the role of an engineered and operated experimental thing, Robert Boyles' air pump, in the coordination of material, literary, and social technologies meant to produce and validate of matters of fact. Their work describes how the rhetorical dimension of argumentation becomes ontologized in step-by-step experimentation, which is a process that connected design and engineering to the production and report of scientific theorization, facts, and arguments. Their work, focused primarily on scientific experimentation and its establishment as an authoritative producer of theory and knowledge, calls attention to the question of how and why engineers "engineer" argumentation that differs from scientific argumentation and what such engineered arguments might look like.
[39] See Keating and Cambrosio (2003) on platforms, Collins (1992) on the tactics of "core sets" of scientists to certify knowledge and resolve controversy.
[40] See MacKenzie (1990) on the ways that the characteristics of military technologies, such as self-contained nuclear weapon guidance systems, are material reflections the arguments in favor of them.
[41] See Bijker et al (1997), Law (2002), Latour (1996), de Laet and Mol (2000).
[42] Space shuttles and their explosions have provided a useful topic of investigation, theory-validation, and debate for a handful of scholars of the history and sociology of technology (Pinch [1991], Vaughn [1996], Alder [2007)], Serres and Latour [1995]}, providing evidence for discussions about how their disintegration as objects calls attention to the complex web of social processes, not just engineering, that constitute them as "things" or "entities" in a social or as Latour would say "material materialist" sense.
[43] Vaughan (1996:248).
[44] See Alder (2007), Daston (2004).
[45] Vaughan (1996).
[46] Godin (1997).
[47] Campbell (1999: 152).
[48] Toulmin (2003: 238).
[49] Toulmin (2003: 238).
[50] Toulmin (2003: 234).
[51] Weddell (1978: 7).
[52] Fabian (2002: 90).
[53] Redfield (2000:23).
[54] See Chapter 2 for my discussion of how the NASA cyborg project to "engineer man for space" emerges in a materially different form than it was envisioned, leading to other ways to co-adapt humans and technology. However, the cyborg simulation project continues in the form of controversial "virtual astronaut" programs designed to generate simulated data on human physiological and adaptive responses to space. At the time of this dissertation, a director within NASA's Human Research Program states that NASA still funds such computerized simulation projects but as of yet their models are still not accepted within NASA as standard as substitutes for experimental data collected from human subjects.
[55] See for example the Tektite and Man in Sea projects.
[56] Collier (2008: 243).
[57] During the time I collected data for my project my interlocutors were participating in or involved with 6 spaceflight analogue programs that were puting participants into indoor and outdoor analogous space living and working sites (NASA's NEEMO, NASA's DesertRATS, NASA Haughton-Mars project, Mars Society's FMARS research station, the European Space Agency and Roscosmos MARS500 chamber living study; affiliated hospital "bedrest" analogue programs). However, the JSC analog data website (https://external.jsc.nasa.gov/analogs/index.cfm) lists 58 "projects," "sites" and "facilities" that have generated data for or relevant to NASA projects, creating a mixed spatial geography of space-on-earth places constituted by data collection. At the time of this dissertation, NASA had moved direction of its space analogue programs from their originating centers (Johnson Space Center and Ames Research Center) to NASA Headquarters in Washington, D.C. This centralized office was moving to require that all space analogues be conducted, like NEEMO and like spaceflight missions, using flight controllers and a timelined schedule. NASA also has networked relationships with space analogues run by other space agencies, such as the MARS 500 (Roscosmos), and 2007 Canadian Analogue Research Net-work (CARN) by the Canadian Space Agency (CSA) that focuses on analogue research in so-called "critical environments."

[58] McCray, personal communication 2009.
[59] Testimony of Sylvia Earle explorer-in-residence, National Geographic Society and founder Deep Ocean Exploration and Research, Inc (based on meeting transcript) (2002).
[60] Paine (1990).
[61] NSBRI http://www.nsbri.org/About/
[62] http://www.nsbri.org/NewsPublicOut/index.epl
[63] Masco (2006: 265). Masco describes secrecy as a "constitutive" element in the "U.S. nuclear complex," meaning nuclear laboratories and the economies and social networks in which they inhere. I was haunted by this in part through Masco's work, which I referred to in fieldnotes as the "evil twin" of my fieldwork and dissertation, understanding my own involvement in the internal experience of the U.S. human spaceflight program's making of, as Masco and I discussed in 2009, a "dual-use" regimen for space, for astronauts, and for an imagined national future.
[64] Shephard and Kosslyn (2005).
[65] During a meeting of space psychologists I attended during the pre-mission planning stage, psychologists discussed the need to examine ways to discover and enhance positive features of extreme exposure, which is a much less investigated dimension than pathology. This aim reflected both their research interests and their sensitivity to the historically fraught position of psychologists and physicians within astronautics based on their power to ground astronauts from flight, as evidenced by the Apollo-era joke that astronauts "won't be happy until the last physician is strangled by the entrails of the last psychologist." Nevetheless, during the time I did my fieldwork at NASA and the shocking "astronaut love triangle" attempted-murder drama happened in 2007, behavioral health grew in stature as a primary "risk factor" for the success of long-duration spaceflight, and many of my JSC interlocutors listed it to me as their top predictor of a Mars mission failure.
[66] This juxtaposition of modern environmental powers is not lost on historian of Houston Robert S. Thomson (2007), who argues that urban climate control projects became a showcase of naturally hot and humid Houston's civic identity as a center of progress that could overcome a "natural climate" that encouraged laziness, racial discord, and immorality through technology, with Johnson Space Center representing the "universal" and "ultimate human control of the environment" (2007:97).
[67] In her essay "The Adventures of the Frontier in the Twentieth Century," Patricia Limerick (1994) traces that shift in a broad sense. She claims that arguments between historians about a loss of specificity in the use of the word "frontier" illuminate, along with its ubiquity as a positive popular cultural reference celebrating the "pioneering" of new things and movements, the detachment of the term from its genesis in the rhetoric of White colonial and environmental expansion
[68] NASA's website for its "Exploration 101" public education effort features the statement by Administrator Griffin that "We are explorers…we dare to explore," and daring is featured prominently as a justification for exploration: http://www.nasa.gov/directorates/esmd/library/exploration_101.html
[69] Space mission patches, as collectable and researchable items, are objects of great interest within the spaceflight community at large as items that allow space historians to identify symbolic and ideological patterns within space programs and among social groups connected through funding and institutional association.
[70] Nye (2004: 13).
[71] Stenuit (1966: 19 – 21).
[72] Rappaport (1984). Watching the play between my interlocutors' directly obtained and institutionally inflused understanding of cybernetics, systems theory, ecological theory, social psychology and even anthropology was like witnessing evidence for a theory of the diffusion of theory (versus culture).
[73] The NEEMO organizers are not objecting to laboratory simulation as a real-like substitute for the real (see Baudrillard [1994]), but are objecting to the absence of any other category of preparatory simulation in the gap between simulation and the real. They are, as Sherry Turkle argues, examples of technoscientific practitioners who perpetuate technologies of simulation yet are "discontented" with particular aspects of it and losses it represents, particularly in terms of generational differences in the characterizations of what constitutes "the real" (Turkle [2009]).
[74] See Kohler (2002), Robinson (2006); see also Mukerji (2006) on the ways state-funded scientists negotiate the co-construction of authoritative field science practices and government policy-making.
[75] That human spaceflight would be perceived as a "boondoggle" because it is fun is a thorn in the side of NASA's whole institutional culture, so much so that "Boondoggle's" is the reflexively self-conscious name

of a legendary bar down the street from JSC in Seabrook that is frequented by astronauts and flight controllers.
[76] Coyne (1999).
[77] Abrams (1971: 412)
[78] Buell (1995).
[79] Cohen (2004: 322).
[80] Toulmin (2003:11).
[81] Historians of science have fruitfully explored Weber's (1958:141) depiction of the importance of the controlling of experience through "rational experiment" and the making of the ethics, social structures, and practices of normative science; exploration retains the mark of the irrational, uncontrolled, and unscientific, which is justifiable historically but, as I am attempting to show here, a much less easy to make distinction in contemporary exploration practices in which exploration bridges labs and fields and virtual spaces.
[82] Verne (1998).
[83] LaViolette (2006).
[84] See Stuster (1996) for an overview of polar and space exploration time studies.
[85] Bass *et al* (2005).
[86] Mirmalek (2009).
[87] Hersch (2009).
[88] See Helmreich (2009) for a discussion of the "alien ocean."
[89] I used the timeline to average out percentages of activities devoted to science (19%), technical testing (18%), exploration (11%), activities of daily living (42%), and "outreach and education" acts of demonstration and communication (10%). These calculations are based on my categorization of NEEMO timelined activities from timeline version dated 03/21/06; in actuality, these proportions changed according to contingencies of the mission, but they provide a good estimate. Mission Day 2 activity proportions are equivalent to the mission's total activity proportions. To my knowledge, these proportions were not deliberately set and adhered to, but are an artifact of funding and workload negotiations between NASA and NURC.
[90] Mirmalek (2009) tracks the temporal problems and solutions stemming from new work regimes required by NASA practitioners working with robots Martian day "sol."
[91] Prentiss (2005).
[92] http://www.canarie.ca/conferences/Neemo/index.html
[93] Foss and Griffin (1995)
[94] Winter (2001).
[95] http://www.canarie.ca/conferences/Neemo/index.html
[96] Aristotle [Kennedy] (2007: 244 – 252).
[97] Helmreich (2009: 172).
[98] Aquarius expedition journals: http://www.uncw.edu/aquarius/archive/2001/10_2001/journal9.htm
[99] Schweitzer and Cicovacki (2009: 229).
[100] In *Better than Well*, Carl Elliot (2003) examines the idea that enhancement not wellness is a desired endpoint in a contemporary America, despite expressions of anxiety over the use of drugs and technologies to attain it.
[101] For discussions of how the categorization of people and things/concepts are co-constituting see Ian Hacking (1986) and Bowker and Star (1999).
[102] Kamler (2004); the volume's Penguin edition is subtitled: *what happens to the body and mind at the limits of human endurance.* There is a body of medical writing on extremity; Ashcroft (2001) writes an almost identical book to Kamler's.
[103] White (1987: xviii)
[104] In her masterful essay "Objectivity and the Escape from Perspective," Lorraine Daston (1992) discusses the origin of scientific aperspectival objectivity in moral philosophy, a process that is resutured within "overview effect" advocacy (see Chapter 4).
[105] Suedfeld (2006).
[106] Watts (1999).
[107] Beer (1983).
[108] Phillips, p 2
[109] Dave Williams (NEEMO 1)

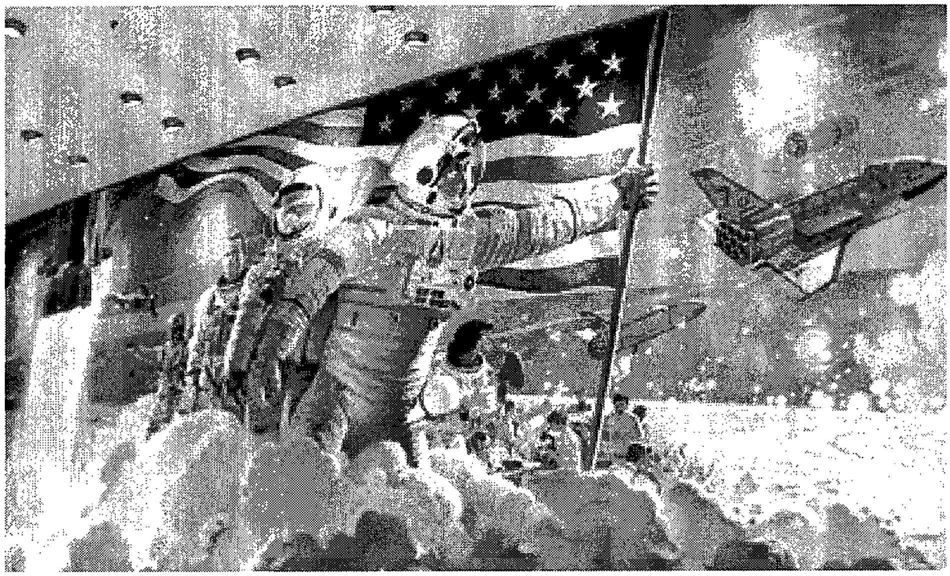
---

[110] Mike Gernhardt (NEEMO 1)
[111] Augustine Commission (2009).
[112] Robinson (2006).
[113] Driver (2001) and (2005).
[114] Tsing (2005)
[115] Robinson (2009b).

Chapter 2

Ecobiopolitics

What we do at NASA is, quite simply, larger than life
-- Mike Griffin,
NASA Administrator[1]



Mural / Johnson Space Center Teague Auditorium

We stand in a wide JSC meeting room hung with lustrous photographs of deep space vistas and luminous white-suited human figures suspended near glossy spacecraft. In these figures are signs of vulnerability and power: the pressure suit's bulky dependence and inflated assertiveness, the bright transcendental arc of each golden visor. Dr. Ken Dempsey, who knows these suited and unsuited human beings well, hands me an organizational chart for the NASA Space Life Sciences Directorate. Boxes and arrowed lines crisply delineate the JSC-based Directorate's subdivisions and project-based associations. It also illustrates something I began to notice after months of crisscrossing the Center's humid lawns to understand how astronautical humans are constituted. In meeting with biologists like Dempsey, with physicians and psychologists in the Space Medicine Division and Human Research Program, and with biomechanical engineers and industrial designers in the Habitability and Human Factors Division, I found several humans: a crewmember, a research subject, a biological system, an environmental inhabitant, and a mission factor. Like other biomedical subjects, the spacefarer is made ontologically "multiple" through distinctive expert practices that are institutionally coordinated.[2] I found, however, that the spacefaring medical subject's first level of ontological distinction does not occur along specialty lines. This distinction is more fundamental, having to do with how astronautics practitioners collaborate to understand and work with human life as an environmentally contextual and contingent state of being.

During one of our first conversations about NASA's efforts to redefine national and human limits, Dempsey asked me, "Have you heard about our 'space normal' work? We need to define 'space normal' so we don't keep trying to treat astronauts in space as if they're sick." Posing normality in environmental terms in order to redefine sickness and health sounded odd to me, after having worked in the medical field where standard conceptualizations of human life are made on biological, not environmental, terms. But Dempsey's question illuminated what I was hearing and seeing at JSC: environments, bodies, and life processes were defined as intimately co-constituting at the micro- and macro-levels. Instead of treating environment as a "given" or as a category of secondary medical variables, space biomedicine puts it center stage. The phrase "space biomedicine" in fact, is an ironic description of NASA biomedical practice and research, which proceeds as if there is little if any "space" at all between bodies and environments. My space life sciences research question became very basic: What kind of medical subject and human being is the astronaut? What I found influenced my larger research question, which asks how shifts in the outer space focus, from territory to extreme environment, render American ecological knowledge and values scalable. In this schema, "human ecology" is instrumentalized and unbounded within a social and political project of optimization and extendibility.

I explore in this chapter[1] how, in an inversion of the usual clinical model, astronauts have become fundamentally "environmental" rather than biological medical subjects. Michel Foucault's (1988) concept of biopolitics provides a tool for understanding how modern forms of normality, health, and sickness come about as power and knowledge are invested in the basic processes of "life itself"[3] -- processes canonically tracked at the level of individual bodies and populations. As such, this concept only goes so far toward illuminating how and where such investments inhere in space biomedicine, which is a branch of environmental medicine focused on researching and managing human life in extreme and artificial environments. Astronauts, as I will show, are optimally medicalized biopolitical subjects, but in a distinctive way not fully captured by the individual-population axes of biopolitics. Space biomedicine is engaged with knowing and intervening in life-environment interactions in spaces where life's "milieu," whether conceived of as a spacecraft or a planet, is not bracketed out from life itself.

The national and international politics that frame spacefaring are well described in numerous histories and policy analyses of space programs, but the kind of politics that I attend to here are different. They are the politics being constituted within American space program spaces where policy mandates meet cultural, technical, and medical theorizations of astronauts as biological and ecological subjects on missions to socially

---

[1] This chapter appears in an abridged form in *Medical Anthropology* as "The ecobiopolitics of space biomedicine" (2010, 29:2).

incorporate new environments. These are the politics involved in the strategic responses by American space biomedical practitioners to what Foucault would describe as the "problematizations" of established notions of life and health that arise when biomedicine extends into environments that require experimental technology for human survival.[4] Using an array of ethnographic data, I argue that American space biomedicine's programmatic biopolitics extend into "vital spaces" where life *and* environment are dually problematized, engendering a distinctively ecological modality of biopolitics. These are the politics of an instrumentalist kind of environmentalism, in which astronautical technologies are tools for acquiring knowledge about outer space as well as for creating new ways to adapt to, characterize, and manage human environments.

I motivate this chapter's specific analysis of space biomedicine by bringing Foucault's concept of biopolitics into dialogue with his mentor Georges Canguilhem's theorization of "milieu" as a "basic category of contemporary thought."[5] Canguilhem writes that the concept of "milieu" has historically competed with "life" as the focal object of theories about vital processes, shaping biological and medical ways of thinking about vitality in contextual, spatial, and by extension, ecological terms. In its various incarnations, such as "organismal milieu," "environment," and "ecosystem," the concept of milieu, which can be defined as life's spatial and relational context, continues to inform modern claims about how to understand and intervene in human limits and potentialities. Space biomedicine takes this project to extremes to render human spaceflight into a transcendental ecological venture. As a result, space biomedicine provides a uniquely positioned window on how technoscientifically defined milieus, and their environmental subjects, objects, concepts, and processes, become elements of biomedical knowledge, politics, and future-making. Space biomedicine only partially represents astronauts in ways similar to other environmentally over-determined subjects, such as those made through colonialism, disaster, and social vulnerability.[6] Astronauts are treated rather as futuristic pioneers of new environmental systems and ecologies that are extendable in scope and scale, creating new ways to naturalize progress in spatial terms. In several ways, then, this chapter elaborates on the previous chapter's analysis of space analogues as *in situ* operational arguments for human extendibility.

I begin by describing the general sociopolitical and scientific parameters of astronaut medical subjecthood and how I conducted earth-based research to understand space biomedicine and its strategies. I then present Canguilhem's historical analysis of the concept of milieu and use it to illuminate space biomedicine's genealogy as an environmental practice. This grounds my depiction of what is politically, conceptually, and operationally at stake when space biomedicine tinkers how to buttress as well as breach body/environment boundaries. I illustrate my claims by analyzing what I call the *ecobiopolitics* of two signature space biomedical strategies: 1) the invention of a "space normal" category that simultaneously normalizes astronaut bodies *and* the outer spatial milieus that they inhabit, and 2) the development of concepts and tools that enable astronautics practitioners to manage astronauts not just as living bodies but at-risk living systems seamlessly integrated with mechanical and environmental systems. Since my aim is to call attention to how astronauts are configured as eco-systemic elements, and to the perspectives and experiences of people associating to achieve that configuration, I limit my discussion of astronaut subject*ivity*, but point to it as intimately bound up with those processes.

By examining how space biomedicine remakes the vital capacities of humans as cosmically ecological beings, I join scholars pursuing two projects: to trace the "return" of environment and milieu to the center of biomedical theory and research,[7] and to amend the concept of biopolitics in order to account for new critical forms and relations that refine "bio" as a medical and political object.[8] While space biomedically-driven techniques and technologies, such as remote-controlled telesurgery, miniaturized diagnostic devices developed to extend medicine into environmentally constrained conditions, and even the idea of an environmentally ecosystemic "spaceship Earth," move between NASA and other domains of American life, they come from workspaces in which an ecobiopolitical theorization of the human is emerging.

Courtesy NASA

Astronaut medical subjecthood: the view from 100 kilometers

For fifty years, from Project Mercury to the current International Space Station orbital laboratory program, NASA has been demonstrating the United States' political, technological, and scientific capabilities by making people survive and work beyond Earth's atmosphere. NASA space biomedicine today is a multi-disciplinary effort to research and manage how people live in environments that are hard to control and predict. It mobilizes intra- and extra-mural research to determine how to keep the people that NASA's first medical director called "superselected citizens" alive and healthy when they are exposed to the adverse conditions of space and when they return to Earth. This is a celebrated form of environmentally at-risk citizenship that contrasts with the abject citizenship that comes with technoscience threats and disasters.[9] In this first section I outline how this heroically exceptional astronaut medical subjecthood is made possible by new technologies and techniques that medicalize human life at the utter spatial and temporal boundaries of survivability and governance.[10] What defines astronaut medical subjecthood is how humans are hyper-medicalized during extreme environmental transitions, exposures, integrations, and adaptations.

My internship with the National Space Biomedical Research Center that brought me to this dissertation project was in some ways an entrée to a familiar world of biomedical language and research, but NASA's biomedical landscape and discourse was unsettling. First, there were restrictions on what I saw and where I went (I could not witness, for example, astronaut clinical encounters) and I was "inside" a zone in which what was being secured from the public went beyond patient confidentiality or safety. But what became more unsettling was the way I had to learn to think differently about what had been "givens" to me: people and even medicine itself became strange to me. The categories of clinical practice and research resembled those in the Earthly domains I knew well. But at JSC the concept of "environment" never receded from view or discourse and instead modified everything I saw, heard, and even touched as an NSBRI research intern and ethnographer. In space, most minor medical and research activities are complicated by concerns about human/environment interactions, from eating to breathing. The collection of samples for research are determined by how fluids flow, how pressure affects instruments and containers, how nothing stays put, how cosmic rays shoot through everything all the time, how every somatic cell is in reaction, and how molecules are disturbed. As an underwater research intern on NEEMO missions (see Chapter 1), it was almost impossible to forget the environmental dimension of anything at anytime; bags of saliva samples I processed from astronauts underwater were wet and smelled of ocean, their sample containers sometimes exploded into bags as they were brought up to surface-level atmospheric pressure, meaning that astronaut spit had gotten everywhere, like it would in space. This need to reorient myself to the practice of medicine reminded me again of the imposition of "environment" into a field that I had originally imagined as being centered on human biology. To add to this, I got to know astronauts as persons, recognizing that the glamour that clung to them came from their exposure to an exotic environment (and one that neither I nor most of my space life sciences expert subjects would ever go to). By figuring out that the problems and conditions of working with patients in environmental extremity anchors space biomedicine practice, and by putting aside my assumptions about what count as the most basic concerns of biomedicine, I mapped out space biomedical subjecthood.

When people are selected as NASA astronauts, a career marked by frequent and comprehensive medical and psychological screening, they are cared for as members of a local community and as government test subjects and political figures. JSC's onsite Flight Medicine Clinic, then, is at the heart of a complex constructed to showcase the fitness of the nation's sociopolitical system as well as that of its exemplary space pioneers. This is where astronauts and their families receive primary health care and enroll in medical research programs. During and after their service in the corps, astronauts are encouraged to participate in longitudinal research managed by the Space Life Sciences Directorate that oversees the Clinic. As one of the buildings in JSC's central cluster of cafeterias and program offices, the Clinic faces a park and duck pond and is situated kitty corner to the Space Shuttle and International Space Station operations buildings and the astronaut corps offices. While in active service astronauts are routinely checked at the Clinic for, as one space biomedical clinician puts it, any "otherwise insignificant problem" that might threaten their space mission-readiness as an astronautical "total performance system."[11] In his analysis of space biomedical organization at JSC, sociologist Joseph Kotarba, who did research onsite, argues that aerospace clinical medicine takes an informally "holistic" approach to the "comprehensive" control of its "high value" astronaut patients.[12] He describes how biomedical practitioners achieve this "holism" by assimilating the astronaut body and mind into total systemic environments: institutional, social, technological, natural.

Outer space environments are extremely and uniquely problematic for human life. Despite being in protective suits and spacecraft and having trained in analogous "extreme environments,"[13] exposure to outer space conditions makes astronauts temporarily or permanently impaired by terrestrial standards. After traveling past the extreme 100-kilometer altitude that officially transforms them into "astronauts," people often experience mild or severe cases of nausea and disorientation called "space adaptation syndrome." Moving beyond Earth's atmosphere brings on a host of physiological effects, many of which are characterized as premature aging. With weightlessness comes fluid shifting that causes temporary cardiovascular and hormonal irregularities and increased risk for renal stones, decreased red blood cell mass, and bone loss that may never fully restore. Enduring constant cosmic rays and fluctuating solar radiation officially categorizes astronauts as radiation workers and they wear dosimeters that frame their careers in terms of lifetime "exposure years," heroically distinguishing themselves from otherwise accidentally or disastrously irradiated subjects. Their neurological and mental status can alter them in unheroic ways, however, making them act cognitively impaired or even psychotic when on orbit or back on earth. When astronauts return to earthly gravity, some space adaptations like bone loss and fluid shifting make them vulnerable to injuries.[14] To alleviate these problems astronauts engage in "countermeasures" in space (e.g., take medications, exercise for hours) to protect their earth-normal health status. As NASA implements its new mandate to build extendible extra-terrestrial human habitation systems, the Space Life Sciences Directorate is receiving input from the Institute of Medicine and other advisory bodies to develop "bioastronautics" research, countermeasures, and telemedicine protocols for long-duration missions.

Dempsey's life sciences manager colleague Carla Prentiss described "bioastronautics" as "all things that address the human," from "medical care of the astronauts" to "the habitat [and] the environmental control systems." In this way, it covers both basic and applied life sciences activities. Changes in presidentially mandated space policy, however, mean that funding for basic and applied science fluctuates according to larger political agendas, a NASA phenomenon coincidently dubbed "biopolitics" by a historian of space biomedicine.[15] When I began my research on the new Constellation program, such a shift meant that funding ceased for basic biological research and became available for applied research into "human systems" as an eco-systemic element of larger "mission systems." The view of what constitute biomedical space and concerns was broad and openly speculative, moving from Earthly life to "beyond, from the intermolecular to the heliospheric.

The eco-systemic integrations that mark astronauts as futuristic and fascinating human subjects are their intimate incorporations with technologies. A celebrated form of space age body/machine integration is the "cyborg," first proposed in a 1960 NASA research paper and which social scientists subsequently elaborated on theoretically in order to investigate contemporary hybridities of living and non-living things.[16] It is important to recall that the original cyborg was a mouse implanted with technologies that would enable space environmental adaptation from within the body rather than through the use of spacesuits.[17] Contemporary astronauts, however, set limits to the kinds of accommodations they make in the name of adaptation, having objected early on to being "Spam-in-a-can" or, in an only slightly more advantaged version of the subhumans that preceded them, "lever pulling monkeys." Astronauts today do not have machines routinely grafted into them, nor have they taken on the mechanically fraught embodiments of science fiction cyborgs. While cyborg study authors Klynes and Cline imagined their technology as freeing for body and spirit, astronauts live and work in a less hypothetical social and technical environment. They have created an occupational culture that resists certain kinds of corporeal boundary-crossings on ethical and occupational security grounds, even as they actively participate in research to design and advance "human-machine" systems integration.

While I was assisting to consent aquanauts as research subjects for the NEEMO 9 mission, a physician astronaut candidate also working on the project reminded me that astronauts qualify as a "captive" and "at risk" medical population; however, their ethical and technical position is actually more ambiguous. Because they are pioneering a new experimental environmental capability and domain of governance, they occupy a biopolitical limbo somewhere between abjectness and privilege. Although they are subject to intensive monitoring, social and medical surveillance, frequent medical evaluations and interventions, and expectations that they will be research subjects, my interlocutors and other sources[18] report that astronauts, unlike non-elite medical subjects, can protect their bodily integrity by retaining the option to refuse invasive procedures and monitoring which they fear might lead to the detection of medical conditions that disqualify them from flight. There are (as yet poorly) documented stories of astronauts resisting surveillance, such as the Skylab 4 "mutiny" in 1974 in which astronauts stopped working in protest against a grueling work and research schedule. I was also assured by two flight controllers and several scientists and engineers that astronauts exert more control over voice and visual monitoring systems than the agency would like by occasionally turning off cameras and microphones. Even as astronauts negotiate their bodily integrity and autonomy, it is ultimately their participation in making humans into environmental "elements" that constitutes astronaut subjectivity and subjecthood.

Astronaut bodies and life processes, then, are not isolated as the primary sites of astronautical monitoring, investigation, and intervention; instead, those activities concentrate where bodies and minds closely couple and interface with technologies and environmental systems. Such interfaces, from workstation setups and food/waste systems to spacecraft atmospheres, are medicalized and monitored through what might be termed NASA's "cyborg epidemiology." The "population" that this epidemiology targets is not classically biopolitical: it is a collectivity of living and non-living things in vital and mutually sustaining if not biologically generative association. NASA life scientists and engineers work together to design and manage semi-closed loop environmental systems in which the "space module and its crewmembers are exposed to an intricate interplay" of "physical environments [...], human responses to these environments, and the environmental design limits that are based on these human responses."[19] NASA cyborg epidemiology produces knowledge about human/environment interactions in order to make biological and non-biological things compatible and to mitigate the "high probability of cross-contamination among crewmembers and between crewmembers and space module."[20] In this cyborg epidemiological model of human/environment interdependence, the definition of astronaut health is still based on biologically-defined "natural" standards of wellness, but that definition must flex to include as manageable and normalizable those biologically abnormal states that come about in the most extremely social and artifactual milieus (e.g., space and marine suits and vehicles, artificial ecospheres) that social groups and nations have the power to create.

The biopolitics of the astronautical milieu

As the "human element" in a national experiment to innovate the knowledge and management of technical eco-systemic interactions, astronaut medical subjecthood highlights the ongoing relationship between the concept of milieu and practices of modern governance. Although aerospace engineering and space biomedicine practitioners use the terms "environment" and "system" rather than "milieu," Georges

Canguilhem's historical analysis emphasizes that "milieu" conceptually bridges the physical and life sciences in ways that have ongoing philosophical, social, and political implications. In his elegant essay "The Living and Its Milieu," Canguilhem explains how the 19th century idea of "milieu," meaning the set of relations between an organism and its environment, originated in physics theories about how objects were connected in space by forces.[21] The concept of "milieu" subsequently became critical to modern biological theories of how and why living things interact and change. Although, as Canguilhem claims, there have been periodic "inversions of the relationship between organism and milieu" that influenced debates in biology about the causes of human variation and evolution,[22] the concept of an organismal milieu has provided an anchor for social projects that mobilize environments for the purposes of remaking forms and ways of life and expanding governance into new spaces. The biopolitical strategies that characterize the astronautical milieu, however, bear down on the technical details of human/environment interaction, not on the milestones of human generative processes.

Since the concept of milieu is historically linked to theories about how living organisms can be *made* to change, it's important to consider how the biomedical subjecthood produced by a national space program is related to social programs that attempt to medicalize and control space in order to effect changes in people. As I discuss later when I locate space biomedicine in the contemporary genealogy of environmental medicine, the political-spatial concept of a milieu is central to enterprises like colonial medicine, public health, eugenics, penal reform, and urban planning.[23] In such programs, sex/gender, race, and other scientifically and socially defined characteristics become key biopolitical targets, for either enhancement or erasure. The latter tactic is present in

American space biomedicine, and echoes official programmatic discourse advocating extension of "humans" in general and "Americans" specifically.

Ironically, however, certain normative life processes at the core of imaginaries about experimental lifeways beyond Earth,[24] and in which biopolitics are deeply invested on Earth, such as sexuality, heterosexual reproduction, and the raising of children, are deemed unmanageable in space. As sociologists Casper and Moore found in their 1995 study of NASA's treatment of gender, sex, and reproduction as mission "factors" to circumscribe and control by targeting female identities and life processes, there is a persistent expectation for crewmembers to be or act male and asexual or constrainedly heterosexual.[25] In the early days of human spaceflight medical experimentation, this bias against the sexually and reproductively marked bodies of women superceded their consistent capability to pass astronaut qualification tests based on simulations of space environmental conditions and stressors, which occurred when a group of women pilots in the early 1960s "aced" those tests but never became actual astronaut candidates.[26] As a parallel to the continuing sex/gender biases and erasures, I found that demographic variation in "race" and ethnicity in the astronaut corps is touted as an example of the space program's all-American inclusiveness, but in mission training and planning such variations from an Anglo-American and Christian "baseline" are labeled as "cultural" or "behavioral" mission factors to be managed through "team cohesion" interventions and limited "personal" accommodations of diet and religious practice.

If space biomedicine does not take on a biopolitical concern with controlling generative life processes it also is not concerned with *end* of life processes. Astronaut life in space exists in a kind of biopolitical holding pattern with respect to birth and death, since the astronaut body on a mission is more than a human life, it is an operationalized biological element within that mission environmental system. Astronaut death, then, is problematized not just as loss of human life but also as a systemic failure. Two longtime aerospace physicians I encountered stated that the human dimension of astronaut death in space is such problem for the agency that until recently development of crew escape technologies was considered programmatically "optional" and even as a possible "threat" to the image of human spaceflight system design as "safe." "There isn't even a body bag on the Space Station" one flight surgeon told me with undisguised disdain, shaking his head. In addition, an engineer who trained to participate in aerospace accident investigations recounted that the remains of humans in one Shuttle disaster were not immediately put into body bags or ambulances, but into shipping containers carried in the backs of unmarked trucks. If I may detour Foucault's description of how autopsies enabled "anatomopolitics" that abstracted life in terms of disease processes, the space biomedical acts described to me do not reveal but obscure "the dotted outline of the corpse"[27] on the body of the living astronaut. They foreground instead that body's abstracted equivalency with other damaged hardware or systems that are investigated as elements of a failed "mission environment."

While NASA holds the body's beginning and end of life processes in space in a state of biopolitical indeterminancy for political as well as technical reasons, space special interest groups and new commercial space companies are remaking the very idea of death in space. As the Obama administration's Augustine commission to re-evaluate NASA's mission and Constellation program was winding down in 2009, and causing anxiety over the future of expensive human spaceflight programs, Lawrence Krauss, a geologist and member of the Mars Society (a non-profit Mars mission planning advocacy and research organization) wrote an Op-Ed piece in the New Your Times advocating a "one-way" trip to Mars. He declares that the assumption that all spaceflight missions should end in a "return" to Earth defeats the purpose of moving toward eventual environmental redundancy for a species currently rendering its own planet uninhabitable. Citing informal surveys among his geologist colleagues working on desert space exploration analogues who stated that they would "all" agree to a one way trip, Krauss declares that the medical risks of space radiation and microgravity to individuals are less important than finding "extreme solutions" to the problem of how to "expand the range of human civilization."[28]

Astronautics memorial activities also reframe "death in space" as a way to perpetuate human vitality. Contemporary notions within astronautics, metaphysical religious, and transhumanist advocacy networks that portray outer space as a transcendentally vital domain in which it will become possible to avoid extinction and connect with transcendental notions of universal conciousness such as the "noosphere" are genealogically related to the philosophical writings and theoretical astronautical calculations of Konstantin Tsiolkovsky, the originator of the still-used Tsiolkovsly rocket equation and a follower of Russian cosmism, a movement to instantiate the next cosmically-directed phases of human evolution.[29] Capitalizing on the environmentally transcendent image of the astronaut and resurrecting Tsiolkovsky's belief that space was alive with spirits, commercial launch company Celestis, Inc offers to send human cremains on "memorial spaceflights" into orbit or beyond it on an endless "journey" into deep space, thereby creating an "undead" "posthumous cremain-astronaut."[30] I witnessed similar ideas and sentiments about the trans-biological vitality of space when I attended an onsite memorial service for one of two employees who died during JSC's hostage/suicide event in 2007. Standard American and Christian memorial practices were hybridized with astronautical discourse. In his colleagues' elegies, the engineer's spirit was described as moving "through the solar system and beyond" perhaps just now "rounding Saturn" for a "trans-heavenly injection" (playing on the term used for vehicles entering planetary orbits). These examples can be seen as evidence of what Paul Rabinow has termed biosociality, in which new possibilities of association come from people's responses to biologized conditions, medical and life risks, and the transformative potentials of science and technology.[31] However, in these death-in-space cases, the promise that space holds for humans as cosmic beings reframes the meaningfulness of environmentally risked life into a dimension of bios understood, *pace* Giorgio Agamben,[32] as the exercise of human potential to expand its milieu.

Given these medical, ethical, epidemiological, and transcendental parameters, what most characterizes astronaut medical subjecthood on the programmatic level is not that astronauts are being biopolitically installed within environments designed to manage biological signs of health, sexual or racial fitness, and normalized cradle-to-grave lifetimes. Instead astronauts undergo protected exposures to health- and life-threatening spaces that are in the initial and precarious stages of national, commercial, and social incorporation. By interrogating how space biomedicine works with the concepts of "milieu" and a species-level "human" in ways that are not precisely biopolitical, I aim to draw attention to the medical theoretical paradigm that underwrites human spaceflight's extraordinarily scaled engagements with organism/environment interactions, from the molecular to the cosmic.

Space biomedicine: environmental medicine on a cosmic scale

In its chartered mission to support human life outside its native environment, space biomedicine is one among many contemporary biomedical enhancement practices that advocate technological interventions to make humans more "flexible"[33] by going "beyond what is 'normal' or necessary for life and well being."[34] While the early American space program emphasized the need for a super human body to fly in space and selected males who presented ostensibly perfect and unstigmatized social and medical bodies, two of my space life science interlocutors reported that astronauts deviate from those standards of unstigmatized perfection today and that some have received formal "medical waivers" to fly. In addition, several of my interlocutors and the space biomedical literature I collected emphasized that the gradual development of "better environmental controls" will compensate for the limits of individual human bodies and the limits of medical technology. For space biomedical practitioners, the thing that extends "beyond" in space and time to enhance human life categorically is not an enhanced biological being. It is instead a vital milieu of interacting machines, lives, and environmental conditions and controls. Dr. Paul Roschmann, a junior JSC flight surgeon trained in occupational medicine, put his commitment to eco-systemic human enhancement in these terms as we sat in a small beige conference room amid the institutional honeycomb of JSC flight medicine offices:

> So my idea and my goal as a flight surgeon in support of astronauts is to get them into their best condition and to reach their human potential in whatever environment they might be, whether it be on earth and the ocean or off the planet.

> That's my job. And so I have to ensure that the human is in good shape, but I also have to ensure that the environment is going to support the human, and allow them to reach their potential.

Paul and most of my space life sciences interlocutors are among the 3,200 members of the international Aerospace Medical Association (AsMA), which publishes *Aviation, Space, and Environmental Medicine*. Let me summarize space biomedicine's history as an environmental biomedical practice and provide some ethnographic examples of how its practitioners orient themselves as scientific and visionary experts on human milieus.

Aerospace life sciences grew out of pre-and post-WWII American and German military flight medicine and human factors science (space physicians are still known as flight surgeons). After the 1960's era of small-crew programs ended at NASA, its aerospace medicine division became one arm of the larger Space Life Science Directorate. Although American space life sciences is a field constrained by turbulent changes in governmental funding and policy, the Directorate's current goal "to be the world's leader in understanding the space frontier and the opportunities, capabilities, and limitations of humans living and working on that frontier"[35] neatly states the field's persistent historical goal to understand and remake the scope and scale of human milieus.

Mirroring what Canguilhem describes as the historical inversion of organism and milieu as the centerpiece of biological theory, the history of space biomedicine as a distinctive modern specialty illuminates two other significant historical inversions: how biology became emphasized over environment as a causal agent, and how the biological sciences gained authority over medicine. Literature on the history of environmental medicine is sparse, but scholars including Foucault describe the mid-19th century rise of the pathogenic model over the dominant environmental model of disease causation, and link that inversion to the ensuing struggles of territorially- and environmentally-oriented medical practices, such as tropical medicine and public health, for disciplinary legitimacy and authority.[36] If "environment" conceived of as climate and ambience lost its meaning as a causal agent, it remained biologically and medically relevant as a constellation of natural and social factors that could be more or less controlled to create healthy, productive social spaces, particularly where lack of environmental controls threatened the reach of programs to civilize and modernize individuals and populations.[37] With the rise of 20th century genomics, however, theories about environment/organism interaction and research into the dynamics of organismal milieus became ever more tangential to an intensifying quest to understand and manipulate biological material in and of itself. For these reasons, environmental medicine has become a small subspecialty of biomedicine with jurisdiction over an ambiguous class of environmentally-induced illnesses, is linked to occupational and preventive health and processes of environmental exposure, and has become a "missing element" in medical education.[38]

Even if the compound term "biomedicine" came to signal the triumph of biology over medicine as "the ultimate description and account of disease origins and mechanisms,"[39] the term is also linked to the beginnings of government-sponsored environmental medical experimentation. Historian Peter Keating and sociologist Alberto Cambrosio note that before 1970 "biomedicine" was specifically defined as " 'a discipline concerned with analyzing human tolerances to different environments and with methods of protecting against the effects of exceeding these tolerances' " that was emerging in the aerospace and nuclear industries.[40] This suggests that for people adhering to this definition of biomedicine, the prefix "bio" authorizes medical practice to include applied forms of biological experimentation in order to make human bodies capable of surviving conditions that technology makes it possible to subject them to. Contemporary space biomedicine retains its historical commitment to both of its disciplinary antecedents: medicine as an environmental practice, and medicine as a tactic for adjusting humans to environments undergoing all manner of powerful transformations. Space biomedicine, with its "cyborgs" and "bioastronautics," exacerbates the proliferation of compound terms that biomedicine fosters as a result of its work within the disciplinary boundaries and conceptual spaces among medicine, technology, and environment that Earthly medicine can still take for granted.

The Aerospace Medical Association website describes its members as "dedicated to enhancing health, promoting safety, and improving performance of individuals who work or travel in unusual environments," and defines those environments as "extending from the 'microenvironments' of space or diving suits to those of 'Spaceship Earth'."[41] By invoking the planet-as-spaceship metaphor and indicating that all kinds of human milieus, not just "usual" ones, can be made vitally commensurate, AsMA makes its philosophical connection to Buckminster Fuller's systems theory and to a NASA ideological spinoff created by a self-described "planetary physician," chemist-physician-biophysicist James Lovelock's "Gaia hypothesis," which posits that humans are part of a cybernetic Earth's self-correcting and self-optimizing environment.[42] Animating this concept is the image of the "whole Earth" photographed by NASA astronauts, which serves as a visual icon for environmentalist imaginaries as well as for discourses of technological mastery,[43] alienated escapism,[44] and an emerging "Earthly politics" in which Western technological and political authority is metonymically associated with the idea of a governable "global environment."[45] The Spaceship Earth metaphor also correlates with two other totalizing ideals about the future of a spatially extending human. The first challenges the notion of Earth as our eternally proper biosphere through the popular space advocacy metaphor, posed by the Russian astronautics theorist Tsiolkovsky, of Earth as a planetary "cradle" for humans to outgrow. The second is the eco-ethical idea, championed by the crew of the 1990s American Biosphere 2 self-contained ecosphere experiment, that despite the nationalistic structures and goals of spacefaring, we are all vitally integrated Earth "ship" crewmembers on the path of transcending global, and inevitably, planetary boundaries.[46] "Life" in AsMA's vision is a matter of situated existence in interrelated microenvironments that are not natural or unnatural but rather — based on the ideal of continual human environmental adaptation and expansion — simply usual or unusual.

Practicing in the cosmos

As space biomedicine practitioners make claims to specially situated knowledge as environmental medical practitioners taking care of astronauts in clinics and in space, they place themselves and the human species in particular within an ever-changing cosmic techno-ecological context. In this perspective, forms of environmental biomedicine and engineering are epistemologically and cosmologically interrelated, particularly if viewed as Darwinian fitness strategies to open up new human "niches." Although past and current NASA physicians and life scientists complain about working as a disciplinary minority in an organization "by and for engineers," they also write and speak about being well-versed in aerospace engineering and environmental science and technology. Most of the engineers and life scientists I interviewed agree that one of

NASA's virtues is its "big picture" view; when asked to describe what NASA "produces," they often point to disciplinary "integration." A senior space science manager with a background in engineering explained:

> [...] we're providing knowledge in the normal categories. I think people are a little less aware of how we integrate that knowledge for making the opportunity available to integrate the knowledge, to understand our solar system, our universe, and our place in it.

A flight surgeon training to participate in a spaceflight analogue simulation excitedly described the requirements for future physician-astronauts to put their integrated knowledge into practice:

> Because when you have astronauts who are physicians [...] this person's primary responsibility is to take care of other humans and human systems on this ship. And their secondary things is that they're gonna be a navigator, they're gonna be a robot repair, they're gonna be a geologist, they're gonna be all those things [...]

During my fieldwork, life scientists were happy to offer disciplinarily "integrated" arguments about how human "evolution," "adaptation," and "survival" ultimately depend upon political and economic investments in space exploration as a "forcing" technology to extend and enhance livable territory. In most instances they supported their arguments with references to the fulfillment of a human "destiny" as colonizers of space, most often expressed in non-specifically metaphysical terms but occasionally in an explicitly religious way. In the colonial model of spacefaring as a species endeavor or destiny, the human social and biological future is shaped by interactions between human (and perhaps nonhuman) exploring groups and the ecologies they make and adapt to. An etic version of that evolutionary model can be found in the writings of anthropologist Ben Finney and astronomer Eric Jones, two spacefaring advocates who hold that space colonization can foster greater and more robust forms of human diversity by enabling speciation in a cosmic multiplicity of environments.[47] Both space biomedical and space colonization imaginaries about the future of human life, in championing the exposure of humans to techno-environmental change on a cosmic level, rewrite the biopolitical goal of maintaining populations in biological equilibrium.

When space biomedical practitioners describe their views on the medical and evolutionary benefits of moving humans off-planet, they consistently contextualize human optimization by emphasizing the dual optimization of life and milieu. Both engineers and life scientists were ready to project the implications of new optimally "manrated" transportation systems and crew habitation into time and space, but several space life scientists expressed their commitment to integrated optimization in a practical as well as visionary and ethical ways. I discussed this with Dr. Sam Pritchard, recently back from participating as a crewmember in a desert space mission analogue, and who described the experience of being in a crew and doing "extravehicular activities" as "absolute joy," which are sentiments that match up with pictures of him, geared up with an almost beatific expression on his face. Sam's enthusiasm was for what he called "the truth" that can be found by putting experimental ideas and things "into operation" in an "*in vivo*" environment became evident as he described the effect extreme environment expedition embodiment, such as becoming an aquanaut in an underwater spaceflight analogue, can have on the scientific, ethical, and religious understanding of environmental integration:

> And as an aquanaut what a better way to understand humans and our environment is to go to an environment which not only makes up most of our earth, but also we came from, and we, if you think of humans, I mean we carry the ocean within us, we carry the salt water within us, we carry the electrolytes within us, we carry an environment within us, we carry our gills within us, our lungs, and our water

> within us, and I balance out my understanding of creationalism [*sic*] with my understanding of evolution, by saying what a beautiful creature we are.

When I asked Pritchard what NASA's new policy to "extend human presence into the solar system" meant to him, he tied together plans for optimizing human life in the context of its milieu, ending up with an anthropomorphized cosmos:

> [...] we're continuing to discover things in the solar system that are going to help us here. So as a physician, and working at NASA, to enable us to extend our human civilization is going to help me in my own specialty, and what my own goal is. Because we're going to discover new things, and we already have, and we're going to be able to take humans and their environments where they would never have done, and we are able to utilize our environment as we should, we should do it smartly to enable us to extend our lives and do good things while we're alive. As a spaceflight scientist, what is it, I mean, to be able to get an entirely new door, open up a door to another environment. [...] I think if we extend the human presence, the solar system understands itself.

Pritchard's claim that the cosmos understands itself through human awareness of it was one I heard often during fieldwork at NASA but usually without reference; by using it Sam dates himself as a probable watcher of Carl Sagan's *Cosmos* television series, or a consumer, directly or indirectly, of the various precursor and contemporary versions to the idea that human beings mediate nature's self-consciousness, from the work of Teilhard de Chardin and Julian Huxley to the work of Passionist priest and self-described "Earth scholar" Thomas Berry. Pritchard situates himself, as an analogue participant, doctor, and ethical/spiritual being, within a recursively optimizing and harmonizing human/milieu feedback process, and outlines the potential environmental benefits of NASA's new exploration program: "if we were able to push our environment and our biological limits by pushing equipment that supports that, then we'll be able to trod less on our environment."

Pritchard's colleague, Dr. Kyle Montgomery, a more senior flight surgeon who has worked to establish astronaut medical and research protocols for two decades, told me that the space program could be a species life-saver by making humans realize their environmental contingency and vital in-born capacity to adapt to, control, and remake their milieus on a cosmic scale. His perspective on what such an effort entails includes his critique of how humans understand themselves as environmental creatures: he has told me that just as Earth should be called "ocean," "space" is an incorrect designation for the cosmic environment humans have to contend with beyond Earth, and that it should be called "radiation."[48] In a bustling coffee shop down the road from his NASA offices, Montgomery told me that a good physician "starts from the Universe" to analyze problems, which for him meant understanding Earthly life's cosmic environment of asteroid impacts, solar radiation variations, and the changing galactic position of the solar system that he noted "may be a cause of pandemics." This perspective relates space biomedicine to its sister discipline, astrobiology, which has adjusted its aim to find extraterrestrial life by concentrating not just on finding the life forms themselves but on recognizing the "possibility of vitality" in the trace chemical signatures of alien milieus.[49]

Montgomery goes on to argue that efforts to seek and understand new milieus enact truths about innate human capacities:

> When I'm giving my speeches I always tell people look, every day we're placing an all or nothing bet on the survival of the human species, someday, we won't be so lucky. [...] [Space exploration] is the most human of endeavors. This is the thing that defines our humanness, and if you retreat from that, you're retreating from humanness.

"Humanness" thus defined dismisses concerns raised from the early days of spacefaring that this quality is Earth-bound,[50] suggesting instead that it is a quality maintained by "endeavor" to access to an ever-changing and extending milieu. It is perhaps not a coincidence that one of the remaining Shuttles is named *Endeavour,* tying together a vessel important to the history of Western military and colonial environmental expansions to a Darwinian view of milieu mastery. This is the sort of "human" that space biomedicine, as an environmental medicine, takes as its clinical, ethical, and experimental subject.

Ecobiopolitics

Outlining the special case of astronaut medical subjecthood and the historical and disciplinary orientation of space biomedical practitioners toward vital milieus has set the stage for me to offer a conceptual modification of biopolitics: *ecobiopolitics*. Paul Rabinow's and Nikolas Rose's recent critical clarification of Foucault's concept of biopolitics reminds readers about the idea's historical specificity and inherent potential for amendment.[51] Although Foucault only sketched out the concept, Rabinow and Rose sum up "the politics of life itself" as: "[truth claims based on] knowledge of vital life processes, power relations that take humans as living beings as their object, and the modes of subjectification through which subjects work on themselves qua living beings."[52] Rabinow and Rose acknowledge that today it would be "misleading simply to project Foucault's analysis forward as a guide to our present and its possibilities."[53] They call instead for it to guide our thinking toward the next "mutations" that biopolitical techniques themselves engender,[54] a call being actively and productively heeded by social scientists who have identified biopolitics playing out at the molecular level,[55] through the "microbiopolitical" enrollment of microorganisms into regimes of social relations and governance,[56] and the symbiopolitics that arise when science presents life as a network of more or less associated beings.[57]

I've tried to show so far that for space life scientists working with engineers and environmental scientists to implement a national environmental expansion policy, having a strictly biopolitical focus on life itself is theoretically and practically untenable; instead, what matters medically and politically is the capability to know and manage vital milieus. In addition, as we have seen, subjects in these conditions are represented as vital elements of those milieus. With this assertion, I modify Rabinow and Rose's succinct definition to delineate an "ecobiopolitical" alternative: *truth claims based on knowledge of vital milieu processes, power relations that take vital milieus as their object, and the modes of subjecthood and subjectification that designate subjects as elements of vital milieus.*

Despite coming out of a fieldwork project on outer space, "ecobiopolitics" is not a far-out concept when put into historical context. As Canguilhem was analyzing the concept of milieu, the study of genetic action effectively eclipsed milieu as biology's research imperative in the mid-20th century.[58] Foucault's focus on life and not milieu as the site of power-laden interventions thus ended up mirroring the biopolitical agendas of his own cultural milieu. Today, anthropologists, historians, and philosophers of biology and biotechnology are beginning to examine milieu's conceptual revival in today's post-genomic research in gene expression, gene regulation, and epigenetics.[59]

By using "ecobio-" rather than simply "eco-," I call attention to how biopolitics are not soluble in the politics of ecology or systems theory. Ecology-centered approaches to medical anthropological problems yield rich understandings about what scholars often call "the relationship of humans to environments" that are made by shifting and reordered categories of nature, culture, technology and the social;[60] further, ecology's status as a "master narrative" for ordering discourse[61] suggests the usefulness of "ecopolitics" as a critical theoretical descriptor for what happens in regimes of environmental citizenship and governance.[62] However, social scientists are also calling attention to how regimes of environmental and biomedical governance are increasingly being sutured together,[63] not collapsed into one another.

While human spaceflight engineers and life scientists both use "system" as a descriptor for structures and processes, this is also not a "systemopolitics" in which technical formalizations of life processes in systems theory terms create a kind of "anti-biopolitics." By saying this, I am not trying to gloss over the fact that "the human" is clearly being categorically redefined in systems terms in many contemporary social and governmental practices, and it is clear that the reworking of the humans as a system element in an at-risk program or mission does fit with the growing tendency of modern "risk societies"[64] to identify social ordering formations like infrastructures, resources, capital flows, and security, rather than human bodies or populations, as prime targets for social risk management and probability calculations.[65] As social scientists have begun to observe, the "vital systems supporting collective life"[66] are becoming identified as key sites for protections and interventions in ways that sideline humans *qua* humans.

To reiterate, however, the astronautical "human system" currently in play within national and space programmatic politics, particularly as the alternative element to an otherwise completely robotic and machine-based space exploration program, is not supposed to dissolve into other systems. Even as the astronaut is "systematized" within astronautics, concern for "the human presence" and intentions to preserve and extend its vital distinctive biological, social, and spiritual processes are at the heart of astronautics culture. In this way, the social presence of astronauts themselves in the design process and the humanistic explanations of the "special" value and destiny of humans *qua* humans in space mark the micropolitics of human spaceflight practice as more properly ecological than formalistically systemic. This is where space biomedicine and astronaut medical subjecthood, while examples of a futuristic ecobiopolitics in the technological and territorial extreme, lose their seeming distance from terrestrial medical and anthropological concerns. As space biomedicine works with human/environment interactions in extremes, it does so as a modern practice engaging with questions about how to manage human environmental health and what count as humanly habitable space, thereby putting into question the futures of "life itself" and "ecology" as separate scientific and political categories.

"Space normal:" the birth of the cosmic clinic and its ecobiopolitical strategies

In the interview snippet with which I opened this paper, Ken Dempsey asked me if I was aware of NASA's "space normal work." This topic came up because we were talking about new biomedical technologies to be used in long-duration spaceflight. I told him about my visit with Rice University engineers who are developing "Robonaut" a virtually-controlled robotic astronaut designed to work outside spacecrafts or on planetary surfaces. Robonaut has a humanoid head and torso but only one lower appendage designed as a grappling hook, so "he" must sit in a wheelchair on earth. "His" designers describe "him" as "analogous" to a human but also as a representation of the ultimate "space adapted" human body for which legs are pretty much useless. I mentioned to Dempsey how this troubled ideas about the social and environmental contingencies of ability and disability, and also highlights the social irony that astronauts launch into space as exemplary normates but become automatically impaired or disabled there. This is when he told me of NASA's efforts to delineate "space normal." The way space biomedical practitioners work with the definitions, problems, and promises of "space normal" classifies it as an ecobiopolitical rather than biopolitical strategy for producing authoritative knowledge about humans as medical and biological subjects.

The process of examining how people and ways of life are "branded" using the binaries of normal/abnormal or normal/pathological[67] is a signature pursuit of medical anthropology. Recent explorations of this topic make use of Canguilhem's historical analysis how scientific medicine came to define "normality" in terms of statistical values and of Foucault's work on how that scientific project supported ways to effect those values in bodies and populations. Following Canguilhem and Foucault, scholars have recently mapped out how new biomedical technologies create differing representations of normality and pathology that must be coordinated across spaces and disciplines.[68] In these terrestrially-focused cases, biomedical practitioners enhance the biopolitical means by which the conditions and possibilities for biological normality are delimited.

Space biomedical practitioners, like their earth-focused counterparts, are also intent on setting statistical "space normal" values for astronaut physiology in space, but doing so is not a smooth operation. My subjects self-consciously told me that their space normal values don't truly represent a physiological state per se but human/environment interactions that are in constant flux and cannot be understood as "natural," whether in the sense of naturally health or naturally ill. Their explicit commitments to knowing the nature and artifice of human milieus put them in agreement with Canguilhem's argument that normality is not a fixed value but a normalizing capacity, spurred by pathologies, to adapt to environmental variation. "Space normal" thus ends up upholding yet breaking the rules about how to represent biological normality, because spacefaring is at its core a bid to expand the possibilities for an endlessly re-normalizing human milieu.

NASA's "space normal" concept is part of its current program to work with the humans as a "mission system," which comes out of collaborative but not unproblematic encounters between space biomedical researchers and engineers. Some collaboration comes as program managers create design "requirements" and "philosophies" that require call for the two disciplinary domains to work together – a situation facilitated by JSC workgroup proximities such as the location of the "Human Anthropometry" labs just down the hall from the "Propulsion Systems" offices in Building 15, but which is ultimately complicated by historical disciplinary differences in terminology, language, objects of study, and expert socialization. Shared concepts like "environment" or "milieu" and "system" serve to soften those differences and create common ground.

In its "bioastronautics risk reduction strategy," biomedical and technology experts define the human as a "critical spaceflight system" that has "operating bands" (i.e., upper and lower performance limit ranges) that "must be understood, controlled, and specified, as well as optimally integrated with other systems."[69] "Space normal" is, as Dempsey indicated, a way to make it possible for astronauts in space to be considered either to be functioning within normal limits or to be patients (i.e., out of space normal "operating bands") by distinguishing predictable adaptation pathologies from sickness. To do this, NASA is building an evidence base of clinical and experimental medical data on each of the environmentally induced physiological changes that happen to spacefaring humans. Ever concerned with how to render space biomedicine ideas "rigorous" in the sense of being legitimate and grounded, Dempsey described joining in with colleagues' attempts to find a suitable Greek word for "space normal." After considering options provided by Rice University Greek language scholars, he liked *euabaria*, a compound expression that translates roughly as "wellness without heaviness." The term references what to him is the pervasive and distinctively unearthly space environmental quality of weightlessness in which the new normality would obtain. Among the other problems space presents to human life, space life scientists focus on weightlessness and its disruption of what they like to call the "only biological constant on earth" and have put "microgravity" investigations at the center of biological and medical experiments since the 1970s Skylab "life in space" research program. The prefix "eu" also optimistically intimates a future for humans in space that goes beyond sustainability "operational" normalization to states of positive and thriving "wellness."

In my exploration of the space normal and bioastronautics projects, I expected to find life scientists expressing concern about the dangers of objectifying humans as "systems" and of letting engineering trump medical expertise, but instead the most critical responses to the concept centered on the problem of being able to even define a static and decontextualized "normality." All of my interlocutors expressed some ambivalence about whether "space normal" or "space adaptation" can actually be defined as a natural physiological state, since it is so contextually and conditionally labile. As Dempsey told me, "normal" is always "confounded" by the "myriad" artificial "microenvironments overlaid…on the human experience of spaceflight." Flight surgeon Montgomery both agreed with and critiqued his colleagues:

> Academically, they're right. You need the dataset that gives you the space normal. [But] space normal isn't space normal if you're doing that while you're

> doing countermeasures. So, define your terms first. It's not "space normal." It's 'two hours a day of countermeasures' normal."

He went on to say that allowing anyone to physiologically adapt to space by withholding such countermeasures would be "unethical," but pointed out that "earth normal" itself is also an inaccurate and relative term because it refers to "normal with respect to subpopulations on earth that meet these select-in criteria, that don't meet the select-out criteria." He expressed the determination of both space engineers and life scientists to view humans as intrinsically environmentally contingent life forms – a perspective reflected in Robonaut's space adapted "body."

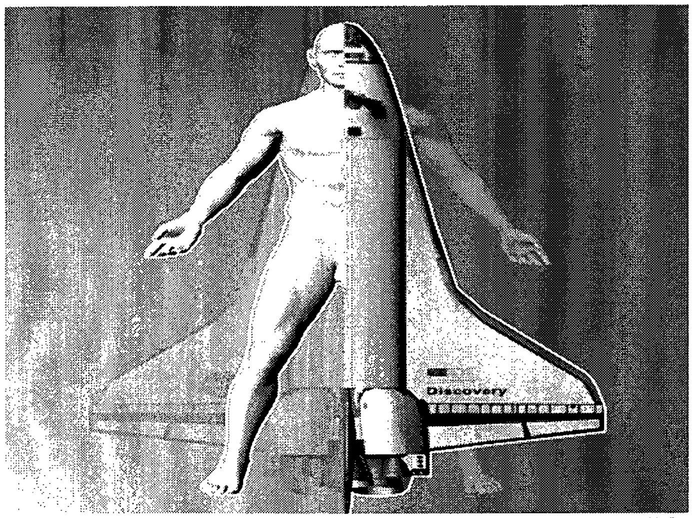
Montgomery's critique of "earth normal" is an example of what I found to be an active recognition among space scientists and engineers that earth and space environments are scientifically, socially, and politically co-constituted. Work by critical medical and environmental social scientists that emphasize the political ecological constitution of "environmental adaptation"[70] would not necessarily be greeted with surprise among these researchers. Because astronautics work involves designing new environments that "optimize" multiple systems within both scientific and political constraints, it is easy to find versions of statements such as one made by a group of NASA life sciences researchers that spacecraft environmental design should not simply reproduce "Earth normal values" but should find the most efficient ways to work with the space program's "physiological, engineering, operational cost, and safety considerations."[71] The patently social conditions determining the human spaceflight milieu also captured the imagination of disability activist, Victor Finkelstein, who argued for recognition that disability is socially defined by using the example that an astronaut's accidental disability or death would never be considered to "reside in himself" but would be the failure of socially-produced technologies and life support practices.[72]

The space biomedical critique of normality as environmentally and socially determined dovetails with Canguilhem's argument that any "physiological constant" is the "expression of a physiological optimum" which "the living being[s], and *homo faber* in particular, give themselves" in a given historical context.[73] Canguilhem sees this as an "organic vitality" that "flourishes in man in the form of technical plasticity and a desire to dominate the environment."[74] Echoing this ecologically modulated vitalist statement, a physician astronaut and former life sciences manager, Dr. John Robertson, also described humans as having an inherent propensity to adapt to and manipulate milieus. He, as well as many of my interlocutors and space advocates in general, originate this propensity at the molecular level, saying "everyone has this little 'exploration gene,' if you want to call it that." He does not explicitly refer to the ongoing and controversial research on genetic "proclivities" for "novelty seeking,"[75] but he claims that this "little gene" expresses "itself" as a capacity to transcend biological limitations and optimize milieus. The "everyone" is subjective; he includes himself as an astronaut within a larger species-level mission nested within American national aspirations.

> [...] the human species are extending our capabilities, we are reaching out into our own solar system, to extend our capability to live elsewhere in our solar system. And then putting that back in the context of theories of evolution and human origins here on earth [...] the proposal I guess is that biology allowed humans to adapt and evolve to optimize their capability to live here on earth, [and now] it's really technology, not biology, that's enabling us to live successfully in these environments.

The concept of "space normal" and its associated concepts end up scientifically and politically sidestepping the biopolitical rule that "normality" as an optimal state of being refers to the manipulated conditions of "life itself." The ecobiopolitical goal for "space normality" as a working concept is not to maintain a state of being but to technoscientifically facilitate a "human" drive to re-normalize. In this sense, the signature biopolitical move to constitute kinds of persons as always already kinds of patients and vice versa[76] is not the most important move in space biomedicine. Instead, the most important move is to create ways to manage how humans and milieus productively and manageably adjust to one another. In other words, the conversion of astronauts from *de facto* patients to biomedically "normal" in space is tied in with normalizing space as a vital social and political environment. Rather than backgrounding "environment" and "milieu," biomedical practitioners foreground these concepts in their ecobiopolitical truth claims and theorizations. If, as Foucault noted, the modern clinic was born as a spatial and temporal strategy to manage a politics of health and normality located in living bodies, space biomedicine initiates a supra-clinical politics of normalization and optimization for human milieus.

For NASA biomedical scientists, making astronauts and space living conditions predictable and normal requires that they convince their engineering colleagues that humans, machines, and environmental conditions make up an interdependent "mission environment." They must show that successful missions environmentally integrate the "health" of humans and machines. In the next section, I show how space biomedical practitioners deploy ecobiopolitical techniques to put living, mechanical, and environmental systems on equal biomedical, social, and political footing.



Courtesy NASA

The human in the loop

During my meetings with Dempsey he gave me, along with org charts and other documents, a set of digital illustrations that juxtapose space shuttle systems with human system equivalents. An anatomical "invisible man" merges with machine schematics in a series of slides that move from surfaces to revealed insides. The vehicle exterior corresponds to the integumentary system, engineered structure to skeletal system, electrical system to neurological system, and power system to digestive system. He and his colleagues intend these graphics to be used in NASA outreach activities, such as science fairs, to interest the American public in its nationwide space biomedicine projects. As illustrations of astronautics as an integrated knowledge domain, they are not meant simply to liken human bodies to machines or vice versa. By portraying human and mechanical systems as complementarily vital and mutually vulnerable "mission systems," they also exemplify space technoscientific strategies to amplify the integration of the human and non-human within "risk environments."

I focus in the next two sections on the spacefaring "human at risk" as an element of design and the calculative integration of different quantitative domains, examining how risk is treated not as a basic problem of bodies and populations but of eco-systemic milieus. Targeting risk in the form of eco-systemic milieus, by creating ways to mutually optimize human/environment interactions and to mix human and non-human data, make human milieus calculable and predictable. These ecobiopolitical strategies can be found at work calculation of "probabilistic risk assessment" for total "mission environments" and in the visionary development of future spacesuits. I want to emphasize that these solutions to extreme environment risk are solutions in practice, but that they are understood as attainable within the context of more "imaginative" solutions established in the 1950s and 1960s at NASA but still unrealized, such as efforts to bioengineer humans in ways that would speed up or target evolutionary change. These are the imaginative human life sciences research and application "extremes" that have been scaled down from humans to plants, such as in Martian greenhouse experiments, or remain in the domain conceptual studies. Several of my interlocutors imagined that many of the environmental adaptation problems they struggled with might be solved by genetic engineering, but also acknowledged biological, political and social risks associated with doing so. However, such imaginative extremes still inform NASA practitioners understandings of what risk management for spaceflight is trying to accomplish for Earthlings on their way to becoming, in unearthly environments, what spaceflight advocate and NASA historian Howard McCurdy terms the "transhuman" project to evolve a "*homo cosmos*."[77]

Risk is a richly problematic concept at NASA, presenting a conundrum for astronautics practitioners who dedicate their lives to minimizing it but also celebrating spaceflight risk as heroic, inspiring, and important for national and species evolution. Dempsey, like most of my interlocutors, both male and female, speak of childhood engagements with space things, places, and ways of being: drawing spacecraft, watching space missions, reading science fiction and shooting off rockets, and learning to do as young as possible, as in the case of John Robertson, risky space-like things like diving. Such engagements were for them not just practice for future jobs but staking out a socially risky alliance with "geeky" things and people, as evidenced in testimonials made in almost equal measure by men and women on the American Institute of Aeronautics and Astronautics "*When did you know*?" website,[78] with its unacknowledged but unmistakable parallels with "coming out" practices and other ethical discourses about ways that people learn and testify truths about their individual selves and destiny. Like many JSC civil servants and contractors, Ken wanted to be an astronaut "as far back as I can recall," and describes that trajectory in wistful and ironic ways, revealing also the breadth of his interests and skills. Born in the early fifties like many of his mostly male and white co-managers, he links childhood play and imagination to his career decisions:

> [on] a sandy dusty playground on a little cement bridge ... I'd lay on my back and put my hands up on the handrails and pretend I was John Glenn. [...I] tailored my education to become relevant to the space business...

Dempsey eventually secured a JSC post-doctorate after getting a PhD working in laboratory analyzing the effects of microgravity on cardiovascular function in dogs that he surgically fitted with artificial valves and spun around in centrifuges as *in vitro* subhuman astronauts. This was a frustrating and shockingly bloody process, but, he said, as a whole project it "appealed to me, it was science, technology, engineering, mission planning, putting together an experiment, making all the systems come together, it was a unique opportunity [...] to demonstrate to NASA I knew how to do complex integrated things." For Dempsey and his colleagues, accumulating such know-how involves getting out of the lab to seek opportunities to participate personally in space analogues, to fly on "vomit comet" parabolic aircraft flights that simulate weightlessness for training and experiments, and, in some cases, to continue or get involved in extreme recreation (*de rigueur* on astronaut resumes) such as flying, rock-climbing, and SCUBA diving.

Although his job at JSC is to "retire risks" through bioastronautics research, Dempsey spoke of his disappointment in the contemporary tendency of American government and society to be "risk averse" or want to lower the space program's "risk threshold." This is a complaint that I heard often from a variety of NASA civil servants and contractors who, like the space analogue participants in the previous chapter, view risk-taking as an "innate" and vital human characteristic (astronaut/physician John Robertson) and criticize the idea that personal or national risk taking should only be done if it will "lead to economic benefit" (engineer and analogue participant Doug Handler).

At first blush, the human in the at-risk vehicle environment seems like a discrete human, sharing a milieu with interacting machines and conditions, somewhat like a human embedded in a terrestrial community, home, building, or car. However, I learned that the space and interactive lacunae that are taken for granted on Earth as existing between living and nonliving things are collapsed in outer space: the integrated nature of milieus, and of risk, is assumed to begin at the molecular level. The young water systems engineer I quoted in the introduction who told me "Our thought process is....environment, environment, environment...everything interacts with everything!" was, at the time, working on a newly deployed environmental technology on the International Space Station which would make it possible for astronauts to drink their own urine. Specific efforts to deal with this problem fall under the larger task of maintaining a normalizable integration of living and nonliving mission elements – something that requires a new way of thinking about risk data.

Toward the end of my fieldwork, I heard that space life scientists had begun to put their "space normal" clinical and epidemiological data to work as risk-management data aimed at improving the systems integration of Constellation's Orion "Crew Exploration Vehicle." Using a technique called "probabilistic risk assessment" (PRA) borrowed from the domains of nuclear power and transportation risk management, space life scientists advocate merging human medical data mixed with hardware and software data when engineers make overall calculations of space mission risks. This strategy creates the possibility for new truth claims about the nature and proper methods of mission systems integration. It makes astronauts into data-producing components whose likelihood of functionality or failure, otherwise known as health or illness, can be statistically represented as connected to other non-living mission factors. As my interlocutors often emphasized, their position as scientists of "squishy" (i.e., biological) things in an "engineering practice environment" meant they must "give the numbers" (i.e., quantitative data about health and safety risks) to engineers in order to manage with "hard data" what human factors engineers call the "human in the loop."

By using PRA, space life scientists can convince engineers that humans do more than occupy vehicles or act like (in the words of one environmental systems flight controller I interviewed) "wild card[s] at play" in an otherwise controllable engineered environment. Life scientists aim to present them instead as part of a milieu where risks to environmental habitability matter for beings as well as for hardware and mission. In a recent article on the potential uses of PRA, space biomedical researchers note that NASA defines risk as "the combination of the probability that a program will experience an undesired event and the consequences, impact, or severity of the undesired event, were it to occur" (Rhatigan *et al* 2008:1). Using the logic of environmental medicine and public health in an ecobiopolitical way, they argue that the best astronaut health risk intervention may actually occur in a mechanical or environmental system and that the best system-wide risk intervention might actually begin in an astronaut's body rather than outside of it. In this model, human and non-human systems are not separate, but exist in an intimate milieu in which they are mutually at-risk and present risks to one another.

I spoke with a researcher developing the PRA project, Dr. Jane Forrest, a young neurobiologist with a local history as a real Southern debutante and a growing attraction to quantum biology; she explained the imperative for redefining mission systems, including "the human system" as contiguous rather than discrete. She said that she and her colleagues wondered at first "can we even apply [PRA] to the human?" but found that if they could make "the squishy nature of the human system" calculable, this would make it easier to "break it all down" to engineers about why humans "affect your vehicle and how your vehicle can affect [them]." Jane used the example of human nutrition "in the loop:"

> So if [astronauts] have an inadequate food s ystem, how does it break down. [...] well, [...] it could be contamination, it could be the food doesn't taste good, it could be there's not enough vehicle resources, that's where the vehicle starts coming in [...] you get into the food's unsafe, well maybe the food's unsafe

> because of something going wrong with the vehicle like the storage isn't right, or something [...]. and so this is where it leads toward the human, now if the human gets sick, they can't do maintenance, they can't do some of the things you want them to do. And so we're starting to put the human in as another subsystem within the vehicular system.

To help me understand their space normal and PRA work, Ken, Jane and others gave me documents that use biological descriptors for machines (e.g., "PRA is a systematic and comprehensive methodology to evaluate risks associated with every life-cycle aspect of a complex engineered technological entity" [Stamatelatos 2000:1]) and technical descriptors for human beings (e.g, Figure 1). In these, humans, technologies, and their environments overlap and merge in an open and lively exchange of molecules, systemic processes, forces, actions, and outcomes. I also collected documents that explicitly justify humans as mission environment "tools" rather than operators, and others, as historian of astronaut labor Matthew Hersch has recently described, that reference non-living but vital mission "elements" like checklists as humanlike actors or "crewmembers" (Hersch 2009). Although PRA calculations and human/non-human categorical slippages in space seem esoteric, they offer new quantitative and qualitative formalizations of a milieu's vital associations, and they portray the human as an environmental inhabitant, factor, and at-risk system element.

One of the ways that space biomedical practitioners plan to manage long-duration mission risk is to embed probabilistic risk assessment into the spatial and temporal environmental loop, making it possible for an integrated mission environment to detect and control to risk to "itself." While I was interning on the NEEMO space analogue missions, the program was being mobilized as a "platform" for *in situ* and telemedical experiments in support of mission "autonomy," that worrisome situation in which all mission systems, human and otherwise, move beyond Earthly support and control. While working "topside" as a NEEMO an assisting with the collection of medical and psychological data, the data were going out into NASA and extramural research institutions to construct comparative epidemiological profiles of "immune suppression" "sleeplessness," or "perceptual vigilance" risk in environmentally-defined "earthly," "aqua" or "astro" populations.

As an *in vivo* testbed for future long-duration space missions, NEEMO is slated to develop inflight behavioral health management "subsystems" that include embedded "unobtrusive" facial and voice monitoring devices and a "computerized psychologist" for astronaut self-diagnosis and treatment.[79] The goal is to prevent crewmember deviation from mission performance parameters, which is often referred to, using the language of engineering, as "off nominal" behavior. This move takes what feminist philosopher Rosalyn Diprose calls "biopolitical technologies of prevention and pre-emption" that focus on forestalling dangers internal to populations over time and projects them beyond purely bio-spatial internalities into the internalities of ecologies.[80]

While the risky space missions that NEEMO prepares astronauts for are currently being conducted in the "international" environment of the International Space Station, my American space biomedical interlocutors and their colleagues tack back and forth between describing its current and future extraterrestrial milieus as full of or evacuated of historical, the social, and the cultural particularities. However, they also express concern about the political as well as technical and medical significance of spaceflight in a way that evinces their concern about national differences in understanding and making of "environments." While interlocutors working on space normal and PRA commonly refer to "the crewmember" or "the human" as their knowledge and risk reduction target, the Vision for Space Exploration proposed a strictly American-made "architecture" that would reassert American control over the "human" and its space milieu after almost three decades of success or failure setting engineering and environmental health standards on the International Space Station. While my subjects almost universally expressed admiration for Russian engineering and accomplishments in particular, most also expressed relief at not having to work with "the internationals." During a "ride along" with a Space Station flight controller, I witnessed attempts to deal with a "substance" leaking from "the Russian side," in which it became apparent how the Station environment was a more or less coordinated domain of risk-prevention compromise. The molecular composition of the space station's air, for example, was ostensibly agreed upon through "systems integration" efforts, but as an environmental systems engineer explained to me, the "integration" process in actuality was more like "bartering" in order to set environmental system "requirements" that all station partners will adhere to. However, some of my interlocutors also critiqued American mission risk reduction strategies as increasingly "conservative" and "risk averse." Even during times in which they would speculate most open-endedly about the possibilities and impediments to extraterrestrial world-making, my American space biomedical interlocutors either explicitly supported or did not contradict NASA's official position that the United States will act in its own interests maintain space "leadership" in the "space environment," by which they meant not only the abstract territorial "presence" nations might claim to occupy in the solar system places but all micro- and macro- environments Americans expect to inhabit.

Concern for the health of "the human" and its space milieu is, in astronautical terms, a concern that loops back upon a concern for the American milieu within the Earthly milieu, imagined not as an island in space but a social, technological, and environmental semi-closed loop system – where "semi" indicates the potential of nations to actively engage and manage the solar system as a space contiguous with Earth. Four of my interlocutors (two space physicians, one chemical engineer, and one mechanical engineer) volunteered their agreement with "anthropology" in the form of Jared Diamond's thesis in *Collapse* (2005) that societies self-destruct through the mismanagement of limited resources. They and others invoke a common argument for the long-term purpose of space programs beyond national contest, claiming that astronautics offers a key to averting "collapse" because it forces people to work with, as one Space Station environmental systems engineer put it, a technical "philosophy" in which "environment" is no longer ignored or fought against but used as the "constraint that drives a lot of the design." When I asked most of my interlocutors to tell me what the end of the American human spaceflight program would mean, they would link its fate to the risks of ignoring limited planetary resources, the national and species risks of "stopping" spatial growth, and the colonial and technical logic of securing redundant or future zones of habitation. In this ecological model of nation-building and human evolution, the milieu of the spacecraft is not just a risky and expendable environment in biological terms, but a kind of ecological risk-circumvention technology that provides an escape from terminally closed-loop milieus.

What begins to matter, then, with schemes like PRA, is the capacity to secure and control nationally vital sites of ecological health, growth, and habitability. Given that space exploration advocacy discourse champions the notion of a "free" future and open milieu of human possibility, the "habitability" of sites and spaces appears, after the manner of biopoliticized bodies and spaces, as a potential site of ecobiopolitical contestation and resistance around the interventional management of health, risk, and life processes.

More so than the spacecraft, the salient symbol of the embodied process of making space habitable is the spacesuit. Perhaps no other astronautical technology is more emblematic of space biomedical subjecthood as a contextual form of life, and of the ways that risks to human life are considered to be an integrated problem for environmental medicine, science, and engineering.

Extravehicular activity patch / Courtesy NASA

The spacesuit and its milieu

The special problem of how to suit up astronauts for going into extraterrestrial spaces uniquely amplifies scientific, technical, and political questions about how and why to shore up or break down human/environment boundaries and limits. The suited astronaut's specific "mission" outside the spacecraft or on another planet is to survive, move, communicate, and build things, which are capabilities that the current International Space Station's mini-spacecraft-like extravehicular activity suit, otherwise known as an

EMU (extravehicular mobility unit) enables -- albeit very awkwardly. The astronaut suited in the EMU's so-called "anthropomorphic independence unit" renders the outermost reaches of the remotely sensed extraterrestrial environment into a milieu potentially inhabitable by human bodies and populations. However, the suit/human "unit's" design theoretical mission is to solve problems in places where life and milieu are dually problematized. The suited astronaut is, in effect, an ecobiopolitical intervention into the vital microspatial dynamics of life/environment interactions that become evident and exigent at the extreme boundaries of Earthly life.

In this last section, I go with space medicine and environmental engineering to their collaborative edges by exploring the ecobiopolitics of American spacesuit testing and design. I move from observation of planetary surface exploration "hardsuit" testing activities at JSC to a "visualization" report on how to build a "biosuit" that was submitted by a group of MIT engineers to the now defunct NASA Institute for Advanced Concepts (NIAC). In both cases, the spacesuited astronaut is imagined as the representative of another astronautical "giant leap" that takes humans beyond modes of survival and moves them toward permanent space occupation by populations that engage in socially if not yet biologically generative activities of building, adapting, and acting sociably. The suited astronaut stands for the movement of the space biomedical subject from a protected mission element to an off-planet social actor, and it bridges the idea of space as alien environment and a cosmic human milieu. The biosuit design also updates NASA's popular biomedical research subject, the "cyborg," particularly in terms of how astronaut biomedical "risk" is re-engaged as a problem with social and evolutionary as well as individual ramifications. It is also an attempt to render the American spacesuit cool and futuristic as an environmentally integrated technology that is also a piece of wearable art heralding a truly phenomenologically cosmic future.

If ethical and sociopolitical concerns circulating within NASA and at the American government level about the "image" of the astronaut as biomedically at-risk subject often cause depictions of medical testing to be hidden from public view, the image of the spacesuited astronaut as medical subject is a different story. When I worked as a research intern, I heard about conflicts between astronaut administrators and life scientists over the release of photographs (to the media and to scientific journals) showing astronauts undergoing medical experiments, a conflict that illuminates the simultaneously famous yet vulnerable status of the astronaut as a person. Astronauts are in general quite subjectively humanized and protected within JSC and within national political circles, but they also convey through gestures, comportment, and presence what Dominic Boyer has called the phenomenological "corporeality of expertise."[81] This produces the extraordinary but potentially tragic astronaut persona, created through the tension between a superhuman ideal and the astronaut's actual experience as a vulnerable and exposed person.[82] The astronauts I observed and in some cases have come to know are quite unsurprisingly confident, capable, self-possessed and even arrogant, but they are also a social group conflicted over how their images, personal lives, and foibles should be made "public," as evidenced by the unusual media exposure of astronaut sexual, medical, and social indiscretions during the "astronaut love triangle" assault case in 2007.

Despite powerful political and social investments to guard against astronauts looking medically abject or exposed, I witnessed a very public test of the joint medical and technical capacities and capabilities of astronauts and spacesuits in a building accessible by streams of tourists who come onsite as a part of the Space Center Houston guided tram tour of JSC. This test underscores the ways in which the suited astronaut is an ecobiopolitical flagship being made – like reproductive and molecular medical technologies and biological and prosthetic enhancement technologies do for biopolitical interventions into "life itself" – to produce new possibilities for intervening, managing, and expanding vital milieus.

Through NASA's public relations strategies, every tourist to the JSC campus gets reminded of what space does to the unprotected human body. Visitors end their tour, the open-air tourbus stops before the memorial circle of trees planted for astronauts lost in the line of duty and a pre-recorded message explains the sacrifices made in the name of the future. However, there is also the image of the EMU suited astronaut that acts to immortalize colonial dreams about things and people implanted in promising soils, American enthusiasms for technology and nature, and triumphant claims staked in the name of territorial and environmental mastery. The puffy white pressure-suited astronaut waving back to us from orbit or another planet is at once a harbinger of such dreams, shows, and mastery, and also an awkward, vulnerable symbol of its unfinished business and imperfect instantiations.

The vital, virile, and sacrificial symbolic aspects of spacesuited astronauts have fascinated historians and social scientists, who, in attempting to diagnose their sociocultural significance as "iconic" technologies and symbols, investigate them as cyborgic technologies that simultaneously break down bodily boundaries where space is represented as a domain for nations or "humanity" to conquer or transcend into and shore them up against the threats the space environment presents.[83] From a medical, engineering, and space colonization perspective, however, the contemporary puffy, awkward, pressurized spacesuited astronaut is not a seamlessly perfect systemic or environmental element, but an artifact of attempts to compensate for the technological and biological limitations that prevent humans from mastering their occupation of space.

The astronaut and suit test I saw in JSC's Building 9 was for a pressurized "suit and life support system" being worked on for the Constellation project and its planetary operations and mission system integration scenarios. I accompanied several biomechanical engineers from the Habitability and Human Factors Division's Anthropometry lab to a spacesuit design test into Building 9 to watch a test of the "MK III" ("Mark three") spacesuit, an updated version of the suit worn during the Apollo era and part of what the current NASA administrator now infamously described as the "Apollo on steroids" "explorations systems architecture" of new vehicle and mission systems. I was surprised to find that the subject slated to do the test was a veteran NEEMO astronaut I knew well. There, in the middle of Building 9's cavernous open space that houses full scale mock-ups of International Space Station and the Space Shuttle for simulations and equipment for hardware testing, and live before a gaggle of tourists watching from a glassed-in catwalk above, an astronaut was being rather unceremoniously zipped, snapped, and laced into cooling system long-john looking undergarmets and hoisted into the bulky Mark III spacesuit suspended from a structure amid a tangle of suit testing technologies.

The test is called a "walkback test." It simulates the combined "performance" of human and space suit as if the astronaut has been put in the risky situation of having to walk back 10 kilometers to a vehicle or habitat on the Moon or Mars. In front of us, the astronaut was suspended in the heavy suit above the treadmill-like set up called the POGO (partial gravity simulator). This is a pneumatic gimbal support structure rigged, very imperfectly my escorts assure me, to mimic the 1/6th G effect of the moon. Awkwardly, but forcefully, the suited human begins to walk rapidly, bouncing a bit in the rig, making the suit move, communicating through the privately with his attendant flight surgeon or openly with the assembled crew of biomechanical engineers from the "extravehicular physiology" and "spacesuit systems" working groups. The suit and test rig come in one size only, and as a result there are only males doing walkback tests at this time. I suspect this man is someone who is not worried about his health status, since I was told by another astronaut that the astronaut corps was nervous about participating in these "suit validation tests" because of the risk of finding out something that would disqualify them for flight. Have heard so much about the astronaut office's protectiveness, I am surprised to see this scene and am as fascinated by it as the tourists above.

The astronaut smiles broadly through the fish bowl-like front of his helmet, looking like he's working out at a fitness center, big space boots pounding awkwardly on the treadmill, trunk covered by a hard body-shaped core and fitted with a life support backpack, arms and legs made fairly flexible by accordion-pleating. Video cameras are recording from different angles, and data from the astronaut/suit unit begins to pour in on the computers of people seated and standing around the test site, objective and subjective: metabolic rate, ground-reaction force vectors, CO2 output, motion analysis measures, skin and core temperatures, heart rate, ECG, periodic voice reports of discomfort and exertion levels. In addition, the whole suspension rig picks up and calculates data on the astronaut's movements to compensate for falling, in an attempt to determine how to improve the engineering of an effective and safe "center of gravity" for the whole human/machine systemic unit. The toleration of uncomfortable hardware-encasement and monitoring have a long history in NASA, mostly a gendered history of male suffering and tolerance of varying levels of bodily degradation and endangerment.[84]

The Mark III suits, clunky as they are, represent improvements over the Apollo-era suits in terms of bulk, flexibility, and general technical life support and monitoring sophistication. As "heritage" designs, the suits are depicted by NASA as the next "giant leap." NASA historian Roger Launius describes the Apollo-era suit's iconic power:

> Often described as a "spacecraft for one," space suits exist as highly complex, technical systems. [They] suggest our connections to our larger environment of Earth, the Solar System, and the universe… [a symbol] that embodies dreams and beliefs about who and what we are, and what we may become….These concepts are not just projected onto the material space suit, but are contained in its physical construction and invested in the astronauts who wear them….Once in operation the physical object projects these philosophies onto the world around it; literally the space suit is a highly charged, metaphysical object that affects both the wearer and the observer.[85]

Even if such mini-spacecraft came to "dominate the essence of what it means to be an astronaut,"[86] Launius also warns his colleagues that the Apollo astronaut in particular (and by extension the Apollo-suited astronaut) remains a "trope" that can also represent a "stalled" national vision. [87] NASA program managers do not see the old-style suit this way. This is evident in a painting commissioned by NASA by prominent astronomical artist Pat Rawlings, who used as his model the wife of African American astronaut Ronald McNair, killed in the Challenger shuttle disaster. Rawlings told me about the painting, in which a Mark III-style spacesuited figure kneels next to a dusty little rover on Mars:

> And it is a thematic human piece; it's not really a technical illustration. It shows this explorer kneeled down next to the [Mars] Sojourner rover, wiping off the

> dust. And she's kneeled down there, and she's a black female astronaut and her badge says "Truth." And she's supposed to be the great great great granddaughter of Sojourner Truth.

The painted astronaut's hybrid biological, technological, and representational identity as a future "Truth" is not reliant on the representation of a different kind of spacesuit.

For visionary researchers, however, such "heritage" suit designs don't meet the astronautical ideals of what kind of "life support system" should be planned for planetary surface operations. The "risk" of heritage designs are considered not only in terms of life support failure, but in terms of exploration capacity failures that come from the suits' continued lack of flexibility and the literal and figurative performance decreasing "rub" happening in the spaces between bodies and technologies. The "personal spacecraft" suits that mediate but also impede human/environment interactions still fail in many ways the visionary goal of space exploration and space biomedicine: the facilitation of direct human/environment interactions that will constitute a true cosmic human milieu.

When I described the walkback test to some space life scientists and habitability designers, several of them suggested that I look at the NIAC-funded "Phase I study" for the "biosuit," a futuristic spacesuit design vision that my interlocutors considered far from usable or testable but which they found fascinating and inspiring.[88] Phase I studies at NASA are early efforts to flesh out an idea, review its feasibility, assemble research teams, and establish a "test bed" on which to propose subsequent steps for development. They often present ideas in what is termed a "notional," or conceptual stage. In its theoretization, design, and media representation, the "biosuit" exemplifies a shift from a biopolitical focus on the anatomo-politics of the human body and the generative politics of populations defined by the parameters of "life itself," to the politics of body/environment interface and integration, and of future populations made generative and social through their enhanced capacities to overcome the inhuman and dehumanizing limits of formerly unlivable milieus.

The biosuit: building skin, re-building the scope and scale of human/environment interaction

Unlike the design and testing of the current Mark III spacesuit model, which has historically frustrated collaborative synergies between medicine, biology, and engineering, biosuit design claims to have an interdisciplinary advantage:

> A Bio-Suit System stands to revolutionize human space exploration by providing enhanced astronaut extravehicular activity (EVA) locomotion and life support based on the concept of providing a 'second skin' capability for astronaut performance. The novel design concept is realized through symbiotic relationships in the areas of wearable technologies; information systems and evolutionary space systems design; and biomedical breakthroughs in skin replacement and materials. By working at the intersection of engineering; design; medicine; and operations, new emergent capabilities could be achieved.[89]

In the "Cyborgology" section of the report in which they locate their design historically, the authors remind their readers that the Clynes and Kline cyborg concept did not only advocate internal adaptations (medical) but "exogenous" adaptation strategies that could act like the enhanced skin the biosuit aspires to be. The designers expand the scope of "environment" that must be addressed by designers, approaching the cross-disciplinary contemporary notion of milieu as a multi-dimensional social and natural environment that can be knowable, designable, and manageable as an "anthropological" problem space:

> If space exploration is going to transgress existing possibilities via the Bio-Suit effort, anthropological issues must be investigated and addressed through the design of such a system. We must re-evaluate the roll of the astronaut as an explorer and as a representative of our species on earth. We must carefully design the physical, psychological, and cultural environment that future explorers inhabit during these explorations and truly understand what we are trying to gain from the experience.[90]

Although the term "transgress" appears to be a malapropism, it evokes the space advocacy goal to refuse given assumptions about the risks and nature of extremes, a goal they call "flexibility for the future." The designers shift the site of flexibility from the human body itself to an "evolvable" body/design system that responds to the multiple "environmental" factors of exploration.

The biosuit design re-makes the body's tegument and turns the body's muscle system inside out, bioengineering a new "skin" to interface with the extraterrestrial environment in order to restore a physical, social, and "anthropological" bodily integrity lost within a pressure suit. Instead of putting the body inside a pressurized volume that creates resistance, torques against movement, and padding that can damage the astronaut's skin, the "biosuit" is a "second skin system." It starts with a spray-on protective film that the astronaut applies to her naked skin then includes the skin-tight suit that "selectively" controls the passing of molecules between environment and skin, allowing the biosuit to sweat, cool off, and heat up as needed. The suit applies protective "mechanical counter-pressure" to the astronaut's body, against the vacuum of space. Embedded the suit are audio and tactile "information" technologies that increase the astronaut's direct awareness of the environment. Human skin and other "bodily systems" such as joints get "augmented" with "prosthetics" and "biomimetic locomotion algorithms" that enhance strength and locomotion.[91]

The designers emphasize that their second skin system eliminates the segregation of human and robotic exploration capabilities: "the explorer is hardly aware of the boundary between innate human performance and robotic activities."[92] This cyborgic condition is portrayed as humanizing, individuating, and socially enhancing because of its environmental integration. Recalling the ongoing objection astronauts have to being "spam in a can," the designers argue that the biosuit "change[s] the exploration paradigm from 'spam in a can' to an individual interacting with and inhabiting an extra-terrestrial environment."[93] The designers include an appendix in their report, which includes an illustration of two biosuited humans in a vital social environmental interaction:

> A vision of a personal interaction on the rim of a Martian crator [sic] made possible by the Bio-Suit. In order to promote the type of research required of a Martian colony, personal interactions must be facilitated. Here we see two researchers finalizing an agreement in much the same way we would on Earth. Due to the low profile of the Bio-Suit and the increased mobility and tactile sense, interactions such as a handshake become possible and pleasurable. This demonstrates how the physical design of a space suit can directly impact the daily experiences of the wearer on a utilitarian, psychological, and emotional level, thereby promoting overall heath and happyness [sic].[94]

The biosuit wearer is not just technically but socially functional.

The "bio" in the "biosuit" design schema is not a quality but a set of functions that relate to bodies-in-milieus, and the design moves those "bio" functions from inside the organism to the outside at the site where organism and environment meet, remaking the nature of the life/environment boundary. Gone are the routine references to the medical problems and design challenges that the pressure suit's "micro-environment"[95] presents, since that term does not appear at all in the biosuit study. Instead, the study focuses on the problem of micro-spatial skin/environment interfaces and "exchanges," where "skin" is operationalized as either "grown" biology or "built" technology with complementary "performance" capabilities. Unlike pressurized suits, the biosuit moves to the next ecobiopolitical level, actually exposing small (1mm^2) amounts of human skin to the space environment. The designers create a body/material surface interface full of sophisticated sensors that qualify the biosuit as a "wearable computer,"[96] and the idea of mechanical "life support" is reduced to portable breathing technologies. The biosuit's futuristic sensor "skin" enhances the capacity of human skin to communicate information[97] about interaction but also creates a digital memory of it. Like biopolitical strategies to enhance and intervene in life and in ways that are transparent to the one who lives, the biosuit is an ecobiopolitical strategy to enhance human/environment interactions, mitigate risks, and make its intensifying body/enviornment interventions and interactions virtually transparent to the one who inhabits a milieu in which one can belong.

The biosuit's future-focused value as a technology that extends its ecobiopolitical logics into aesthetics is enhanced by the collection of illustrations and photographs that accompanied its debut. The suit exceeds the boundaries of typical NASA aesthetics. The design team's charismatic and athletic leader, MIT aerospace engineering professor Dava Newman, appears in the suit in a variety of shots that showcase its flexibility and skintight appeal, and unlike current disputes about the ethics of athletic enhancements, the biosuit's capacities to enhance and even perfect human bodies are built into its purpose as space expeditionary equipment. Although the biosuit looks like the Mercury-era intravehicle spacesuits in their unpressurized state, when they looked futuristic and sleek, her poses in the suit mark a break from spacesuits of the "past" and are suggestive of additional gendered and erotic genealogies, including sci-fi and fetishistic fashion, even Victorian corset pornography. As aerospace historian Matthew Hersch has argued, post-War "high tech" women's undergarments and pressure suits were "complementary technologies" designed to defy and remake the body's forms and environmental limitations by fusing futuristic technology and beauty (Hersch 2009). Unlike the walkback test scene I witnessed, getting into and wearing the biosuit looks not uncanny and dehumanizing, but inviting and sexy. Along with photos of Newman, illustrations in the Phase I report and in popular press articles about the biosuit consistently feature obviously female forms, conspicuously differentiating the biosuited explorer's silhouette from the "generic" (desexualized or presumably male) pressure suit form. It also decouples exploration from an association with sacrifice and suffering, [98] reorienting it to the possibilities of extreme enhancement and environment enjoyment afforded by the pleasures of flexible design.

Making NASA's reference to da Vinci's "Vitruvian man" seem antiquated and abstract, the biosuit is a piece of wearable bioart in which biomedical risk appears duly retired and alien environments comfortably and vitally inhabited. Next to the biosuit, the "iconic" old pressure suit looks quaintly artifactural, invoking the historically religious valence of a quaintly depicted "icon."[99] Newman's biosuited explorer seems, not by coincidence, to be the logical inhabitant for the mobile biomimetic vehicle/habitat designed by her husband Guy Trotti's architecture studio in another NIAC proposal, as I describe in Chapter 3.[100] In a photograph of Newman in the biosuit taken on the MIT campus, she is perched on a futuristic spaceship-ish form that turns out to be Henry Moore's environmental/anatomical sculptural hybrid "Three Piece Reclining Figure, Draped." This, the MIT "sculpture guide" explains, is a sculpture designed to "assimilate" into its surroundings as well as to signify a reclining nature goddess representing tensions between the built and natural environment, masses and voids. Perched between mass and void, occupying both negative and positive space, the biosuited female body is poised to integrate, interact, and engage, in multiple senses of those terms. Flexible but tightly wrapped, the astronaut body is exposed through a stylized biophysics that appears to take the human out of what cyborg originators Clynes and Kline called the pressure suit "fish bowl" and into what appears to be a less mediated, but in fact more thoroughly intervened in, interaction with natural and artificial milieus. Embodied confidence exudes not just from the astronaut herself but the whole suit design, making it illustrative of a theoretical and physical "integrated" future in space environments that are more thoroughly social, nascently erotic, recognizably "human," and potentially habitable.

The biosuit complicates the notion of the insides and outsides of living spaces, suggesting instead a spatial model of milieus within milieus. Outer space represents the modernist utopian "outside" and "beyond" but, if humans really try to live there or prepare to do so, forces direct confrontation with the idea of a discrete "outside." In trying to manifest the *res extensa* promised by science and technology and "our action travel around the blue planet," as anthropological theorist Bruno Latour noted in an address to a design college, the result is a "shrinking enterprise" haunted by a growing concern that there is "no outside left."[101] The biosuit is an ecobiopolitical artifact of attempts to deny, accept, manage, and exploit that concern.

Conclusion

While at a coffeehouse with Kyle Montgomery, just off Saturn Boulevard down the road from his JSC clinic office, I told him that I was interested in how space biomedicine intersects with terrestrial biomedicine, especially as existing environmental problems magnify and new ones arise. I noted that space physicians deal with futuristic molecular-level environmental problems in real life and in science fiction, and cited a recent BBC mock documentary about a long-duration space voyage in which an astronaut sick with radiation-induced cancer commits suicide because he refuses to contaminate his crewmates' closed-loop water system with chemotherapies.[102] As we sat amid the mid-day caffeine-refueling rush of NASA employees and contractors, Montgomery responded to my observation that terrestrial medical institutions are joining NASA as customers for solutions to problems related to bridging provider/patient distances and the molecular-level "healthiness" of micro- and macro-environmental "loops." What used to count as unique spaceflight problems suddenly seem relevant on Earth. He replied:

> And in a way that's a kind of Copernican inversion. I mean in the old days you were limited in, you took your garbage and you threw it away, and now we know, there's no away into which one can throw it. OK? […] Copernicus was the first guy who took the same observations [that others did] and all of a sudden realized, wait a minute, this means the sun is the center of the universe. […] It's the same dataset, but the interpretation, that's called a Copernican inversion. And that's totally different than a paradigm shift. A paradigm shift is a minor course correction. A Copernican inversion is an absolute breakthrough.

Viewing biomedical datasets and scenarios differently, by applying an interpretive shift that moves from the biological inside to the eco-systemic inside/outside, is the hermeneutic move space biomedicine at JSC both pursues and is forced to make when working with its biomedical subjects.

Through technical theorizations and visionary assessments of micro- and macro-ecologies where "life" and "milieus" are dually problematized, human spaceflight scientists and technicians take an ecobiopolitical position toward humans and environments as co-constituting. By modifying Foucault's notion of biopolitics, I have described some ecobiopolitics at work: how space biomedical subjects are understood and managed at a fundamentally environmental rather than biological level, how their biologically pathological responses are made "normal" in ways that politically and socially normalize outer space milieus as well, and how humans are viewed as calculable "at-risk systems" made predictable and manageable on equivalent terms with technological and environmental systems that intensify and enhance what it means to be "ecological." I have offered ecobiopolitics as a concept to supplement biopolitics, hoping that what became obvious in my analysis is just how problematic the concepts of environment and milieu continue to be, how they get bracketed in and out of scientific and medical discourse and practice, and what is at stake when scientists and engineers collaborate to manage the limitations and enhanced potential of the human and its milieu.

------//------

---

[1] Griffin (2007).
[2] Mol (2002).
[3] Rose (1997).
[4] Foucault and Kritzman (1988:257).
[5] Canguilhem (2001: 7).
[6] See *inter alia* Stepan (1991), Kroll-Smith *et al* (1997), Fortun (2001), Petryna (2002).
[7] See Van de Vijver *et al* (2002), Frank *et al* (2006), Lock (2005), Landecker (2007).
[8] Rose (2007), Paxson (2008), and Helmreich (2009).
[9] Petryna (2000) provides a thorough examination of the "biological citizenship" that emerges as Ukrainians negotiate new forms of citizen/State relations at the intersection of two fraught environmental conditions: the post-Soviet and the post-Chernobyl nuclear disaster.
[10] Lock (2002), Petryna (2002), Casper (1998), Rapp (1999).
[11] Kotarba (1983:279).
[12] Kotarba (1983:285).
[13] A literature search in PubMED for "extreme environments" yield citations beginning in the late 1960s with psychological evaluations of "performance" of military and scientific teams in polar extremes, a topic I examine more closely in Chapter 1. Recently, "Extreme medicine," is explored in a *Lancet* special issue of that title which vaguely defines this category as encompassing medical practices pushed beyond their situational or practical norms. The issue includes an article on space biomedicine, as well as others such as Olympic medicine, medicine among laboring children in India, rodeo medicine, battlefield medicine, remote community medicine, and refugee medicine. While the editors of the issue are unclear about the criteria that unite these practices as "extreme," they allude to medicine practiced at the "ends" of "spectrums" listed variously as environmental, disciplinary, financial, scientific, and experimental.
[14] IOM (2001).
[15] Pitts (1985).
[16] See Haraway (1991), Gray (1995), Downey and Dumit (1997), Davis-Floyd and Dumit (1998).
[17] Clynes and Kline (1995).
[18] See IOM (2001).
[19] NASA (1995: section 5.9.2).
[20] NASA (1995:section 5.1.2.3.2).
[21] Canguilhem (2001 [1952]).
[22] Canguilhem 2001 [1952]:7).
[23] Foucault (1994), Redfield (2000), Stepan (1991), Nash (2006).
[24] Penley (1997).

[25] Casper and Moore (1995). NASA institutional mission management culture is becoming less hegemonically definitive of space exploration gender and sexuality; NASA people actively participate in commercial space activities and virtual outer space world-making where alternative discourses shape other kinds of spacefaring bodies and social practices.
[26] Ackman (2003), Weitecamp (2004), Stone (2009).
[27] Foucault (1994: 162 –3).
[28] Krauss (2009).
[29] In "Tsiolkovsky –Russian Cosmism and Extraterresrial Intelligence" (Lytkin, V., Finney, B., & Alepko, L: 1995) two historians and an anthropologist situate Tsiolkovsky's work within the context of the Russian cosmism movement but also claim that he was an early theorist of "extraterrestrial intelligence" (ETI) by linking his ideas to contemporary philosophical ideas within the SETI (Search for Extraterrestrial Intelligence) science and ET contact activism networks. The authors claim that Tsiolkovsk y anticipated both the Drake equation (an conditional mathematical expression of the approximate number of intelligent lifeforms in our galaxy) and the Fermi paradox (the position taken by physicist Enrico Fermi that if intelligent life exists in the universe it would have contacted us). Tsiolkovsky's famous quote commonly translated as "Earth is the cradle of mankind, but we cannot live in a cradle forever" is frequently used within governmental and non-governmental astronautics advocacy discourse, including NASA's own website.
[30] Cutting (2009).
[31] Rabinow (1992).
[32] Agamben (1998).
[33] Martin (1994).
[34] Hogle (2005:695); see also Clarke (2003), Elliot (2003).
[35] NASA (2008).
[36] Foucault (1994), Jordanova (1979), Porter (1999), Nash (2006).
[37] Foucault (1979) and (1994), Rabinow (1995), Stepan (2001), Redfield (2000).
[38] Pope and Ralls (1995).
[39] Keating and Cambrosio (2000:354).
[40] Stedman, quoted in Keating and Cambrosio (2000:353).
[41] Aerospace Medical Association. http://www.asma.org/aboutasma/index.php.
[42] Lovelock (2000 [1979]).
[43] Haraway (1995).
[44] Garb (1985).
[45] McGuirk (1997), Jasanoff and Martello (2004).
[46] Poynter (2006).
[47] Finney and Jones (1985).
[48] Compare Kyle's observation that "Earth" is a misnomer to a microbial oceanographer's declaration that Earth should be called "Ocean" or "Ocean Life" (Helmreich 2009:3). As Helmreich notes, this microbial oceanographer uses space satellite imagery of the whole Earth to represent his work as "reaching across scales of human and planetary embodiment" (4), a goal and perspective that demands, as it does for space life scientists, a deliberate rethinking of how environments and ecologies are named, understood, and represented.
[49] Helmreich (2006:71).
[50] Arendt (2006 [1961]).
[51] Rabinow and Rose (2006).
[52] Rabinow and Rose (2006:215).
[53] Rabinow and Rose (2006:204).
[54] Rabinow and Rose (2006:215).
[55] Rose (2007).
[56] Paxson (2008).
[57] Helmreich (2009).
[58] Landecker (2007:152).
[59] See Frank *et al* (2006), Landecker (2007), Lock (2005), Van de Vijver *et al* (2002).
[60] See Douglas (1982), Low (2003), Mol (2002), Whatmore (2002).
[61] Harper (2001).

[62] Conley (1997), Strydom (2002).
[63] See Petryna (2001), Clarke *et al* (2003), Shostak (2004), Frickel (2004).
[64] Beck (1999).
[65] Strydom (2004), Petryna (2001), Sunder Rajan (2006).
[66] Collier and Lakoff (2008: 27).
[67] Foucault (1995:199).
[68] Mol (2002), Keating and Cambrosio (2003), Vailly (2007), Novas and Rose (2000).
[69] NASA (2005b:1).
[70] See Singer (1989) and response by Wiley (1992), which is a dispute over the value of the "biocultural" explanation of "adaptation" (both cultural and environmental), which Singer dismisses because it does not account for the role of social relations in constituting health and Wiley defends as useful based on a correct empirical operationalization of the term. Critical anthropological work on concepts like "deforestation adapatation" and "climate change adaptation" (see Brosius 1999 and Baer 2009) are providing ways to reconsider "adapation" in the context of political economic and political ecological contestations over the effects of anthropogenic climate disruptions.
[71] Waligora *et al* (1991:171).
[72] Finkelstein (1980:22).
[73] Canguilhem (1989:171).
[74] Canguilhem (1989:201).
[75] Historian of exploration culture Michael Robinson describes ways that contemporary researchers have attempted to locate "novelty seeking" and "risk-seeking" behaviors in the heritable or environmental formation of personalities linked to individual genetic proclivities, such having a "longer sequence in the D4 dopamine receptor gene" (Robinson: 2009). None of my interlocutors referenced this research, but they create discursive links between attributing "exploratory behavior" to genetic expression and arguments that maintaining a national environment of support for exploration is critical to perpetuation of an American national "explorer" character (see Chapter 1). Robinson cites this as a genetic dimension of American exceptionalism. This can also be interpreted as a modulation of molecular biopolitics (Rose 2007), but one in which national environment is explicitly invoked as a necessary genetic "activator."
[76] See Hacking (1986).
[77] Anonymous (2008).
[78] Unavailable at the time of this writing, but integrated into headers on the AIAA website: www.aiaa.org
[79] NASA (2005c).
[80] Diprose (2008).
[81] Boyer (2005).
[82] Csordas (1994).
[83] Haraway (1991: 182), Shaw (2004), Launius (2005). A catalog and guidebook for the National Air and Space Museum's spacesuit collection describes space suits as both icons and artifacts. (Young: 2009).
[84] Shaw (2004:141), Hersch (2009b:362).
[85] Launius (2005: 8)
[86] Launius (2005: 8)
[87] Launius (2005: 9).
[88] Pitts *et al* (2001).
[89] Pitts *et al* (2001: *i*).
[90] Pitts *et al* (2001: 5.2.1.2).
[91] Pitts *et al* (2001b: 1).
[92] Pitts *et al* (2001b: 1).
[93] Pitts *et al* (2001: 13).
[94] Pitts *et al* (2001: 35).
[95] Harding (1989: 113).
[96] Pitts *et al* (2001: 1.2.4.1)
[97] Jablonski (2006); see her chapter on "Futuristic Skin" and its reconfiguration of sensory communication.
[98] As I argued in Chapter 1, Herzig's (2005) argument that Artic polar exploration thrived on an ethos of willing sacrifice and voluntary privation is compelling within the historical framework she puts on it (late nineteenth and early twentieth centuries), but it does not explain the visionary trajectories of extreme environment exploration as both an act of endurance and a challenge to maximize the pleasures of risk-

taking and the sensual and affective possibilities of "bio" and "eco" prefixed design modalities (See Chapter 3).

[99]Dr. John Charles, a JSC space life sciences manager and amateur space historian, gave me a photo essay called "Helmets and Neckrings," in which puts portraits of astronauts showing the shiny neck rings of their pressure suits next to other historical symbols of heroism and sacredness such as laurel wreaths and halos. Personal communication 2006.

[100] Trotti (2007).

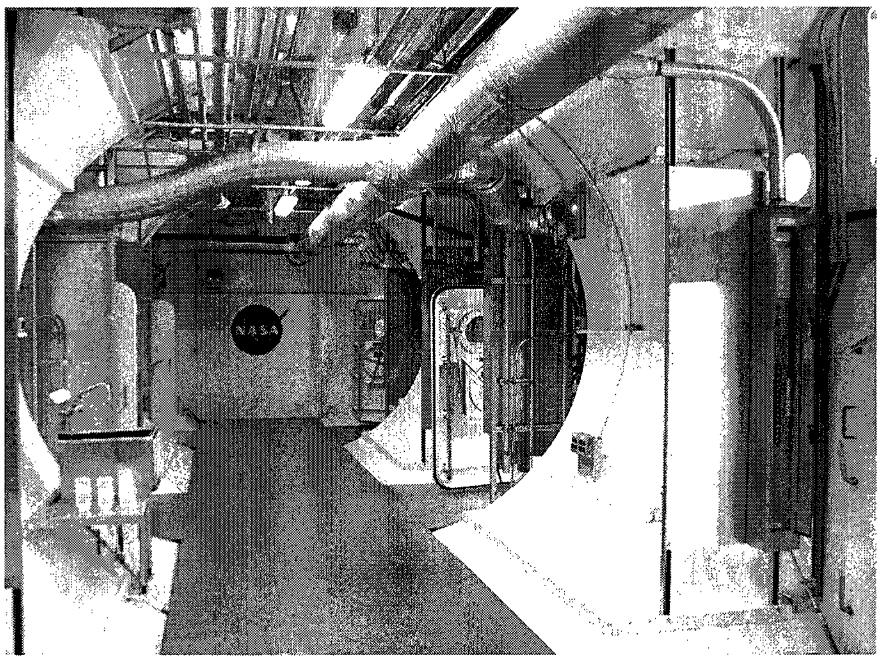
[101] Latour (2009:6).

[102] BBC (2004).

Chapter 3

H a b i t a b i l i t y

> If we take the worst-case scenarios, does that drive some of the solutions that more generally apply to everything? ... How do we transport our minds and thoughts beyond our traditional way of thinking and doing things by going to extreme conditions, extreme environments, extreme analogs, and maybe get a better sense of humans, technology, economics, and how all these things connect together?
>
> --Larry Bell, professor and space architect



BIO-plex interior and module hatches / JSC

In the midst of torrid Gulf coast marshes, inside JSC's aging industrial compound, tucked in an environmental systems testing facility, lies something designed to be a world unto itself. The Bioregenerative Planetary Life Support Systems Test Complex, or BIO-plex, is a cyborgic habitat that could make its own environment. Pressure-vessel modules designed to as labs and living spaces are joined by stainless steel tunnels, buttressed by recycling-based life-support machinery, and covered with veiny conduits. It fits into the future-aimed heritage of this cavernous building, which once also housed a spacewalk practice pool and a human centrifuge. But BIO-plex is in suspended animation, with conduits quietly void and apertures open to space and time. Unlike other controlled ecological life-support systems habitats built and used in the late twentieth century, it has never been closed up and inhabited; like other NASA one-off projects subject to policy and funding cutoffs, it ended up as a technical placeholder for the future. In design parlance, it's both a "conceptualization" and "prototype" for living in spaces deeply perturbed by the exigencies and contingencies of extremity and limitation. During the beginning of the Constellation program, this whole facility was a vital experimental zone for designing and mocking up lunar base habitats, where people involved in these projects also pursued terrestrial-based questions of "how to live."

In spring 2007, Building 29's spacious rotunda was full of the skeletons of old projects and strewn with freshly done prototypes, drawings, plastic and paper models, and wood and foam core mockups of habitats. As designers and social scientists both know, design processes are materially and temporally messy and non-linear. People tack back and forth between imagining, drawing, and prototyping, between renovating and innovating, all in an effort to make things and that evince progress.[1] One afternoon I found myself inside this JSC *matroyshka* of living spaces and mock-up mess, sitting inside a BIO-plex habitation module's mocked-up crew quarters with two experienced American space architects. At a plywood dining table in front of pretend windows with astronaut-on-the-moon photos glued on, I asked to them define the aerospace concept of "habitability" that is the objective of all this. One replied wearily, "It's so messy." Rather than a definition, he offered:

> …we're in an engineering-oriented environment. You'll get an engineer to [say], 'Well, a lab's habitable.' You know, I'm starting to think, be the devil's

> advocate, because you're going to have to respond to it. So, a lab is going to be in their mind habitable, so if you're talking to them about habitability they don't really see it in the same vision as we do in terms of that. The lab to us is a place where you work, and the habitat is where you do have your true habitability functions, so habitability may not, probably is not the word to use. For our external community, like with architects and industrial designers, they know exactly what you're talking about, but here.... My main focus right now, is how do we continue funding a group of folks to be able to do what we've been doing up here as a stepping stone instead of it going away like a lot of times it does.

"Habitability" may not work well as a precise engineering term, but as a quantitatively and qualitatively hard-to-define concept it nonetheless brings disciplines together[2] and invites reflection. In NASA astrobiology and in cosmological theorizations of an "anthropic principal" that explains the existence of a habitable universe, the concept of habitability is being narrowed down scientifically as the set of cosmic environmental factors within which life *could* exist. At JSC, despite fifty years of human habitat engineering and messy mock-up work, "habitability" is still only tenuously defined by scientific and technical fact-making standards and is constantly troubled by open questions within and beyond NASA about how people *should* inhabit environments.

During the time I was at JSC, before as they say, actual spacecraft "metal was bent," a key task for my interlocutors was to elaborate habitability as a concept that could fulfill engineering requirements as well as architectural recommendations and "desirements" (their word). As I found over and over, when my requests for definitions of habitability were deflected, that I was collecting instead explanations of how the concept puts different kinds of practitioners into negotiation, brings historical and future conceptual designs together, delineates space architects' disciplinary and visionary work, and is emblematic of desires to make a difference for ways to live on any scale.

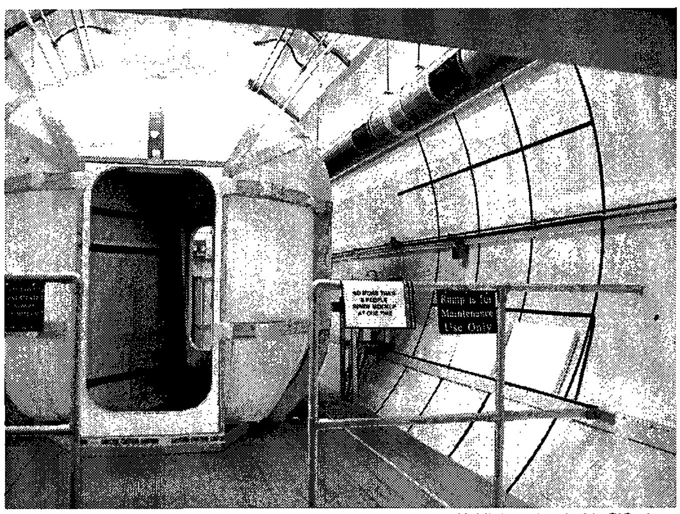
This chapter examines the messy in-formation concept of habitability and the connections between thinking and enacting that it fosters. It focuses in particular on how and why space architects work to make extremity habitable, and how through this work they articulate generalizable truths about human/environment interaction and offer solutions for technical, political, and ethical problems of contemporary human habitation. Part of the messiness of habitabililty as a concept is that it manifests in a tangle of NASA "concept" thinking and work: the "brainstorming" of "concept habitats," the practice of "conceptualization," and efforts to get a chance to mockup, prototype, and build things known first as "concepts." I suggest that habitability is therefore, following Sherry Ortner's useful description of "elaborating symbols," an "elaborating concept." In Ortner's typology "key symbols" have a formal or organizational role in social and cultural thought and action, and she distinguishes as actively "elaborating" (as opposed to the more statically "summarizing") those symbols that relate forms to meanings, experience, and action. This kind of symbol causes people to open up, reflect on, and sift through given and alternative ways to conceive of, feel about, and do things by "chaining" together other things seen as formally related. The ethnographer can detect and analyze such elaboration in the "root metaphors" that "order conceptual experience" in universalistic ways and in "key scenarios" of people, actions, and things engaged in narrating strategies and achieving purposes.[3] While such theories and methods are targets for critiques about over-mentalizing the social and cultural, in this case it is exactly interlocutors' explicit commitments to the conceptual that make them relevant here. I found people preoccupied with the problems, desires, and transcendental visions of concept elaboration, which they viewed as necessary to making their designs and processes illustrative and applicable.

As an elaborating concept, "habitability" is key to these processes and in its messiness it stands out for analytic consideration by me and by interlocutors, particularly because their work to "humanize" extreme environment habitation is loaded with expectations that it can innovatively "environmentalize" un-extreme living. In both technical and cultural terms, habitability is an elaborating concept being worked out at the conjuncture of what historian of concepts Reinhart Koselleck calls the "space of experience" and the "horizon of expectation."[4] Put into action by space architects and industrial designers as part of their programmatic work, the quest to conceptualize habitats and habitability asserts differences between established ideas and practices and hoped-for alternatives. However, even more so than similar "promissory"[5] technoscientific work such as the bid to establish the PCR technique into a concept that makes biology technological in a wholesale way,[6] astronautical design concepts are rankled by perceived failures of twentieth century futuristic design to make outer space fully habitable and American life tangibly better. However, for space architects and designers, concern with "habitability" is still legitimately future-focused, in their view now more than ever. I attend in particular to how collaborations and tensions within JSC design sessions and studios evince this expectation and its politics, aesthetics, and ethics. This expectation complements NEEMO extreme environment advocacy and the ecobiopolitics of space biomedicine but is even more recognizable as one form of what anthropologist Paul Little calls new "environmentalisms."[7] Although Little and others are most concerned with environmentalisms explicitly organized around territory, ethnicity, and gender, I examine how they can also be tacitly organized around technical practices.

Below, I detail my experience being invited into two settings where habitability was being conceptualized on a horizon of expectation. The first was a series of lunar habitat concept "brainstorming" sessions sponsored by the Constellation program office. The second was design conceptualization work done in the Life Sciences Directorate's new Habitability Design Center, a part of the Habitability and Human Factors Division. Tacking between these sites, I followed acts of definition, representation, and debate clustered around what quantitatively *counts as* and what qualitatively *should be* "habitability." In both settings, architects and designers aimed to manifest habitability in contrast to its signified other condition, uninhabitability, and also considered how astronautical problems and solutions were exportable to wherever habitability on any scale is threatened by inefficiently normative modes of living. Such problems bring two typically distinct analytic topics into a certain amount of dialogue: the historically anchored making and meaning of living spaces and the future-focused practices of design representation and technical prototyping. I foreground interlocutors' understandings of this topical intersection as they try to turn the technical logics and meanings of extreme environment living into a sentinel space of experience.

I also find compatible with ethnography the idea that concepts are "mocked up" out of different kinds of materials to give them dimensionality and see how they hang together. To ethnographically mock-up the in-formation concept of habitability, I hang together three examples. First, examine how the conceptual pre-prototyping of a lunar habitat signals ways in which habitability is being prototyped as a technical concept, following lines of investigation concerned with processes of thinking, association, categorization, and contextualization involved in the making of proto-technological things.[8] I then explore how the task to produce a "habitable volume" metric for engineer customers serves as conceptual backdrop against which JSC architects and designers assess their roles and expectations; I pay attention to how the terms "crazy, good, minimal, and integrated" anchor those assessments and point to the ethics and aesthetics of JSC design work. To flesh out the mock-up, I end by examining how NASA habitability concept work intersects with burgeoning American architectural and design interest in post-catastrophe, low-resource, recycling, autonomous, and semi-closed loop living designs. To do so, I follow habitability work out of JSC, in the form of a prototype camper-trailer "Cricket" built by Habitability Design Center architect-consultant Garrett Finney. Cricket's "shakedown tour" shows how JSC habitability moves on and gains cultural capital as a concern about how to live well and inhabit an extendible human environment described more frequently by architects than by others I met at JSC as "nature." It's launch as a prototype during the time Constellation was threatened as a program, and its relationship to lunar habitat design projects, retools a dread among interlocutors -- that their NASA designs would remain forever on "digital shelves" and, like BIO-plex, be uninhabited.

In examining NASA-based space architecture and its concerns to reframe habitat and habitability, it's possible to see how its technocratically-determined moves are complicit in modern spatial practices of power that authorize new forms of what sociologist Pierre Bourdieu would call habitation *doxa*. But following architecture historian and critic Kim Dovey, it is also possible to perceive in space architecture a "noisy complicity,"[9] based on attempts to conceive "visions of a better world"[10] based on "spinning off" (or in this case cycling in) extreme habitability, environmental integration, and autonomy to everyday spaces. I illustrate this chapter more than others in this dissertation since my interlocutors so often indicated that habitability may or may not be totally calculable but its "design goodness" should be intuitively recognizable by people with and without technical knowledge. Pictures and mock-ups have what sociologist of engineering design Kathryn Henderson calls a "meta-indexical quality" as a "holding ground" that creates a "negotiation space for both explicit and yet-to-be-made-explicit knowledge"[11] – in this case, for experience and expectation.



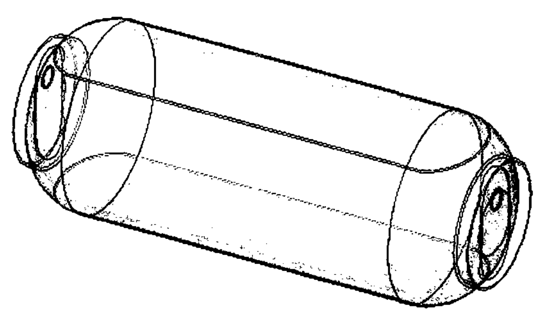
Habitat mockup inside BIO-plex

Lunar habitat / "universal home:" space architecture and the conceptual prototyping of habitability

Before attending my first spring 2007 brainstorm meeting, architects and designers in the life sciences division had introduced me to "habitability" as set of engineerable factors but also as a way of conceiving and designing well the spatial, energetic, and integrated arrangement of "human," technical, and environmental elements. Jens Larsen, a Danish architecture student studying at the inter-disciplinary

International Space University, showed me his new foamcore habitat mockup within an empty Building 29 BIO-plex module. His objective was to make it possible for astronauts to turn spent fuel tanks into living quarters on the lunar surface using fabric and lightweight furniture. We walked through bright white interiors hung with fabric walls meant to cover what Larsen called the "weird" gridded walls of a fuel tank. He explained that he was interested in the engineering constraints and restrictions that come from "experience" with "minimizing or optimizing" in extreme environments. He preferred architecture to engineering, however, because his general interest in "philosophy" was compatible with architecture's goal to "have a lot of open questions all the time." Praising "space people" as "sane" with a "unified peaceful approach" to the future of humanity, he claimed that outer space was where "we're gonna learn so much more about everything." In his claims, the broad elaborative and connective power of habitability as a universal conceptual tool is evident, and in the brainstorm I saw its elaborative capacities being implemented.

The brainstorm sessions took place upstairs above BIO-plex in a small conference room. There I encountered a more formally restrained elaboration of space architecture's meta-epistemological ambitions to know habitability on small and large scales. There, JSC space architects and designers were working with some of JSC's most basic engineering and architectural thing-concepts. These include "vehicle," "environment," "habitat" but also conceptual conditions like "launch-able" and "habitability." During the brainstorms, participants did the representational and calculative work that moved them toward future prototyping by putting design options into a conceptual "trade space." These brainstorms and their conceptualizing and "trading" situations make what Ortner calls "scenarios" for making "means-ends" relationships, specifically by taking key engineering requirements like lightness, smallness, systemic efficiency and functionality and coming up with the ways to achieve not just engineeribility but a condition of habitability understood as "livable." These scenarios fostered kinds of activity that social scientists interested in the politics and practices of moving between drawn concept, prototype, and production[12] have noticed. They were shaped by visual work that facilitated disciplinary boundary-crossing,[13] by the acts of drawing in real time and between times,[14] by supporting the work of habitability mock-ups that perform as pre-prototype artifacts that consolidate interdisciplinary interaction,[15] and by people's concerns about how their creations will fare in their intended environment of use.[16] However, it was also clear that habitability was being in some ways prototyped *as* a concept. The brainstormers worked to definitively shape a process that professionalizes and naturalizes designing for habitability in extremes as a useful practice.[17] Outside of the brainstorm session meetings, people interpreted for me their broader expectations for space habitability conceptual design as a universal tool, by making sense of past expectations that were now experience, and by getting excited about future potentials.



"Soda can" in the trade space / courtesy HDC

In March 2007 I headed into Building 29 for the first of almost four months of lunar habitat "brainstorming" meetings. The first thing one encounters in the building's foyer is a small model of the inflatable "Transhab" space station habitat module that was never built, the little object appearing like a cross between an architecture model and a futuristic dollhouse. It was most definitely not an engineering model. The socially limited but visually intriguing presence of architects and industrial designers at JSC is attached to the history of NASA's connection to military and industry research in cybernetics and human factors. Bringing in architects and designers was an effort to increase the human/machine/environment "functional integration" that is understood to determine mission success. Interlocutors and archives mark habitability's emergence as a NASA "problem space" beyond issues of sheer survivability when debates started in the early 1960s over why space capsules should have windows. This problem space expanded through more or less collaborative engineering and architecture work on spacecraft design features, from water drinkability to decor, geared toward making long-term space-"stationing" successful. For the design of Skylab, America's first space station launched in 1973, NASA included industrial designers Raymond Loewy as well as futurist artist Syd Mead (who later designed the future for movies like *Tron* and *Bladerunner*) to work on "man-machine" interfaces and make its hollowed-out rocket tank interior "livable,"[18] which included advocating for a window, designing a better toilet, and apportioning a space for crew socializing. Despite these efforts one JSC architect told me that astronauts still reported Skylab interiors as "ugly as hell." And, as with most NASA designs, Skylab bore almost no resemblance to the visualized architecture of space stations drawn in the 1950s by futurist artists and the man known in some NASA circles as its "first architect," Werner von Braun, whose visions were translated visually for Disney's *Tomorrowland* specials. Transhab was more in line with such visions, representing a "next generation" of flexible design.

Although JSC architects and designers I met often noted with disappointment how "un-designed" the International Space Station is and looks and complained that habitability design work at NASA has always been, in the words of a brainstorm leader, "reactionary," they were enthusiastic about architect-crafted elements making it into orbit, such as a portable fabric "temporary sleep station" designed recently at JSC. During fieldwork I came across people engaged a variety of habitability projects, all aiming to mitigate, within programmatic focuses on function and safety, what architects like Anthony Vidler would call the "uncanniness" of its "unhomely"[19] space vehicles.

Despite their increasing presence at NASA, architects do their design work there in social, theoretical, and practice gaps. In habitat and habitability design projects such as the one I was headed to witness there were already gaps between architects' and designers' expectations of what they are capable of doing and what the agency needs them to do for a so-called "Apollo on steroids" program with an inadequate budget. They also worked in a disciplinary conceptual gap between engineering and architecture. In those gaps, space architects worked on designing what social scientists and design theorists refer to as "built environments" and categorically-speaking "the house,"[20] but they are also involved in a large-scale technocratic scheme to manage logics and problems that problematize those categories.[21] This causes them to address as well as question, more comprehensively than most in their profession, the material aspects of Le Corbusier's dictum that the house is "a machine for living in."[22] But neither "house" nor "machine" adequately describes their design object because they also work more than their engineering colleagues do with the ecologically situated spatial term "habitat." These are the conceptual spatial gaps Kathleen Stewart describes as "ideas as ideals," rich with room to maneuver in, but also haunted by the fear that everything will remain "just talk."[23]

The Transhab prototype as a vehicular housing project that fell into the NASA gap of the much talked about but unbuilt, was an idea and an ideal, responding to a problem set that included houses, ecosystems, and humanness. In 2005 German space architect Andreas Vogler, a colleague of JSC architects who worked on the "Transhab" space station living quarters prototype, reworked Le Corbusier's metaphor. They were "complete machines for living."[24] Vogler argues that as such they are "prototypes for universal homes" that can lead general "trends" for homes to be autonomously "minimal" in space and energy use in a way that makes them an "active part of the planetary ecosystem."[25] He calls this "space age housing," pointing to a persistent horizon of terrestrial expectation unfulfilled by the 20th century futurist aesthetic *and* by human spaceflight.[26] Space architects at JSC still look to this horizon by describing their designs as having the potential to evolve, even though they struggle to get their most innovative designs, like inflatable habitats, built instead of decades-old pressure-vessel types. As I was to find, the problem of how or if space habitat design will evolve is conceptually attached to anxieties about the future of terrestrial societies and ecologies. Ultimately, as I discuss in more detail in the later section on "habitable volume," Vogler and other space architects work with a kind of conceptual mash-up of systems theory with humanism: by mastering systems architecture in terms of optimizing ecosystemic couplings human beings can inhabit the most inhuman of environments, within which they will become more rather than less aware of their humanness. Although such philosophical considerations were not elaborated directly during the brainstorm, they were part of space architecture's networked professional visions to link their "concept work" to conceptual design problems grounded on Earth.

I walked past the BIO-plex, past the mockup zone, past the astronaut training pool where a lone swimmer was doing laps and up metal stairs into the Lunar Habitat Team's brainstorm "war room." University of Houston space architecture program alums, Jake Hayle and Peter McManus, were running the meeting. They and their mentor Larry Bell told me that the U of H program began as a specialty in "extreme environment" architecture, but, with an endowment from the Japan Shipbuilding Industry Foundation it became the "Sasakawa Institute Center for Space Architecture" and offered the U.S.'s first masters degree in space architecture. Hayle and McManus favored "brainstorming" as a kind of studio space for re-evaluating current habitat design options, some of which came from their past experience with the short-lived lunar return program mandated by President Bush senior in the early 1990s. The room I entered was covered in computer aided design (CAD) drawings from previous meetings, and also visible was a JSC poster reminding participants of meeting ethics: "listen respectfully."

As the meeting began, I met the between five and ten people at the table and others attending via conference phone from other NASA centers. All were from a variety of disciplines including architecture, industrial design, engineering subspecialties, flight medicine, and mission operations. The "customers" for their design concept "products" were decision makers in Constellation's Lunar Architecture project, where "architecture" (as architects often noted cynically) didn't refer to the discipline but to the overall assembly of lunar mission technologies and mission operations plans. Those plans still being debated, meaning that it wasn't clear what astronauts would be doing in their habitat on the moon. The senior architects I had begun to interview complained to me that designing "to" vehicle specifications rather than "for" the purposes of lunar missions were antithetical to their disciplinary training. However, Hayle and McManus had ample experience modifying the expectations of their disciplinary field in order to adapt to what McManus called "the engineering environment" and were now training a new generation of JSC architects and designers for that environment. The table held its JSC par normal complement of middle-aged males but also male and female interns from the University of Houston and several young men newly graduated from the Rhode Island School of Design who worked in the Habitability Design Center (HDC).

Hayle held the floor and laid out the plan for the next three months. Ultimately, their habitat designs would be "downselected" within a design "trade space," an oft-used term meaning a process "space" full of visual materials described by scholars of science and technology as "inscriptions"[27] and "conscription devices."[28] The "inscriptions" in this case were diagrammed, charted, graphed, and drawn representations of building materials and processes and their systemic properties that matter for making decisions about how to make habitats habitable according to a huge (in revision) manual of engineering requirements called the "Man Systems Integration Standard 3000." Increasingly fleshed out CAD and hand drawings, sometimes done during the meetings, served over the weeks to "conscript" people into the process, inspiring work and debate. Although they were technically "notional," meaning they were ideas only, the habitat design drawings gradually went from simple to elaborate, including cut-away views of people, spacesuits, surfaces, hints of engineering systems that would keep everyone on the same page when "working" conceptually with them as outfitted and inhabited spaces. Using such drawings as baselines, people would discuss how to approach an engineering and habitability "requirement." Requirements in the epic Man/Systems Integration guidebook were usually written like a biblical commandment. For example: "Sufficient total habitable volume *shall* be provided to accommodate the full range of required mission functions."[29] The concept design task at hand was to think through all the engineering, medical, operational, architectural, social, and psychological dimensions of the requirement, particularly its conceptual parts, such as what counts as "sufficient" or "volume." As I discuss later, "volume" was a particularly fraught and provocative topic for architects.

Generic dimensions and fair trade: habitability as evidence-based yet intuitive and anticipatory

As the meeting began, some of the large design questions to be worked out surfaced quickly: Should the habitat be one "monolithic" pressure or inflatable vehicle brought to the surface in one launch or made up of interconnected modules brought up in multiple launches and repurposed from lunar lander fuel tanks? What pressurizable shape would be the most cost effective to transport to the surface, the safest, and provide the most habitable volume: a tuna can, a soda can, a hamburger, an egg? What airlock design would keep the superfine razor sharp lunar dust to a minimum in the habitat?

It was then that Hayle added this additional broad conceptual task: the group was to generate "generic dimensions of habitability." This statement encapsulated what I found to be the constant slippage between the work of producing fact-like physical dimensions of a prototypable habitat and prototyping a process by which to conceive, perceive, and negotiate habitability. Here's where much of the conceptual messiness inheres, but it was to be contained within the rules of problem representation and evaluation that engineers and designers called a "trade space." The trade space was a for making comparisons and trade-offs between values, such as the weight and strength of materials, the volume of shapes, the susceptibility of materials to degradation. Also part of the "trade" are generic features of habitability like "function," "integration," "performance," and even "happiness of the crew," all of which bear the discursive accretions of past debates over how to "trade" the basic features of good rocket-building economy (lightness, smallness, cheapness, safeness) and to account adequately for all the "dimensions" of habitability that make spaceflight not just workable but livable. Hayle warned the group that the many machinic, environmental, and human "factors" to be conceived of, calculated, and compared for these habitats meant that the "trade space" was "big."

I quickly learned that like in space biomedicine the most seemingly "generic" things about inhabiting, like breathing and the shedding of skin cells, are messy in the conceptual design scenario,[30] making the search for the "generic dimensions of habitability" a contingent and imprecise process. It was at this time that I began to search online databases and JSC office shelves for references to habitability from the 1960s forward, and found repeated references to habitability as a human/enviroment relational "state" of "tangibles" and "intangibles" rather than a property of a habitat,[31] to its "tacit" understanding in astronautical practice as a sum total of conditions,[32] to its status as a relationship between "shelter characteristics" and crew capacity to perform "habitability functions,"[33] and even to nothing at all in studies that didn't bother to define it. Habitability as far as I could tell was in a kind of conceptual limbo as something to, in one study's words, "design for,"[34] or in McManus's words to me in an interview, the process putting together "an integrated solutions" that makes "the best environment" to live and work. It was *generically* messy.

The first tangible example of habitability's messy genericness was the accretion of ways to represent and think about the "habitat:" because it was and could be a lot of things at once, its habitability became a matter of a lot of factors. The "habitat" I first saw was generic in the extreme: simple shapes passed around or projected onto the digital screen/wipe board (the soda can, the hamburger, the egg) which also echoed the shapes I discovered on shelves in JSC archives of earlier lunar habitat; but as conversations got going I started to keep a list of the different descriptors that constituted "habitat." No one called it a "home" or "house" in the brainstorm but it wasn't always a "habitat" either. People referred to it in terms of its hybrid astronautical functions that needed calculation for systems engineering, medical, psychological, and operational "requirements." It was: a vehicle component, a hard or inflatable pressure vessel, a laboratory or a "hab-lab," a "habi-tank" made out of a lunar lander fuel tank, a shelter, a lunar base building element, crew quarters. Mid-way through the meeting some of the HDC designers brought out drawings they described as picturing the basic human habitability "needs" for the lunar "shelter" – food storage and eating space, entertainment zones, workspaces. But Hayle steered the topic back to space architecturally basic problems how to think about making the habitat small and light enough to fit into a rocket, one of many reminders during the brainstorm that habitats are weird homes in modern American terms, invoking exotic or historical images of nomadic shelters or prairie sod-houses.

Designing a "habitat" as an "integrated" vehicle/machine/life-support-infrastructure structure is what gives NASA space architecture its distinctively hybrid architectural "vernacular"[35] but also points to its divergence from architecture's historical "space of experience." Its work to create vehicle-habitats is meant to successfully *un*settle and *dis*place humans from an Earthly "home" that is usually taken, as Martin Heidegger and Hannah Arendt have outlined it in their respective critiques of the technological overdetermination of human experience and spaceflight specifically,[36] as the proper referent for human existence and its attendant modes of dwelling. They're not even habitats for the building of optimally reproducing social units; they are placeholders for the future but also, as I've outlined in Chapter 2, at odds with modern architecture's efforts to frame human existence biopolitically.[37] As if echoing philsopher Emmanuel Levinas's herald of Yuri Gagarin's 1961 spacewalk as a way to supercede Heidegger's nativist concept of place with an open human "horizon of homogenous space,"[38] one of McManus and Hayle's senior architect colleagues told me during an interview that "it's almost like we're existential professors" teaching "an exploration of design knowledge," by which he meant moving outside of architecture's and society's usual sensibilities about proper places and styles of habitation. But he also came down to Earth quickly by adding that he has his own business designing homes because (as opposed to working on NASA habitat design and prototyping projects) "it's nice to see something get built." For the under 100 multidisciplinary-trained people calling themselves space architects in the U.S. and still trying to organize themselves professionally, space architecture defines itself generically as "the theory and practice of designing and building inhabited environments in outer space."[39] But in practice they still work mostly with the theory, conceptual design, and promise of that definition, which includes working out the "generic dimensions" of habitability.

During the verbal hustle and bustle of this first brainstorm, a prototypical example emerged of what it took to conceptualize habitability in terms of given and possible dimensions. It started when a U of H student, Sandy Hunter, interjected the magic word "radiation" into the conversation: she wanted to know how radiation shielding would be handled. How to deal with radiation's constant and accumulating biological threat is a really electrifying topic at NASA and can have the same social and political polarization effects as the topic of climate change -- I saw people yell at each other over it in meetings, and I watched a friendship between an engineer and a life scientist dissolve over a passionate debate about whether or not the radiation problem could and should prohibit human deep space travel. In the brainstorm session, the topic of radiation protection brought forth the creative and even transgressive dimensions of conceiving habitability solutions for extremes, and also signaled how radiation-prevention design conceptualization has as much of a "political career" as Henderson has documented for prototype objects in engineering workspaces.[40]

Hunter brought up "radiation shielding" as an example of a key quantiative problem to brainstorm but it was soon debated also in terms of its qualitative entailments – marking the broad scope of consideration that characterizes architect-lead habitability concept work. She brainstormed: "We can compact trash and build a [radiation] shield for the habitat with it, but we need to know how to calculate the production of trash."

Trash was one habitat shielding option, so was covering it with lunar regolith [*lunar soil*]. Another participant countered that another option would be to "stick with water," which was a relatively easy to handle, "systemic," and renewable resource unlike the current standard radiation shielding material for spacecraft interiors, polyethylene, which is a "single use chemical." Sandy agreed that water could be "scavenged" from "the system," which she enumerated as potable water, grey water, urine -- all cycling into and through the habitat as a supply, but within reach as a recyclable resource and even a building material. "Water" in the conversation was imagined cyclically and in multiple forms, suggesting the outlines of a trade space that included human alimentary systems as building material sources: urine or trash could be shielding, therefore radiation shielding could be as simple and light on launch as deflated bags ready to be filled with trash or urine.

It was soon clear that it was not waste as stuff *per se* that was being assessed in habitability terms here but the very *concept* of waste. Andreas Vogler in partnership with his colleague Arturo Vittori addresses treatment of waste as a hallmark of space architecture's distinction as a "new field." He states that "on a spaceship the concept of waste is redundant;" meaning that the term "waste" exceeds its systemic specificity as "resources in different states of processing (just like in a natural system)"[41] but he also invokes the famous NASA value that things must have multiple uses. During the brainstorm, the nearly universal taboo against living "in" one's own waste was barely joked about, because in the habitability trade space it was a practical, resourceful, calculable, redundant in an engineering sense, and evaluable both numerically and intutively. According to a handbook sponsored by the Department of Defense and NASA

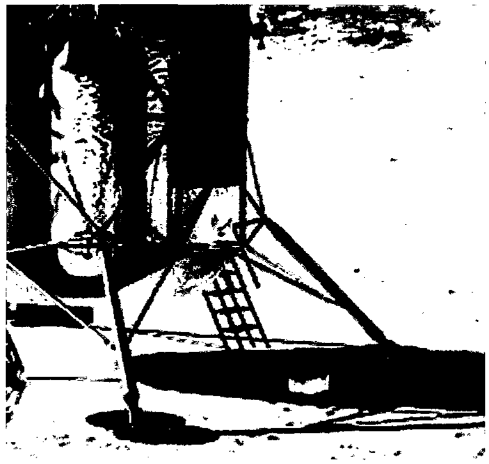
I saw often on office shelves in the Habitability and Human Factors Division, *Human Spaceflight, Mission Analysis and Design*, humans are "thermodynamically speaking"

> open systems – they exchange matter and energy with their environment. They consume matter to provide the building blocks for biosynthesis and the fuel and oxidant required to run their biological "engines." The engines produce energy for growth, mobility and maintenance of internal (human) systems. This "combustion" process produces thermal and chemical by-products. The "matter" people need is mainly food, water, and oxygen and their main outputs are heat and metabolic products such as sweat, urine, feces, and carbon dioxide.[42]

In brainstorming discussions about the habitat's "closed" or "semi-closed loop system," human waste becomes metaphorically and practically the same as other output or available "matter," such as lunar regolith: both are polluting contaminants that can be transformed into plant fertilizers or building materials.

All of these "trades" in meanings, use-values, and assumptions about matter in and out of place added a new dimension to Vogler's vision about how environmental constraint and extremity can open up a conceptual space for devising a futuristically ecological "universal house," where "universal" refers to location as well as ways to categorize how homes "work" as a system of systems within systems including the whole Earth. The idea that an American space habitat might serve as a universal or ideal model for a home links to historical utopian visions of "healthy houses" for perfectly functioning American bodies and families that emerged in the mid nineteenth century. As Victoria Solan argues, health and home became inextricably intertwined, but healthy home conceptualizations were not always commensurate with prevailing medical theories of health, sometimes offering alternative explanatory models for good dwelling based on utopian concerns not with cleanliness or reduction of exposure to the elements but with ecological fitness, resilience, and a return of integration of people with nature.[43] The lunar habitat brainstorm, with its proposal of living in waste reframes medical models of health as related to systemic capacities of environmental efficiency and integration.

The animated conversation quickly turned to considering ways that waste was generated in general, a move that began to materialize in habitability terms what human factors experts call the lateral "loop" of human systems. A senior engineer with lots of space shuttle and space station experience connected up for the brainstormers a relationship between another of JSC's departmentally separate systems work and its bearing on their work. "Guys, the food people [*JSC dieticians in charge of Space Shuttle and Space Station nutrition "systems"*] are trying to minimize trash by having the astronauts eat together rather than all these individual meals with individual packages that all weigh something -- you know, family style meals." Going with that idea, he offered, was how to save on mass and volume. But then the discussion turned to the fact that family style meals would mean less trash, therefore, trash would become less of a reliable resource for building or protection. One of the architects summed up the state of the generic elements in the habitability trade space at this point: family style meals "cut down on waste, but increase the social benefit." All of a sudden, radiation protection became related to social cohesion, and the "styles" and detritus of eating rather than what is eaten became intimately relevant to problems of survivability. Jason, an engineer contractor then asked Hayle: "Are we gonna do a trade study that shows differences in value between polyethylene or water as radiation shielding?" Hayle responded, reminding them of what their brainstorm revealed about trade spaces for habitability: "In order to do a fair trade we have to account for other things."



Soda can "evolving". Courtesy NASA

Accounting "fairly" for other things in a systemic yet intutive way, by mapping trade-off relationships between building materials, survival, waste, and social cohesion, made up the material and moral economy of what Hayle calls taking a systemically "hab-centric point of view." All elements of the "generic dimensions of habitability" would be made into numbers so that habitat designs could be "downselected" by upper level management. Presenting "solutions" to management that made for what interlocutors called combined engineering and habitability-centered "goodness" were also a way to organizationally distinguish space architecture expertise making some of the more imaginative "hab-centric" point of view workable, such as making it possible to evaluate radiation projection by technically accounting for and theorizing bodily/social/environmental systemic causes, effects, and relationships. Most of the time during the brainstorm the ecological politics of this accounting and theorizing stayed within the NASA project "trade space" technical and moral economy, but which once in a while these politics skirted larger geopolitical issues beyond NASA.

Designing for everything, everyone

In June, when the major work had been done to produce habitat design options, discussions continued about how to continue to evaluate "everything" used for habitability "goodness" in increasingly spatially and temporally broad terms. "Everything" was a totalizing conceptual space relevant not only to lunar habitats but to habitability-related projects going on in the world in general. For example, in one meeting a discussion ensued about how to make the foam material to pack scientific instruments "human compatible" not just in terms of being chemically safe for "outgassing" within the closed, pressurized environment but also useful for moving toward what Hayle described as the "evolution" of lunar living from "open loop, to semi-closed loop, to closed loop" systems. This schema doesn't refer to the "closedness" of the physical space to protect human life from environmental elements such as radiation or the vacuum of space, but the openness or closedness of the habitat to the lunar environment considered as a place in which humans could eventually "sustain" themselves through "*in situ* resource utilization" such as growing their own food, turning lunar materials into building and life-support materials. So, the conversation about lunar packing material turned into a consideration of how to "close the loop." Fresh from conversations with Swedish colleagues about how to do carbon dioxide recovery, Hayle suggested that the instrument packing foam could be used as compost for a lunar greenhouse, to which a flight surgeon brainstormer responded with a laugh, invoking another "trade" space being negotiated globally: "Hey, you could get carbon credits too!" With that, issues about the fairness of building at large entered the lunar habitat's loop in a way evocative of global discourses about the humanistic and ecological politics of "fair trade." It also served as a reminder of the relationship between the "fair trade" process of equitably accounting for "lots of things" and what McManus told me later had become a mark of the space architects' "extreme success" in being counted as crucial members of NASA's engineering environment.

I often heard engineers, space architects, and designers sum up the work they did in terms of its inherent "elaborativeness," expressing their work as uniquely challenged by having to deal with more than a normal amount of "details" in terms of "everything." Within NASA's systems engineering culture, this had caused their work to be increasingly valued. McManus and Hayle told me that they offered an attention to "detail" and "rigor" necessary to create the kind of thorough accounting for project "elements" that program managers wanted but in doing so they also accomplished something of interest to them as designers: cultivating within NASA and possibly outside a broadly ecological "hab-centric view" as a perspective that he called an "experiment."

Both Hayle, who like other interlocutors came to space architecture not because of spaceflight but because of interest in extreme environments, and his mentor Larry Bell described space architecture as concerned with the assembly of "everything;" because as Hayle said, in a "very extreme environment, everything gets stacked against you." When I asked Bell, about how to define the concept of habitability, his response was not to provide a definition, but to speak about what the question inspired, which was his own history trying to understand global cultural differences in the "preconceptions" of "privacy." I met with Bell, an elegantly articulate older man, in his Sasakawa Institute Center for Space Architecture (SICSA) office at U of H, surrounded by his paintings and designs of his students. Telling me that "space sounds sexy" but that he would have preferred to have been able to call his endowed program the 'Center for Extreme Environments' or something," Bell gifted me during the interview with a huge conference proceedings report from a 1991 interdisciplinary conference SICSA sponsored in 1991, called "The First International Design for Extreme Environments Assembly."[44] Bell explained how he and his students view the broad scope and scale of space architecture's "extreme" conceptual spaces:

> ...do we design everything? No we're kind of dilettantes, we don't design everything, but we organize the design of everything. 'Architecture' is a term that is used in space parlance and perhaps in other fields, is the kind of organizing logic. You've heard of the architecture of a system, or the architecture of this or that. Which I think is a very nice term, it says that we're not necessarily talking about habitats, we're talking about coherent logic, we're talking about creating things were all the parts fit together and humans are part of that system sometimes, or at least humans are part of the creation of that system. And [the system] also has to work, and humans are involved in living in that system and performing in that system, and so architecture is not about buildings exclusively. [*Astronautical*] architecture is inclusive and it deals with everything from planning a mission down to designing a space suit, which is architecture....So, it's very, for us, very exploratory... In the future [*of Earthly social life*] the need for conservation is not gonna go away, energy issue's not gonna go away, we're gonna have to learn to live more effectively, best thing will be not to consume more than we need in the first place, it would make more sense not to recycle but to reduce consumption, then next thing is now do you recycle the thing that you need. We live in a time when there's a broader consciousness of this Spaceship Earth notion.

Referring to the root astronautical metaphor of "spaceship Earth" and the processural usefulness of working with extreme "worst case scenarios," Bell talked about how systemic climate change doomsday predictions are now matters of "uncompartmentalizable" detail on the personal level when it comes to making decisions about what kind of house to build, what kind of clothes to wear. Gesturing to his jacket, he put his concerns into geopolitical systemic terms:

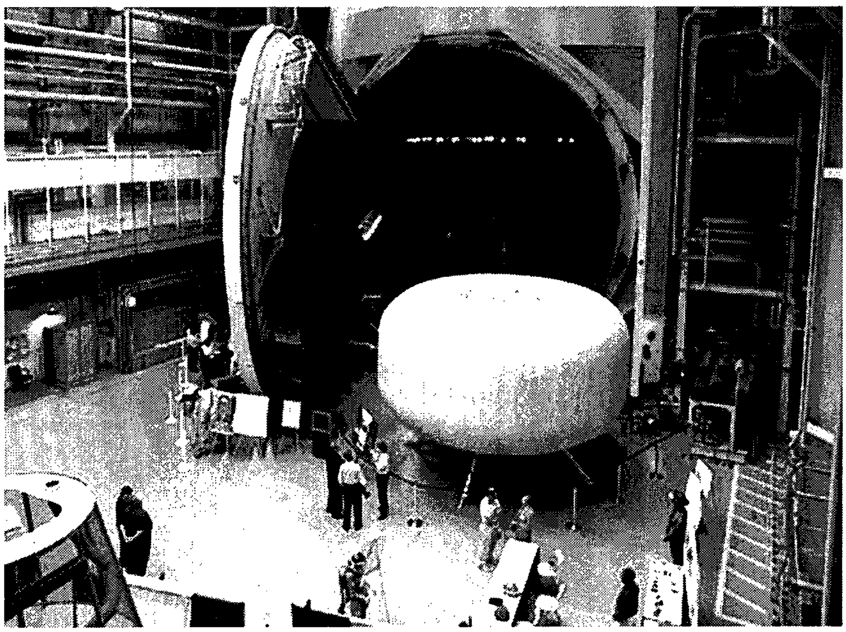
> This jacket came from China, the Sperry [*jacket brand*] came from China and Mexico, but it's incredible, now we're supporting countries that have no pollution standards, not to mention minimum wages, and we can't compartmentalize that. We're sending business overseas, [if you want to do] carbon trading..in France... it's down their alley, we've exported all the technology to do that, sent our industries overseas, and then that pollution comes around, is that part of spaceship

> earth, absolutely it does. So all these things, all these things are interconnected. So space architecture, and architecture in general, we look at the architecture of our planet, you can't separate it out into buildings and infrastructures and systems, it's all connected.

The NASA and space architecture totalistic focus on detailing and accounting for "everything" in design pre-prototyping phases, and the larger reflections they make on it, reminded me of how a space station water systems engineer summarized his training and work (reported in Chapter 2): "everything interacts with everything!"

The brainstorm sessions I watched that were so deeply focused on the everything-details of little soda can habs sometimes obscured the fact that a larger habitat meant for space *had* been prototyped. What about Transhab? It was also designed for the first time not in a "reactionary" way but by, in one architect's words, "designing backwards" from the future objective of having it serve as crew quarters for the long, strange, and precarious trip to Mars. Even so, it was hard to get people to talk about it at length, although several architects were happy to share their technical papers with me. In a dramatic blow to space architects at JSC and to the discipline, Congress cut its funding due to Space Station budget overruns in 2001 after it had reached substantive stages of testing. This seemed to have broken hearts, but the Transhab-stung leaders involved in the brainstorm were consummate professionals and did not show it. Transhab had been featured widely in popular and astronautical trade journals, and the design plans had just been given to budget hotelier Robert Bigelow who put a derived prototype in orbit, full of cockroaches and other "subhumans," that was being monitored closely for leaks and problems. My inquiries to speak to someone Bigelow Aerospace were unceremoniously rebuffed without an invitation for negotiation, reminding me once again of the difference between my reception at NASA and the proprietary closedness of the burgeoning "New

Space" enterprise sector. In a paper on his experience designing Transhab, JSC senior architect Kriss Kennedy praised its human-centered designs and its innovative "endoskeletal" typology based on intricate fabric weaving and materials layering that "put the 'Living' into 'living and working in space;'[45] JSC architect Constance Adams, in an interview about her work on Transhab described her time at NASA as inspiring her to write a book about how NASA is a "holdout in our civilization of the culture of Great Projects."[46] Architects I interviewed talked about how Transhab work lead to work

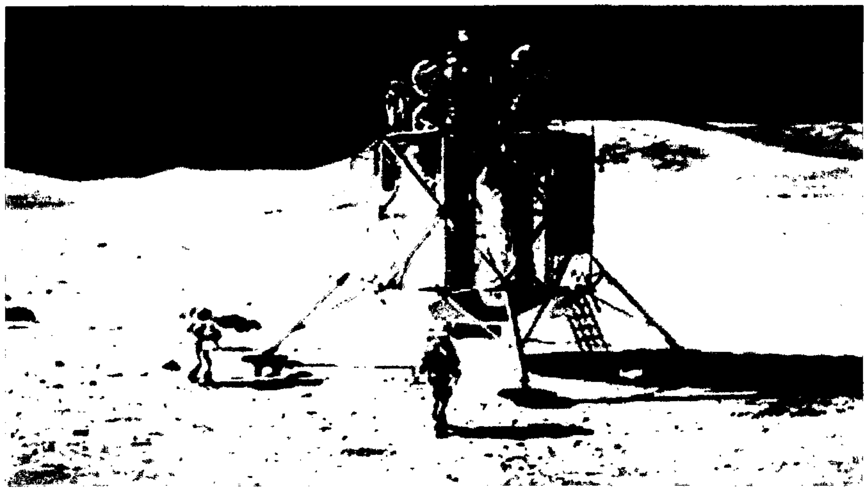


Transhab prototype pressure test / courtesy NASA

with the National Science Foundation on Antarctic habitat building and to other "long term technology planning" design concept sessions with industry and the military for "living, breathing habitats" also "self-healing" based on putting "micro technologies in skin of habitat that absorb CO_2 in, take through skin the other way, like gills, turning it into oxygen."

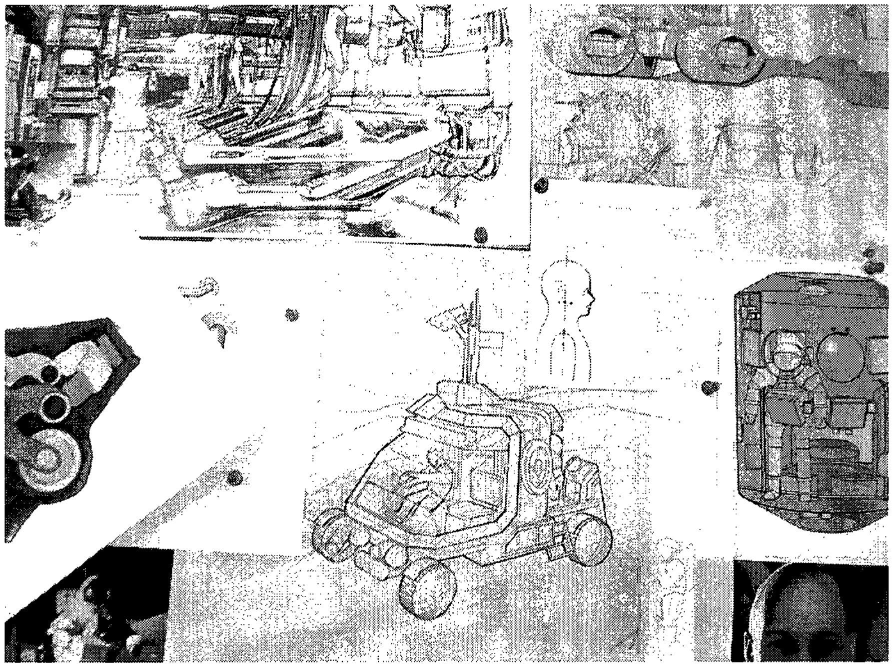
It was easy to see how space habitat designs understood as technical inscriptions, conscriptions, and prototypes with political careers could also be understood as "cosmograms."[47] The transparencies, exploded views, conceptually integrated components, and imaginative merging of the qualities of inhabiting and living in these design concepts show them to be conceptually cosmic things. The unbuilt Transhab was a prototype for a vision of an inhabited cosmos, imagined ambiguously as full of "universal homes" for everyone or increasingly technologically sophisticated habitats for millionaires, militaries, or governments. The imaginary of a cosmos made up of potentially democratic or powerfully-deployed super-habitats elaborates the futuristic politics of habitability in the terms begun during Cold War spaceflight -- as attached to universalistic hopes and dreams for "human" greatness, but also to specific mechanisms of social distinction and superpower.

During the brainstorm and my meetings with Houston space architects at large, "habitability" emerged as an elaborating concept space within which space architects think about the prototypicability of habitats and the prototypicality of habitability. Several space architects, including Bell, saw the "process" of space architecture design conceptualization as the real "legacy" regardless of whether things got built. Andreas Vogler writes about the relationship between his real work and its potential in this way: "the prototype of an [sic] 'universal home'... has to be able to offer in one way or another all basic functions, which we usually get for free on our home planet. It thus forms an 'archetype' of architecture" In a note he clarifies: "Archetype is not understood temporally of what has been first, but as the general concept of a minimal optimized system for the human being to 'live' (not just survive) in the most extreme environment of space. Today's spaceships are still far from that optimum."[48] This is the horizon of expectation for prototyping.



Altair lunar lander - Courtesy NASA

Toward the end of the brainstorming project, the team had produced concept designs for what kind of habitat system the "Altair" lunar lander (as it was now formally called) would bring to the moon. Habitability as a conceptual goal had been thought about, drawn out, and discussed in conceptual scenarios; details had been enumerated, calculated, evaluated and accounted for in attempts to account for anything and everything. But this process was only half the story of habitability's vivid life as an elaborating concept at JSC, especially for people given the task of designing very specific "concepts," from things like tables to metrics like "habitable volume," considered relevant to the engineering and life sciences production of habitability. During the brainstorm I also spent time with industrial designers in the very un-NASA like studio-office space of the Habitability Design Center, who were charged, to their delight and chagrin, with turning into "a number" the definably specific but also perceptually subjective problem of "habitable volume." For this task, the generic perspective on habitability went from a "hab-centric" to "human-centered."



HDC bulletin board

Elaborating on "crazy, good, minimal, integrated" design

Narrowing in on a "habitable volume" number was NASA's tactic for making the "generic dimensions of habitability" tangible as an engineering requirement. But for JSC's most unengineer-like designers who came to NASA to learn about systems engineering, this task caused them to work with their expectations about how space design could and should open up ways to improve systems of inhabiting in any place. In this conjuncture of engineering program requirements and design expectations, work on habitability by young designers in the new Habitability Design Center (HDC) elaborates a landscape of practice tensions. These tensions are institutionally formalized in the HDC's charge to be "advocates" for "human centered design" against space engineering's historically machine-system centered design. It would be neat to argue, *pace* Ortner and colleagues,[49] that there was a "clash" of symbolically separate design systems at JSC, namely systems engineering design versus humanistic design, vying for the central role in determining how habitability works to order extreme design and extreme living experiences. While the hallmarks of such a clash are obvious, I didn't find space architects and designers taking a "side" in a simplistic way. Instead they played with practice-based and conceptual tensions in order to make the "systemic/humanistic" dyad compatible in ways that would make their work relevant and revelatory -- at NASA and in the world. This section fleshes out this angle of habitability as an elaborating concept by focusing on terms that illuminate what it means to work and play with the habitability concept.

At the HDC, the task to generate a "habitable volume" number was making habitability more orderly, communicable, and workably differentiable as a key elaborating concept following Ortner's formulation, but that project also inspired designers to think about their responsibility (in one's) words "not just how to make it work but how to make it better." I'm interested here in how their habitability numbers work and reactions to it catalyzed understandings of themselves as environmental design experts and the concept of habitability they wanted to materialize. Caught up in the ambiguity of NASA's design conservatism but its claims also to changing the future of human life, they reflected on the promise of extremes and outer space as vital, under-explored design space for the conceptual frontiers of efficiency, function, and the experience of inhabiting "better." One way they did this was to merge their work on habitable volume with their "outside the box" pursuit of astronautical habitability ideas, aesthetics, and ethics. Even if as senior HDC architect Finney says that among engineers one doesn't talk about aesthetics, there was aesthetic talk in the HDC nonetheless. Certain terms helped me to understand what was at stake for them as designers interested in living experiences, environments, and futures, in engineering efficiency as well as architectural aesthetics: "crazy, good, minimal, and integrated." I show here how these terms point to what HDC participants and their mentors recognize as their "unique position" to steward habitability in terms of "human centered design." However, it also clarifies their concern that designing "for the human" included what for them was the frustrating, interesting, and theoretically key task of designing *against* the idea of the human as conceptually separate from systems and environments. As a result, they make explicit what they see as problems with contemporary design in general.

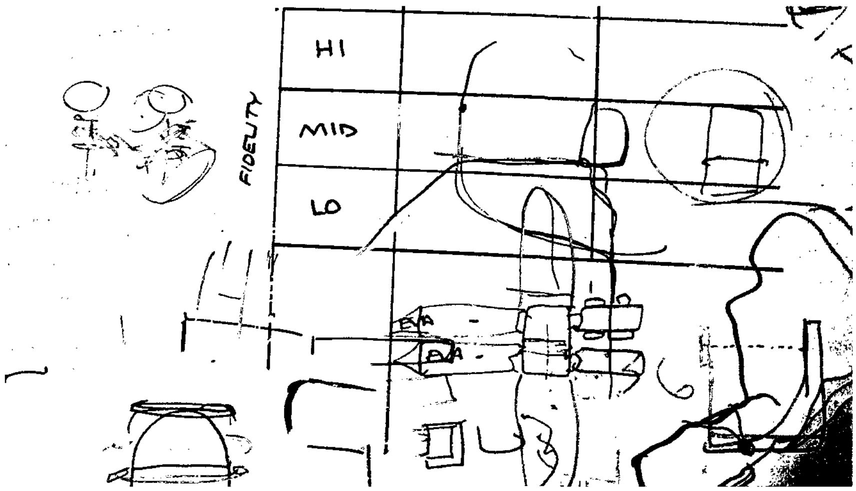
From fall 2006 through the end of spring 2007 I visited the HDC designers in their studio-like office and followed their work. I did this while traveling around the corridors of the Life Sciences directorate's Habitability and Environmental Factors division in Building 17, digging into archives and observing and interviewing people. Branch chief Jake Santini had given me an office near to the HDC office, as he was sympathetic to my quest to understand the astronautical human, in part because he and his division colleague Susan King were trying to formally install "human centered design" processes into the Constellation program's extensive technical planning "architecture." The HDC was created to give this process a central clearinghouse. Building 17 was full of offices dedicated to the "factors" relevant to vehicle design systems integration and habitability, such as propulsion systems, thermal systems, and the several offices dedicated to human factors. As described in Chapter 2 "human factors" conceptualizes the human from the surface outward as a biological and work performance system that is part of the mission "environment."

When I started to visit Building 17, the HDC had been given "ownership" of the quest to determine process for calculating a minimum "net habitable volume" number: the number that indicates how much space a crew needs in a capsule or habitat to ensure safe and successful mission operations. Such tasks were, in the words of their team leader, "great but horrible." The task legitimated their presence but it was a static number summarizing what they felt was an inherently subjective and objectively poorly defined concept. It wasn't clear yet what the human would be "performing" in spacecrafts or habitats, or what kinds of furniture and equipment would be sharing the volume with them. According to the agency's "habitable volume" engineering requirement in the Man-Systems Integration standards manual, human bodies exist geometrically in space and in mission-relevant spatial relation to one another and the things they will interact with. In particular, bodies exist in a "body motion envelope" that is a "conceptual surface which just encloses the extreme body motion of an activity."[50] The goal of a "habitable volume" number was to specify the space needed to "accommodate the body motion envelope of the 95th percentile male crewmember performing various IVA [*intra-vehicle activity*] activities" as well account for "social design" considerations like "visual privacy," the spatial privilege of "leadership status," and (via the contribution of human factors psychologists) the "proxemic" space that "mediates communication."[51] That last idea was particularly formulaically mind-boggling but points to extreme and powerful rationalizations of the social that underwrite government spaceflight:

> 1. When conversational or recreational space is necessary, the space should be configured so that the crewmembers can be at distances of 0.5 to 1.2 meters (1.5 to 4.0 feet) and at angles of approximately 90 to 180 degrees from each other. In general, 90 degrees is preferred for casual conversation while 180 degrees is for competitive games or negotiations. 2. Equal relative heights among social conversant should be maintained through spatial configuration and the placement

> of restraints. 3. In a socially communicating group it should be possible for all to position themselves in relatively similar body orientation and limb location. Maintaining a similar vertical orientation is also desirable.

In the division, the work of providing data on people in terms of habitability dimensions was centered in the "Anthropometry" office, which regularly recruited astronauts and other JSC employees for its experiments and activities. There, I watched as engineers modeled human dimensions with scanners and manual measurements, creating a geometric population universe of "95th percentile white males and 5th percentile Japanese females." This kind of work tied NASA human factors work to automotive design, and in fact I discovered that many JSC architects and designers produced papers for the "Society of Automotive Engineers," an organization that supported any work that makes it possible for persons and societies to move themselves. I stepped in the anthropometry scanner once myself, watching myself be made calculable as a shape with volume. Such exercises were part of habitability at work as an elaborating concept at NASA, where it was reframing historically powerful and meaningful human trait- and type-sorting in new conceptual terms as part of the continuing role of technology to code and sort bodies. Donna Haraway has characterized this as the act of making bodies into "biotechnical" and semiotic" "strategic systems" that in turn make up meaning-producing fields, [52] to which "habitability" as a conceptual field could be added. This type-range data influenced infrequent joking I heard elsewhere at JSC that future crews should be made up of females or even "Japanese females" in order to save space and money. Such jokes cross-referenced more oft-expressed fears that Asian countries were going to "beat" the U.S., and, by extension, its (volumetric outlier) population of males and females, to a space colonial future. I was reminded of the role of anthropology in the history of body-measuring and sorting when time and again people at JSC understood me to say that I was doing an "anthropometry" dissertation.



HDC wipeboard

My visits to the HDC workspace showed why these designers were capable of inventing and "designing to" a thoroughly conceived habitability volume metric, but also why such a task was not their style. Several of the small group were graduates and interns from the Rhode Island School of Design and affiliated institutions like the International Space University. Other consultants to the Center drifted in and out, such as Garrett Finney, also working offsite on his prototype Cricket camper. Entering the HDC office was like going into an architecture studio; it was full of spacecraft models, drawings, and highly intelligent and clever discourse. In some ways it was a distinctive kind of space, but it was also deeply connected with other futuristic outer spaces in "Space City" Houston, from the University of Houston space architecture program offices to the Museum of Fine Arts' collection of space-themed art, including Argentinian artist Gyula Kosice's "Hydrospatial City" installation of 3-D space habitats that illustrate his 1971 manifesto that future "habitats" should be based on "mobile and shiftable environment and form." Such ideas, Kosice claims, came from "intuitive insight," but "are also marked by an impending and inexorable rationality" toward achieving the "synthesis and integration" of art, life, and the "dwelling-place" [53]

At the HDC, it was possible to hear vigorous irony-tinged critiques as well as deeply held affection for NASA, and the whole space was a kind of lively homage to the design concept power of science fiction and NASA-as-vision. Much less museum-like than other NASA spaces, the HDC office was a mixed-media installation. On tables were CAD drawings of lunar habitat "soda can" cutaways for the brainstorm meetings, next to anthropometry books. On shelves and on walls were astronaut Barbie dolls, gorgeously rendered drawings of techno-biomimetic things, books about space-affiliated design heroes like Loewy and Mead, and icons such as a portrait of Star Trek captain Jean-Luc Picard. The hipness, relaxedness, informality, and the presence of non "work-related" stuff deviated from the norm at JSC; a testimony to NASA's attempts to accommodate its workspaces and work practices to a new generation, a topic of much intergenerational debate on space community blogs and more intensity at Ames, for example, than at JSC. Sounds of pounding and powertools would often came through the walls, from ongoing mock-ups of crew capsule and habitat "volume spaces." Mockup was a task the designers had been hired specifically to do, and which gave them great pleasure. I spent time being oriented to their mockups and sitting inside them, taking in their black and white simplicity, the smell of their freshly cut materials, and the flimsy flexibility of the dimensions that could be changed easily. Despite their fragility, they had great power to provide a sensual connection to the habitability concept, to touch and be enclosed within a visualization. This was an experience that that HDC industrial designer Keven Long did right when he arrived at JSC, marveling with a grin on his face at how it was "a crazy thing to happen for your first day. 'Cause when we finally see the CEV [*Constellation's crew exploration vehicle*] take off, it's gonna be like, crazy."

Image collection / HDC

Crazy: the passions and parameters of good design

During discussions with HDC designers who I interrupted in the midst of projects, comments about their social and conceptual stewardship of "habitability" were significantly punctuated by the word "crazy." The term is common among younger Americans to label something as "cool," but it could also be used to connote something conceptually bewildering or extreme. "Crazy" also connected other agency goals with their goals, in an overlap of meanings. As I was following life sciences people develop their goals for Constellation astronaut "performance-readiness," I was aware that design for habitability was not only being linked to survival but to prevention of spaceflight-exacerbated social and mental disorder. For HDC designers, the "crazy-making" power of space was a dimension of the eccentric and unpredictable genius inhering there, what two referred to as a "traditionless" or "wild" site on the design concept frontier. Space for them was not a utopian destination, but a heterotopic site for exploring essential and transcendent design experiences and possibilities. Crazy cool/bewildering/loco also resided in the juxtaposition of their work with quantified body envelopes with their desire to push some design envelopes by participating in what Transhab architect Constance Adams calls "something as insanely challenging as a spacecraft" [54] that requires a level of design detail within rigid parameters that her colleague Jake Hayle says will "drive you crazy." I learned a lot from listening to and for the "crazy" injection.

As usual, I began my relationship with the HDC by asking them to define their Center's stated fortés: "space conceptual design" and "habitability." To the first question, their team leader responded by differentiating between how engineers "define" it according to numbers and how the HDC team "approach[es]" it as a conceptual problem that involves mental and embodied work. Randy Feher explained to me that they "approach" it "totally" differently from other JSC groups, as an iterative and visualization-heavy process of drawing and redrawing whole vehicle or habitat design concepts that "go outside the bounds of the performance requirements" to get at the less tangibly defined "human requirements." Key to their success doing this would be to prove that "we're not some crazy group that does nothing but hand sketches…we have engineering prowess." But they also had to enact a prowess distinct from engineering, which meant that they had to establish the value of cultivating an embodied habitability design sensibility through processes like auto-experimentation, something they saw as consistent with the whole space exploration enterprise. Randy said that the HDC difference was that they were going to get to the "habitable volume" requirements not just by looking at and organizing the "zeros and ones" of human factors data, but by doing mockups based on options for those numbers so they could "get inside this thing and see what it's like." They were making an effort correct the insensible and de-aestheticized technical work with bodies as volumes in motion, and to enact their desire to see and know "what it's like" to be in a space capsule. Their distinctive legitimacy as a group, then, came from its mind/body iterative concept design process. As if to underscore the extent to which they pursued conceptualization as embodied experience beyond JSC, they invited me to go surfing with them, which is where Long joked that they did "all their best thinking."

"Crazy" also marked moments of reflection on what it was like to think and work in the architecture/design "gap" at JSC. Working within "real" engineering constraints was both frustrating and inspiring, conceptually. Long, an accomplished artist as well as designer, now realized that his adjustment to design work at JSC had been a process of seeing himself working not inside just NASA but outside the science fiction art and movies that still inspired him with all their "idealized fantasies" of "cool and futuristic" space living, from "virtual reality pods" to "crazy wallpaper." He called this the process of acclimating to NASA's "real world" constraints, what senior architect McManus described as the process of learning how to suggest "crazy" ideas (or what Finney called "crazy better" ideas) like making lunar landers capable of turning into habitats like "transformer" robots -- but then knowing how to deal with the impossibility of those ideas.

Long and his HDC colleagues and mentors learned to keep from being driven crazy by detail and NASA's "real world" by focusing on the richness of their play with the real/unreal boundaries. They expressed disappointment with NASA design restrictions dictated by budget, policy, and even uninspiring astronaut tastes, and their fears of just doing what Long called "reenacting the future" by recycling Apollo-era designs, but they still imagined they were getting the experience necessary to solve large scale terrestrial design problems in the "real world." They used that phrase to distinguish the NASA design they were able to do versus sci fi design fancy, but also to mean the terrestrial world as opposed to the enclavist world of space design. Long imagined addressing "real world problems such as how to create a space that is perceived as being very wide having a lot of volume and in reality it's actually an idealized volume, really tiny -- because that's gonna make design history right there." He imagined in this way the capacity of "real" space design to become a broader part of the human experience. Finney added in this conversation that it was important to always take into account that within the NASA domain designers were responsible for giving astronauts "habitability" in terms of the standard "homes" they were used to, not the "zippiest crazy science fiction future thing." Comparing what was on the HDC walls and shelves with other walls and shelves, where the HDC had limited references to Star Trek and Star Wars and featured more prominently images less popularly recognizable, it was clear that they were inspired by different sub-genres and practices (design) within science fiction than other NASA groups, making clear the need to fine tune analyses about how science and technology practice and science fiction are related.[55]

A key part of making themselves useful to the organization was also to show how a purely "engineered" solution could actually be crazier, in a bad way, than one of their "human centered" solutions. One day Long pointed to the poster of the space station on the wall of the HDC: "I mean you look at that space station picture over there, it's like, it's crazy looking. But it wasn't the work of somebody consciously trying to style it, it's just all engineering." In a conversation about the HDC "difference," Feher offered the hypothetical example of sleeping bag design conceptualization. In such a scenario, the HDC would present a solution after investigating the range of ways people can and want to sleep, an engineering solution would make it a problem of how to put together sleeping bag components. He imagined that "our sleeping bag would just look clean and inviting and you'll want to tuck into it and fall asleep, their sleeping bag is gonna have some crazy stuff going on, different layers, different things coming off of it, and it's going to look so over-engineered and so uninviting in a way." Across from us, working on a project but half-listening to this conversation, industrial designer Scott Latner spoke up about a different kind of design essentializing challenge and vision, that of naturalizing space travel through design:

> I just went off on a little mental tangent that I think would be fun to discuss, it would be interesting to implement a department here like a biomimetics department. And going back to like we're our own biological spaceships surviving and sending out things that are harmful to our little ecosystem, it would be interesting to think about how can we essentialize space hardware, space travel, and maybe get the machine out of it altogether and what if we were to genetically design this giant creature where we are, where we're like, it's a host, and it's like we have a symbiotic relationship with it.

I asked, "It's not physically alien to us, it's something like us?" He replied:

> Yeah, something like us, and then we can live inside of it and travel through space, and it's our protective layer and it's a closed biological system, and how you launch this creature into space... We may have to grow it in space....You should check out this artist, his name is Joe Davis...he's the artist in residence at MIT, and he does really cool stuff, he's a genetic engineer, he never graduated from high school, he's from Louisiana, and the guy's just a crazy genius. A creative genius. He built an ornithopter, do you know what an ornithopter is? It's a mechanical, flapping plane with wing flaps, powered by frog-legs.

This kind thinking out on a limb, which was everywhere in space building technical reports, such as the NASA-funded collaboration between the McDonnel-Douglas company and Iranian ceramic house builder Nader Khalili to fashion lunar soil into ceramic bricks, underscores space architects' and designers' interest in doing work that is hyper-rational and a little crazy. They like the mix-up of how to work within restraints yet with wildly open space, how to stay within but transgress boundaries, how to design the craziness and dysfunction out of individuals and populations through spatial order but to open up creativity and freedom.[56] In space design, these mixed up goals are nonetheless part of what Jens Larsen calls the "saneness" of space design's visions for the peaceful and orderly evolution of design and human societies, which I describe in more detail further on.

While I was at JSC, I watched architects far more than engineers try to go deliberately and productively out of their minds, following architect Larry Bell's desire to "transport our minds and thoughts beyond our traditional way of thinking and doing," to think about how to go beyond the standard human/house or human/machine conceptual dyad. In conceiving of the habitable dimensions and promises of the biomimetic, they engage what Lévi-Strauss terms the more "raw" biological modes of living within protective enclosure, of traveling, and of contained symbiotic integration. "Human centered design" then becomes a cosmic conceptual elaboration of what Hannah Landecker has called the meaning and "task of being biological."[57] Interested in biomimetic design and also what Constance Adams calls "metabolic" design, the HDC designers admired as evolved and innovative those design concepts that looked biological. When biosuit (see Chapter 2) spacesuit inventor Dava Newman's husband, Boston architect Guy Trotti, came to JSC to present his NASA Institute for Advanced Concepts-sponsored scorpion-looking lunar rover that, among other things, could burrow into the lunar soil for radiation protection, I went to see this presentation with the habitat brainstormers and the HDC designers. I noted in the room rapt attention but also a strained silence. Within the NASA "real world" and the "real world at large," there could only be a subdued enthusiasm for this work that Trotti described as designed "to" the concept of exploration as a mobile, flexible practice. The design was conceptual to the max, therefore it was clear that people couldn't get *too* excited about it. What brought order to the disordered but inspiring openness of design craziness was its attachment to the other ethically and aesthetically motivated conceptual goals of goodness, littleness, and integration.

HDC's Temporary Sleep Station: "a good solution" / Courtesy NASA

Good: the scope and scale of space design virtue and value

In conversations with HDC and other JSC designers, the question of the relationship of "good design" as an aesthetic virtue to astronautical design's ethical potentials was a hot topic. Two of the HDC designers in particular described themselves as existing in a kind of ethical self-formation crisis in the JSC practice environment, questioning both why they continued to stay and even "what design is." However, they viewed this as productive. Thinking that, working as if, and hoping that astronautical design would be scalably good provided them with an aesthetic and ethical anchor. In addition, it caused them to think about what it means for space architecture to have a good reputation within and outside of NASA.

Feher, responsible for coordinating his colleagues tasks at the HDC, had defined "human centered design" as the equivalent of "good design" and to describe both as the obligation of the HDC to "introduce" to JSC. It wasn't that engineers hadn't been designing with those concerns, it was just that the HDC and their supervisors wanted to convince JSC engineers that "good design is more than survival." Feher's supervisor Jake Santini saw it as an opportunity give "every young engineer" at JSC the chance to learn the concept of human-centered design. In such ideals there was a line being drawn between specific projects of design for survival in extremes and what astronautical design has to offer in general as a "good" solution for human habitation in general. Such ambitions to invest in interiority and architectural detailing of spacecraft might be evincing in part what Joseph Masco has called the technoaesthetics of contemporary Cold War practices, in which institutions facing limitations on the practices they did earlier (such as detonating bombs or having enough funding to actually go to the moon) can shift their practices to more internally-relevant aesthetic pursuits. [58] Masco says that this creates a space for experiencing nuclear weapons science as pleasurable, but also has the dangerous effect of superficially detaching Cold War work from its goals of empire and a war-based economy,

Designing for astronautical things that never get built at JSC is a kind of technoaesthetics in action, but it is critical to see the difference here: every architect and designer I took had as their goal to better and more explicitly *attach* and export NASA extreme design to the terrestrial world as a way to improve it. This is where their presence at JSC aligned with that of other engineers and astronauts, such as Jennifer Cantrelli, to create a "goodness" loop between Earth and space:

> I don't think it's a naïve thought that even though you extend and move out, that you can still have goodness here...whatever we're doing to move out makes it better here as well... you're just trying to extend good things from where you came from and to where you'll be.

As with space medicine, JSC architects and designers generalized the "good" of their space habitability expertise by referring to its potential to make the space habitat microcosm relevant and revelatory in a macrocosmic sense. They achieved this by making cosmological correspondences between the people and logics of spaceflight habitation and larger processes and schemas of habitability. This was often specifically gender-inflected. For several of my interlocutors in their written work and in interviews, "spaceship Earth" was not just a dislocated system but biologically shared, not as an organism or machine, but as hybrid "mother ship," not just as way of understanding its material functions but recalling Buckminster Fuller's specification of the planet as an "exploratory mothership" for a "design revolution."[59] JSC architect Constance Adams explains it this way:

> A spaceship is a delicately balanced environment. Every element that doesn't contribute to the overall functioning of the system is by definition working against it. The same is true of our planet—our mothership—though sadly, most architecture today is slowly fatal to nature's systems. 60

In the spirit of this motherly metaphor, interlocutors were concerned to make clear that their work in an elite domain with elite people was not just imaginable in terms of power-over verticality, but as a kind of looping exchange or overlapping of spheres. Space living seemed poised to transcend the politics that create a gap between design for powerful interests and, in Hayle's reference to a design installation including some of his colleagues, "design for the other 90%" living in comparably extreme conditions.

Several of my interlocutors described the goodness of their work in terms of its affinities with the outside world of "green" design concepts, but also saw that kind of design as, in Finney's words, "only a third of the way there" as way to conceive of habitability in ecological terms. Although only three of the ten architects and designers I spoke most at length with identified explicitly with environmentalist movements, all expressed their faith that space architecture's principles had the potential to benefit Earthly considerations of environment and ecology. In an interview with online design journal, Core77, HDC designer Chip Conlee wants the space-Earth design "transfer" process to improve:

> As excited as I am to be working on stuff that will travel to the moon, I would rather see us focus all of these resources and great minds to bring the efficiency that has been developed and refined in the spacecraft to Earth: We have people who don't have fresh clean water and are dying of dysentery, and technology NASA has developed can recycle wastewater into potable water. The population is always growing, and we're constantly fighting for space. This problem is not going to go away, and one obvious answer is to be more efficient with the space we have. This is a great model—sort of an extreme model, but an applicable one.[61]

Peter McManus didn't describe space architecture's solutions for extremes as extreme themselves, but instead as "basic." He noted that both "green architecture" and space architecture were moving from "traditional architecture" with its "ornate design [and] trickery" and "back to fundamentals and basics." He didn't describe this shift as going back to some historical originality, but as toward the "core" of design, as if such basics transcended specific times and places.

Others saw that space architecture's extreme models could transcend both the politics and terrestrial assumptions of green design. As Jack Simpson, a close collaborator of Constance Adams, reminded me, the Earth itself wasn't the ultimate source for information about the potentials of habitation autopoesis: "There's no evidence Gaia is a self-regulating organism." JSC architect and human factors manager Susan King -- ecology major and self-professed "home-oriented nester" raising children with an astronaut husband -- outlined the space architect's differently colored conceptual landscape for habitability:

> [Y]ou're taking what you know as a human for habitation within an Earth environment, and you go out forward…you disengage with what habitation meant back here on the blue planet, now it's on the gray moon, what does it mean there? What does it mean when you progress and move on to the red planet? It may change there again, so you shed away, you strip away the earth based aspects of it… to begin civilizing the unknown, we have to put the human in the middle of it and build around him.

Thus the ethics of astronautical human centered design is informed by a quest for essential and scalable truths about human habitability in unknowns and extremes, truths that can potentially reveal and trump what Finney calls the historical tradition of designing with unexamined "assumptions" about human/environment relationships. Rather than investigating the politics of these assumptions as a part of their habitability conceptualization work within NASA, however, most interlocutors appeared to be envisioning the political goodness problem-solving potential of their work from within the conceptual "place of no place" of space architecture and design. However, their worksite brushes with the political in terms of design goodness was also tied to a fascination with the aesthetic virtues of the extremely minimal. As HDC designer Evan Twyford explained in the Core77 article:

> If I see something that's pure style and aesthetics, it still speaks to me in a visual, sensory way, but I see that as being the fat and happy. Now it's the extremely efficient, minimal and economical design that appeals to me. I see that as real problem solving, and that's good design.[62]

Minimal: beautiful utility

For space architects and designers, mastery of the minimal in systems engineering as well as aesthetic terms was key to representing their habitability design processes as good and useful. However, they did not refer to this mastery as a matter of sticking with formal scientific, engineering, or aesthetic rules. Although they were nonscientists and nonengineers in a technoscientific workplace, they showed me through conversation and examples how they recognized the appeal of the minimal in terms of scientific parsimony and the engineering elegance of making tools that fit the job. And, although their training would have familiarized them with architectural and artistic minimalist movements, none named that history as an influence on that work in conversation or in documents. As a result, I watched them engage the minimal as a process of interpreting engineering requirements as beautiful utility, by focusing on the engineering/aesthetic complementarities of such ideals as lightness, smallness, multi-functionality, efficiency, and usefulness. When I was with them, this work was informally nascent in their Center's work to distinguish itself and to produce what they called "cool" stuff meaning that both they and engineers were satisfied with its design goodness. They provided some key examples of how they approached refining established forms and processes of NASA minimalism into beautiful utility through conceptualization of what it meant to them, in particular how the minimal should be technically and aesthetically comprehensive.

In the HDC office one day, Garrett Finney, the most experienced member of the team, mused on space architects' potential to out-minimalize engineers. Noting that what appears to be "high tech" design at NASA is a collection of one-off "handcraft" made to fit together but not designed together, he said the HDC crew had to be "geniuses" so that they can

> figure out the aesthetic solution that answers their engineering requirements better than they even thought. You know, it's lighter weight because we put a big hole in the middle, because no one realized that they were just using the edges, you know, some weird way that we see the world that they don't necessarily. It's hard, it's a weird, I mean all these issues exist in the real world in architecture. 95% of the houses that are built are ugly, bad, stupid houses. But it's much more gray [*in the terrestrial housing world*] somehow, it's a big shifting mass of gray, and here it's quite stark because there's only one of them, if some bad decision was made design-wise on the space station then all these decisions have to follow it because it's up there and everything that has to attach to [it].

The HDC team wondered then how many "tax dollars," for example, had gone to retroactively correcting several badly designed components of the Space Station. Other people I spoke to at JSC joked about the bureaucratic complexity of making things simple, which they claimed (and I noticed when I found a 40-page manual on how to make labels for items on the International Space Station) was often just a matter of writing instructions for dealing with overly complicated "bad design."

However, out-minimalizing engineers was also a matter of being aware of the minimal as a master-planning strategy. As a result, space architects and industrial designers I spoke with imagined systematizing minimalism more comprehensively than their engineer colleagues. Jens Larsen explained the appeal of space design's simplicity/complexity tension over the compartmentalized architecture and industrial design he had been trained to do, calling normal design its opposite "extreme:"

> You need to have it as simple as possible, and you need to work out many complex procedures or whatever..I mean, in the other extreme in design is creating maybe the design of a cell phone, because the designer doesn't have any idea what's going on inside, which is fine, but you create a style or image and there's nothing wrong with that, but it doesn't really interest me to shape stuff because it has to look cool.

In these points of view, a truly valuably "minimal" design is one in which designers apply criteria for technical and aesthetic minimalism from the inside out, and in a way that stretches outward to the structure of systems. In their 2008 Core77 interview, when the team was deep in their lunar rover design phase, the interviewer notes that Evan Twyford names as one of the HDC's prime inspirations the mid-century experimental avante-garde Archigram group, in particular their survival-technology experimentations with "modular city 'plug-in' concepts [which] portrayed a future where intelligent buildings made from independent life-sustaining pods could reconfigure, allowing their nomadic inhabitants to roam free."[63] Archigram practitioners' avowedly apolitical, individualistic, and technocratic quest for nomadic design, following Buckminster Fuller's formulation of "ephemeralism" as the value of doing more with less, was inspired by NASA lunar modules.[64] This connection elucidates how aspects of habitability-as-progress are being worked on as an intergenerational dialectic within the HDC.

In this sense, the minimal is also linked to the autonomous, and I found that the future vision of autonomous habitation among JSC space architects was imagined not as the technological power to access resources but to have the technology to use limited resources well and elegantly. While there is a modern history of finding beauty in machines because of a "happy marriage of simplicity to power,"[65] those I spoke with were more convinced that NASA had become too invested in promoting the relationship of machinic complexity to power, and as a result it was not doing enough to emphasize the beauty and utility of its efficient habitation systems and their minimal-waste, maximum-use value philosophy. My discussions with engineers working on astronaut Ron Garan's Mana Energy Foundation's work to build village "infrastructure autonomy" in Africa and Mexico in the form of free standing water purification systems dovetailed neatly with my discussions with architects and designers about their efforts to explore ways to make Earth and space habitation come together. A book of collected articles on space architecture as a discipline, which featured several of my interlocutors, contains not just designs for space habitats and colonies, but speculations about how small, mobile, autonomous technologies coming from space programs will spawn "eco-units"[66] on Earth. These would, in effect, restore autonomy and the choice to be interdependent to people (all the pictures are of ex-colonial sites, doing things like drinking from personal water purification straws) being threatened by global systems that make them dependent. The use of *in situ* building materials are not just "traditional," they are, in Vogler and Vittori's words, "the spaceman mentality."[67] Here is the temporally and spatially looping utopian dream of astronautical value. As Carl Conlee told the Core77 interviewer about the lunar habitat work they were doing: "Essentially, you have a small life support system where you recycle as much as you can with minimal waste and have localized energy production. It's an awesome model for living."[68]

Minimalism-as-awesome refines the modernist faith in what the Archigram group called "people-oriented technology of modern liberation," by offering a "design solution" that steers its way between "hippy" environmentalism and a more "sophisticated" technoscience. [69] In the HDC point of view, sophisticated minimalism that is not simplistic or disconnectedly atomized promises to deal well with the sublime dimensions of nature and the social. As Peter McManus explains:

> And for the folks that go through engineering school, the mentality is all about optimizing the design, and so that means the minimal, the best, the highest performance, all that, and that's not always the right solution, because it needs to be an integrated solution...

However, the concept key to the JSC architect's and designers' passionate pursuit of how the minimal and the autonomous contribute to habitability on any scale is "integration."

International Conference on Environmental Systems logo /
Owned by American institute for Aeronautics and Astronautics

Integration: building the moral, aesthetic, and political economy of holism

Along with the HDC's need to, in Feher's words, "integrate ourselves" as the center for habitability conceptual design into the JSC engineering process, the HDC also meant to conceptually distinguish what they did from the human-machine "integration" being done by engineers following the Man Systems integration bible. One of the hallmarks of this distinction could be found in the ways that talk about "integration" goals and work slipped into talk about "holism." This term invoked, explicitly and implicitly, astronautics' larger visionary aims and claims. Although "holistic" as a term was authoritatively located in human physical and cultural evolutionary theory, systems theory, and complexity theory, interlocutors sometimes spoke of it with a hitch in their delivery or even a tinge of embarrassment (more detectable in the audio than transcribed versions of my data), presumably because of its associations with the poetics and metaphysics of social ecology theories and the American counter-culture practices opposing technocratic enterprises. However, *how* they tacked back and forth between "integrated" and "holistic" as ways of describing their work is part of what marks "habitability" as an elaborating concept that connects experience with expectation, projects with enterprises, procedure with style, and local JSC environmental technoscience with larger environmentalist practices and discourses.

While "integration" was the common working term for process of making connections between things at JSC, "holism" was connected with meanings beyond the technical. It was critical to the ways that architects and designers understood their contribution to the politics and economics of habitability. When I was doing fieldwork, "holism" was in the process of being integrated into NASA's under revision "Human" Systems Engineering Handbook, partly through NASA's inimitable style of "black boxing" concepts and processes as acronyms in order to standardize them. This contemporary work on formalizing the use of that term at JSC was part of HDC's branch to show that "HCDP" (human-centered design philosophy) practice can "go further" than the HAAS (human-as-a-system) model, because HCDP "emphasiz[ed] a holistic and iterative human-centered systems design concept" and therefore would be installed in the Integration manual as a "recommended practice." [70] However, there was a backstory to the strategic use of "holistic," one part of which branch manager and ecologist-turned-architect Susan King recounted for me by describing a part of her master's degree project.

> The discipline of architecture has not embraced space as the place to practice our [craft] and [show] what we can bring to the table. I asked people [*in her space architecture program*] to bring me quotations as to what architecture brought to the space program, and in the 100 plus [story]boards I had in my master's presentation, I got quotations from all the architects, and the most common repetitive aspect was the "holistic approach" and that is what we can bring to the table. In that tiny little widget that an engineer can focus on, it can be magnificent piece of equip, but we understand how it fits into the big whole.

Once again, the term "approach" indicates that there is more to their work than calculation or making things look good, and that the results of thinking and working holistically go further than ensuring "mission success." Architects' and designers' shared the view that their "holistic approach" was conceptually and theoretically robust in very tangible senses, particularly in its capacity to anticipate. Jake Hayle summed it up this way: "we make pretty good systems engineers because we're not trained as a systems engineer, but the way we look at things in a holistic kind of systems approach." Garrett Finney explained that "this is the designer's brain to have this holistic application." Randy Feher gave me the example of how this sensibility and mental orientation allowed the HDC to predict the need for a "hand restraint" (a handhold) in one area of the Space Station that engineers did not install because there was no "requirement" for it; the corrective measures were over-the-top expensive.

References to holism were also ways to signal interlocutors' conceptualization of scalable habitat/environment integration. Jack Simpson, a senior contractor who worked in the space station "Integration Office" and the Transhab project as well as mentoring HDC staff, started his career with Harvard architecture training for "big master planning" and then went to space architecture after a search for what's "what's cool" and "the ultimate [design] solution space." After I asked him to characterize "habitability," he explained how his desire to do "elegant" design was satisfied by the holistic perspective afforded by astronautical work. It allowed him to think beyond systems theory conventions by seeing the essential ecology-dependence of discrete systems.

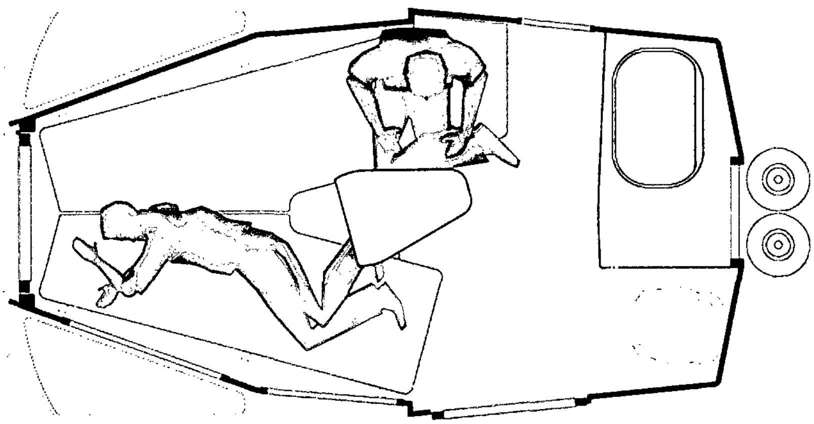
> So, whole idea of looking at a project holistically, it sounds New Age and it's been overused, but I now use the word systems engineering, in terms of the systems engineering, because having read my Smith and my Mill and my Marx and my Hegel, and my Durkheim and my Hannah Arendt and my Foucault, [I know] that economics, actually, economy is not a separate thing from ecology. It's all the exchange of energy… What I've learned in spacecraft design, which is if you optimize one system, chances are you're creating problems for the rest of the spacecraft. Every system has its own rules, but those rules only function fully in internal interactions. External interactions have to follow different rules, and that involves cooperation with the systems with which they're interacting. Economics in considering itself an independent entity is destroying a lot of the systems it's touching, because of that break, that fallacy in thought…I've learned constraints, how to make things better but not heavier or more expensive.

Noticeable in the long and complex interview is not Simpson's use of systems engineering or architectural terms, but his capacity to mix them up and fit them back together: besides economy being the same as ecology, human beings are technologies, people, the spacecraft's primary system, interactive agents, and Earth's gametes; Earth was nature and mothership.[71] Based on his writings, his work, and what I heard, integrating philosophies and terms was, as with other space architects and designers, part of Simpson's style. When I asked him to explain the relationship of his stated interest in the future of Earthly infrastructures with his interest in space colonies, he responded that he agreed with other architects, such as Constance Adams, that this all had to do with "big picture" processes, such as helping Earth reproduce itself. But he slipped back easily from viewing the human relationship to the "big picture" as primarily biological to seeing it as primarily technical, as the exercise of what he called our unique ability to merge "techne and logos." He was interested in working with and within the "big picture" as one big design concept space:

> I've had people call me, oh, so you do biomimesis….I'm not setting out to do biomimesis, and I'm not going to start my next design by looking at a leaf. I'm going to start out my design with the technical challenges, and I'm going to work the various systems, chances are when I start getting close to a solution, when I'm having only a couple of options now, when I'm trading, the chances are there's a paradigm existing in the natural world, at whatever scale, it might be microscopic, it might be macroscopic, it might be cosmic, right, depending what is the problem [to be] solved, that will give me a cue as to what will be the more efficient way to go, what may be the more elegant way to go.

I asked him: Do you do this by working to combine two different domains of nature, Earth and space? He replied: "There's only one paradigm, it's all the same." In light of the rest of the interview, it became clear that he was referring to a one existential paradigm for design, for living, and for inhabiting, illuminated by engagements with extremes and (in the words of Simpson's colleague Larry Bell) their conceptually and experientially challenging worst case scenarios.

In the end, after my fieldwork was over, the HDC did produce its habitability number. I put my head in mockups elaborately marked up with grids, made to get at the distances between people's bodies and the surfaces of walls and things, and to measure people's perception of roominess as a function of where they stood or sat. Gridlines for calculation recalled the work of previous space architects to develop metrics for "inhabited" versus "habitable" volume and to statistically analyze data on "sociokinesis," or group movement patterns, in order to establish the "quantifiable relationship between environmental factors and human behavior."[72] It underscored the fact space architecture contributes to a powerful modern technocratic orthodoxy of public space study and design, and also that such work can be restricted from public view, the internal JSC document explaining the HDC's number is at this time still categorized as "sensitive but not classified." Nevertheless, there is something in the juxtaposition of their work to grid out the constraints of habitability with their valorization of nomadic off-the-grid desires and dreams that makes it impossible to see their concept work as purely technocratically instrumental.[73] Space architects and their concepts travel outwards and engage with other environmental and public projects beyond JSC's gated walls.



Cricket interior © Garrett Finney / used with permission

Cricket: sensible space architecture for all

> cricket has big wheels now. not super big, appropriate big.
> 2:53 PM Aug 21st, 2009 via web
> (Twitter™.com)

I was able to "follow the concept"[74] of habitability at JSC beyond the brainstorm and the HDC when it literally got wheels, went places, and its designer "tweeted" on its behalf from a social network site creating an "internet of things." Moving outward from my foundational fieldwork data I now use contrasting material here, mock-up style, by emphasizing external perspectives rather than my own interactions with HDC architect and Cricket camper designer Garrett Finney. In shifting context and content, I'm aiming to give the JSC habitability concept some more dimensionality.

Having garnered awards and media fame making furniture for clients like small-scale-event theorist Malcolm Gladwell and on "small houses for the next century," Garrett Finney (as an article on his work declares) "brings space habitability down to earth."[75] Finney took his training at Yale (with an emphasis in blacksmithing) and, as a Rome Prize in Architecture winner and HDC consultant, decided to build an innovative camper trailer. However, Cricket was not as a "house on wheels" but "equipment."[76] Although he doesn't cite space architecture philosophers like Andreas Vogler as inspiration, Finney's habitability equipment follows Vogler's "three principles" for space design: it is mobile, autonomous, interactive.[77] Finney had detoured Buckminster Fuller's call for a design revolution into what he called a "camping revolution," and in doing so, he wrote to me once from the road, he was going "Cricket crazy." Cricket was crazy-cool, good, minimal, and all about integration. It was also a response not just to a market for vehicles, but, as he told a local newspaper, "the problems of state and national parks, the ironies of eco-tourism, and designing a 21st century sustainable campground."[78]

Finney took Cricket on what he called a "shakedown tour," borrowing the maritime and aerospace practice of doing a final structural test by putting the prototype vessel in motion. But the trip was also a way to get Cricket and its concepts out in the real "real world." With its lightness, its toy transformer-like modularity, and its insect-like silhouette, it seems to be a terrestrial concept incarnation of architect Guy Trotti's scorpion-like lunar exploration vehicle – only, Cricket exists and works. In a *House and Garden* article done while he was working on lunar habitat design, and which he brought in to the HDC when it was hot off the press, he is dubbed "the Thinker" among a bevy of

"New Tastemakers." In the article he sums up the HDC ethos: "I see the world quite differently having worked for NASA. Sustainability is certainly creeping into my work. I am very aware of what civilization takes for granted here on the mother ship."[79] A Houston news article also made sense of the Gladwell connection by explaining that Garrett was a "natural born" example of what Gladwell calls "connectors," as in people who "make linkages" and "spread ideas."[80] But Finney was also responding to his environment, Houston, as a place from which to escape, physically and conceptually:

> Why is it so uncommon to take into account the environment you are building in and adapt the building to it? While this seems obvious, it must not be, because it is clearly not done. For example, here in Houston so many houses are built with no consideration of how to keep them naturally cool. Instead, everyone leans heavily on the air conditioner instead of designing to minimize its use.[81]

Finney's airy, flip-open camper was designed to be self-cooling, or, in biomimetic terms to have a circulatory system. He demonstrates his interest in systems integration by making space design's habitability concept sensible in a publicly empirical sense, by making something spacey be "built" despite the fact that the space station table and lunar tent/habitat he designed would, it was almost certain, never be built. But some of Cricket's shakedown cruise tweets came from some out of the way places, places much less connected to outer space as a promising environment than Houston is.

Because some Cricket tweets display a kind of self-consciousness of being out of place, about feral hog warning signs and encounters with people in camouflage, I often imagined Garrett and Cricket parked at the side of the road out in Oklahoma, Missouri. There I envisioned designer and design standing both in and out of Kathleen Stewart's "space of the gap." On the one hand, the space habitability concept has been prototyped into equipment that is more than just talk or "ideas or ideals."[82] But, parked off to the side in a place very different than the Houston Heights where he launched from, his work sat in a space of ambiguity: it could be recognizable as intended or not, seen as innovative or just plain weird and not very sensible, appear as a new concept or as a rickety-looking trailer thing on a hitch. But Cricket is also meant to invite speculation about its relationship to other things, to stand alone but to blatantly negate the notion that anything stands alone. In diagrams and photos of Cricket, drawn up like a lunar habitat cutaway or photographed under trees, the little camper made me imagine a John Muir quote oft-used in environmentalist literature and websites: "When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

In this chapter I hope to have analyzed, mocked-up, and tracked habitability as an elaborating concept at JSC, from lunar habitat brainstorm conceptualization work to a concept-trailer on the road. I've been particularly interested in how the habitability concept is worked out to humanize spaces through the application of both systems engineering and space architecture ideas and processes, processes that have different commitments and obligations to processes of distinguishing spaces of experience from horizons of expectation. In lunar habitability brainstorming sessions and efforts to create metrics like habitable volume, habitability is something to be engineered by taking account of the human as a primary system. In space architecture philosophy and its ethical and aesthetic efforts to establish what habitability should begin to do and look like on any scale -- in talk about the crazy, the good, the minimal, and the integrated -- I found enthusiasm for the awesomeness of autonomy, totalizing visions of social and environmental integration, and convictions about the liberating potentials of constraints. The habitability concept helped to smooth over contradictions, fractured ecologies, the big gap between the imagined and the actual politics of survival. The habitability concept is meant to get very specific things done at NASA, but it also opens up questions about how to get a better sense of what inhabited space is in general. It aims to make use of and prevent American worst-case scenarios of limitation and contingency -- to keep integrated under one well-designed roof grand concepts such as (in one young JSC designer's words) this: the purpose of doing "what is quite possibly the most difficult thing mankind does" is to "feed the collective soul."

------//------

---

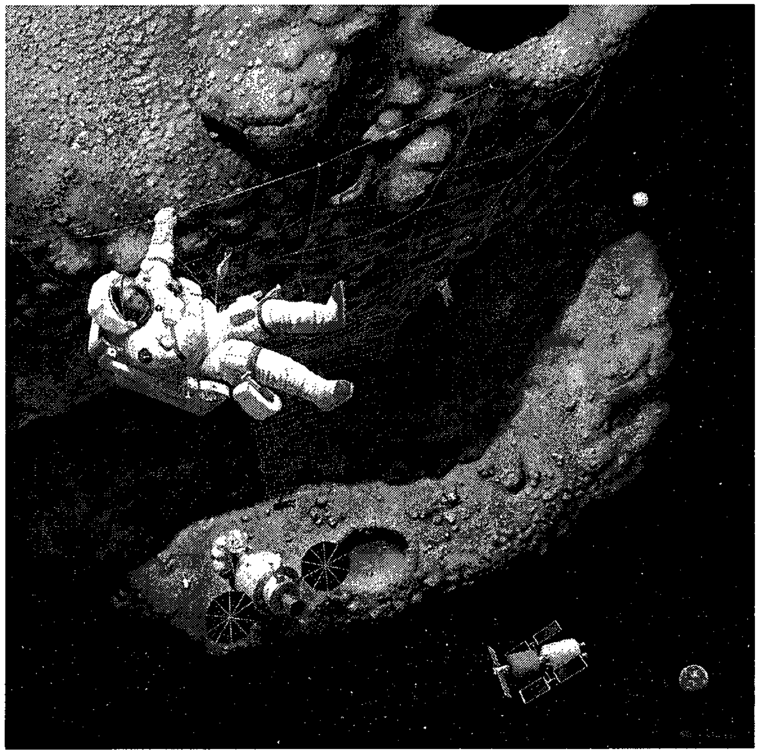
[1] Inaugural work on this topic was pursued by science and technology studies theorists of technology building (Latour 1987 and 1996), actor network theory (Law and Callon 1988), and followed through in, for example, Henderson (1999).
[2] The authors above, in complementary relationship with work on scientific and technical collaboration, conflict, distinction, categorization, and modeling [Bijker *et al* (1987), Bijker (1995), Star and Bowker (199), (Griesemer (1990)] and boundary objects and boundary work [Star and Griesemer (1989) and Gieryn (1983)], focus on the sometimes harmonious sometimes contentious multi-disciplinary work of elaborating things, categories, and actor/actant assemblages out of designs, and institutional goals and projects.
[3] Ortner (1973); she incorporates "root metaphors" from work by Pepper (1942).
[4] Koselleck (1985: 267 – 288).
[5] Fortun (2006).
[6] Rabinow (1996).
[7] Little (1999: 264).
[8] See work of Suchman (1999, 2002) on prototypes as artifacts that perform in-formation ideas, Carroll (2000) on how scenario-building of human/computer use makes "concretizable" stories about the nature of activities, uses, and functions, Godin (1997) on the imbrication of ideas of healthiness into healthcare identification technologies, and Kirby on how filmic scenario-based conceptualizations of proto-technologies and normalized uses (which he calls "diegetic prototypes") become catalysts for the making of actual protype objects.
[9] Dovey (2005: 291).
[10] Dovey (2005: 294).
[11] Henderson (1999:199).
[12] See notes 1 and 2 above.
[13] Henderson (1999).
[14] Bucciarelli (1994)
[15] See Suchman (2002).
[16] Suchman *et al* (1999).
[17] In this way, space architects are working toward making the space habitat and extreme environment habitability "prototypical" in the ways investigated in prototype theory – the theory that understanding "types" includes a process of evaluation that leads to some categorically related things to be imagined as more quintessentially "typical" than others. However, I don't force that parallel with semantic theory here, but explore how they are caught between the task at hand and their convictions that extreme habitation promotes essential qualities of design and habitation "goodness." Henderson's (1999) excellent chapter on the "political career" of an engineering prototype object does not engage specifically with semantic "prototype theory."
[18] Hitt et al (2008: 27).
[19] Vidler (1992).

[20] The "house" has a conceptual career that includes being a social category and space of structuring social relations, importantly articulated in Lévi-Strauss's "house societies" typology and Pierre Bourdieu's explanation of the co-constituting habitat/habitus, to a built and dwelled in cultural artifact. It is now a topical element in examinations of the "built environment" and "space and place" with seminal work now organized in collections and reviews by Low and Lawrence-Zuñiga (1990 and 2003). As Vellinga argues, work on the anthropology of "architecture" understood as a formal practice category and a profession is still emerging and has continued its focus on the house, but a collection of work revisiting Lévi-Strauss's work on the relationship of the house to kinship but with more emphasis on how both structure "processes of becoming" (Carsten and Hugh-Jones 1995) signal a space for broader examinations of the co-constitution of social imaginaries and house-like structures such as space habitats.
[21] In the manner suggested by Foucault (1973; 1994, 1995) and Rabinow (1995) and discussed earlier in Chapter 2.
[22] Le Courbusier (1986:95).
[23] Stewart (1996:179 – 181)
[24] Vogler (2005: 77).
[25] Vogler (2005: 77).
[26] As I indicate in the introduction, there is a whole critical sub-genre of the space age and its failures, to which also can be linked design history literature such as Sean Topham's *Where's My Space Age?* (2003) and even architecture and design literature and projects that are now reappropriating "space age" terms like "spacecraft" (see Klanton and Feireiss 2007) and "escape vehicle" (see Morsiani on Andrea Zittel 2005) for critical engagements and experiments with spatial and environmental constraints, modularity, isolation, and "hideouts" or "escape."
[27] Latour (1986).
[28] Henderson (1999: 53).
[29] NASA Man Systems Integration Standards 8.6.3.2:
http://msis.jsc.nasa.gov/sections/section08.htm#_8.6_ENVELOPE_GEOMETRY
[30] See Carroll (2000).
[31] Fraser (1968).
[32] Meleshko et al (1993:359).
[33] Showalter and Malone (1972: 26).
[34] Showalter and Malone (1972: 26).
[35] Kennedy (2009: 7).
[36] Arendt (2006); Heidegger (1975).
[37] See note 19.
[38] Gauthier's (1995:180).
[39] Sherwood (2009: 3 – 6).
[40] Henderson (1999: 107 -134).
[41] Vogler and Vittori (2009: 393)
[42] Larson and Pranke (2000: 539 – 540)
[43] Solan (2004).
[44] Bell (1991).
[45] Kennedy and Adams (2004).
[46] Adams (2003).
[47] Tresch (2007), following multidisciplinary work on this idea established in Melik Ohanian and Jean-Christophe's collected edition Cosmograms (2005).
[48] Vogler (2005: 78).
[49] Ortner (1973: 1339) lays out this schema by referencing David Schneider's explanation of American kinship (nature versus law) and Benedict's representation of tensions in the Japanese value system (chrysanthemum versus sword).
[50] NASA Man Systems Integration Standards 8.6.3.2:
http://msis.jsc.nasa.gov/sections/section08.htm#_8.6_ENVELOPE_GEOMETRY
[51] NASA Man Systems Integration Standards 8.6.2.4:
http://msis.jsc.nasa.gov/sections/section08.htm#_8.6_ENVELOPE_GEOMETRY
[52] Haraway (1991: 211).

[53] From Kosice's "Hydrospatial City Manifest" accessed at: http://www.kosice.com.ar/eng/la-ciudad-hidroespacial.php.
[54] Adams (2003).
[55] Constance Penley has argued well the reciprocal influence of Star Trek and NASA (1997), but there is clearly more interesting work to do on the appeal of different kinds of science fiction across NASA groups. People within the "space community" already understand their differences as alliances to different visions, as promulgated by New Space leader Rick Tumlinson's idea that he and his colleagues are "disciples" within a schema of "Von Braunians" (who are interested in developing a centralized technocratic and militarized infrastructure controlling human spaceflight as a specialization not a way of life), Saganites (environmentally concerned scientists who want to explore with robots) and O'Neillians (people aspiring toward decentralized space colonization and resource development projects for large populations).
[56] See note 20.
[57] Landecker (2007:235).
[58] Masco (2006: 43 – 96).
[59] Fuller (1973: 112).
[60] Quoted in *Design Feast*, http://www.designfeast.com/thoughts/index.htm
[61] Taylor 2008.
[62] Taylor 2008.
[63] Taylor 2008.
[64] Sadler (2005: 100). Archigram's and Deleuze and Guattari's "nomads" are not completely compatible, nor is it clear how they were related historically.
[65] Gelernter (2005: 2).
[66] Vogler and Vittori (2009: 399)
[67] Vogler and Vittori (2009: 399)
[68] Taylor 2008.
[69] Cook (1973:78).
[70] Abstract for Wong (2009).
[71] Hans Blumenberg (1987) writes that the Earth "mothership" is not the mothership for astronautics because it is the place from which humans wish to escape from or find an alternative for, as a way to assert the metaphysically transcendental value of the universe compared to Earth. While this argument about the illusory "centrifugal impetus of astronautics" (685) follows Heidegger's and Arendt's views of the absolute status of Earth as human place, its privilege of the experience of "turning back" as an ultimate philosophical position (685) glosses the meaningful existential experience of "inhabiting outside or alongside."
[72] Adams (2002: 174)
[73] Per note 58, a more comprehensive consideration of this work in terms of Deleuze and Guattari's work is well-warranted.
[74] Marcus (1998).
[75] Whitehead and Finney (2004).
[76] Finney (2008).
[77] Vogler (2005:78).
[78] Finney (2008).
[79] Mayer and Frieze (2008: 138).
[80] Gray (2008:1).
[81] Whitehead and Finney (2004).
[82] Stewart (1996: 179 – 183).

Chapter 4
N E O e c o l o g y

Single planet species, intelligent or otherwise, do not survive.
- NASA life scientist and "NEOphile"



Summit / © Pat Rawlings 2009, used with permission

Under contemporary Earthly landscapes made lively and smooth by time are moon-like geohistorical scapes of craters and space-rock impact debris. Houston is triangulated within such cratered areas. The arid lands of northwest Texas preserve the Odessa crater and the Sierra Madera astrobleme, or "star wound," with their wide blast field remnants. Due south is the Gulf of Mexico, where you can sail in autumn to watch meteors slash the sky to blazes. Under its waters on coastal edge of the Yucatan lies the great Chicxulub asteroid impact crater. On radar images made by oil prospectors and astronauts, the dinosaur killer's evidence remains behind like an extraterrestrial thumbprint. In a Gulf coast pub in August 2008, meteor month, evening light shoots warmly across the faces of six people who know about those sub-landscapes and their histories. They care about traveling space rocks. Not just about the shattered food chains and environments they cause on Earth, but of their existence elsewhere in the solar system as things to know and engage. The pub goers are part of a small NASA mission design advocacy society trying to pull asteroids out of ignominy, to convert their baleful image into allure – to bring us to them.

Drinking beer and eating from plates of charcuterie and cheese laid out on a dusky wooden table are a physician, a neurobiologist, a physicist, two astronomers, and me, the ethnographer. The voluntarist JSC group has convened since 2006 in bars, boats, homes, and virtually, as well as in NASA cafeterias and meeting rooms, sharing their dedication to a philosophical and technical campaign that one participant likens to that of a nineteenth century rocket club. Their purpose, however, isn't to build machines but to rebuild NASA's mission architecture. The group's network extends farther than this table, including astronauts who led the group's inaugural technical study on behalf of their goal: a federal mandate to send astronauts to a NEO – a Near Earth Object. NEOs are a surprisingly large group of comets and asteroids with Earth-crossing orbits, and the threat of NEO impact has become a matter of concern and disputation among scientists and technologists as well as risk-management policy experts. Despite NEOs' bad reputations, the people I'm sitting with call themselves NEOphiles. "NEOphilia" is more than an epistemological devotion to an astronomical object; it is an ontological commitment, technical and visionary, to a drastically re-imagined human environment and ecology.

In the media the NEOphiles[1] are called "an asteroid underground," "rebels," a "small band of believers;" within NASA they are labeled "a distraction" or "heretics" who threaten NASA's lunar-return architecture. One of them, engineer-scientist Rob Landis, summed up for me the physical, temporal, and transcendental dimensions of his commitment:

> I think this work is most important. It feels like a calling (like when I went to the Air Force Academy -- only bigger, much bigger)...the message that comes ringing loud and clear through all the bureaucratic nonsense and clutter is: use these unique astronautical tools to 1) explore the solar system via NEOs, 2) disperse ourselves, or 3) go extinct.

By late 2009, the NEOphiles' cause was gaining ground. NASA's costly lunar base plan appeared unjustifiable and going to an "old" rather than new world was unpopular. In contrast, attention to NEOs was being fueled by government-funded detection surveys, media reports of close NEO fly-bys, and science fiction catastrophe movies. As the NEOphile campaign also makes clear, asteroids continue to inspire theorizations about their part in "seeding" and shaping the course of Earthly life, with their latest proposed role being to replenish Earthly raw materials or to serve as resource depots to fuel deep space access.

Whether or not the "NEO option" becomes an actual mission, NEO activism in the aughts reveals much about the heliospheric imaginaries and politics of American astronautics. NEOs have garnered attention precisely because they are "boundary objects" of the sort now conceptually familiar to social scientists of science and technology. In keeping with Susan Star and James Griesemer's original theorization of boundary objects as things that consolidate "institutional ecologies,"[2] NEOs align diverse disciplinary practices and strategic agendas in ways that bolster institutions like NASA and the US military as well as international networks of NEO scientists and interest groups. In most analytic deployments of Star and Griesemer's useful construct,[3] however, "ecology" *per se* takes an analytic backstage to the object(s) in question and boundary work they focus, remaining tacitly understood as institutional or as a given space of associative interdependence.[4] NEOs, on the other hand, bring questions of boundaries and environments to the fore. Attention to what NEOs are and what they do aligns expert activities in ways that rescale given human ecologies and associated understandings of evolution.

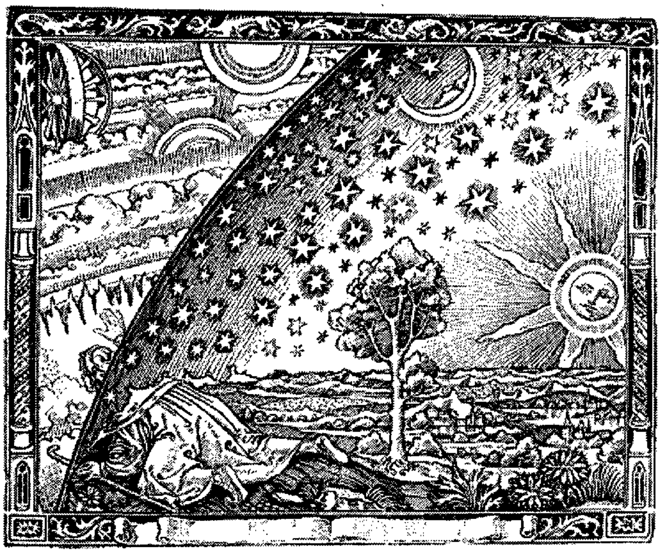
In this chapter, I use my experience among the NEOphiles to track NEOs as extreme environment objects that are not only cosmological but ecological *boundary objectifiers.* By "objectify," I refer to forms of modern epistemological consensus that make facts and perspectives communicable and shared: that is, processes of reasoning, calculation, and characterization that, as historian of science Lorraine Daston argues, are made to appear universal and free of idiosyncrasy.[5] The cosmic objects that NEO activists want their audiences to recognize as both threatening and available occupy the inner solar system but are linked to Earth and the human species – to distant pasts, to outermost environments, and through expert foresight, to uncertain but hopeful futures. Of course, "objectify" also connotes acts of dehumanization or the immoral treatment of subjects as if they are objects, but as Martha Nussbaum has recently suggested in her essay on the conditions of human objectification, there is much to be learned by examining how inanimate objects are "objectified" – including, among other factors, how ideas about their "instrumentality" (usability), "boundary-integrity," "violability," or "autonomy" are constituted – sometimes in ways that "urge us" to "think differently about parts" (or in this case wholes) "of the natural environment."[6] NEOs are objects that call attention to the continuousness of spaces and the ways that boundaries should be understood, and urge revised assumptions about the discreteness of solar system objects, sites, and processes.

Through technically and socially elaborated attention to NEOs as cosmically near/far objects with life-impacting boundary crossings comes new quantitative and qualitative representations of a human environment bounded at a new *upper* limit: the heliosphere. As material and conceptual boundary-crossers, NEOs are being made to objectify, like no other planet-like objects, an ecological heliosphere in which Earth inheres. As with other NASA practitioners, the NEOphiles refer to "environments" rather than "ecologies," but in their explanatory models of the human/environment relationship they take a perspective akin to ecological determinism by objectifying key forces of that relationship. These objectifications formulate a human/space relationship that spans the atomic and macro-systemic, the prehistoric and the futuristic, the technical and the prophetic. In astronautical conceptions of this deep space ecology, human evolutionary progress is contingent upon moving from a passive to active engagement with heliospherically scaled space, dynamics, energies, and materials. I present here key heliosphere-bounded calculations and characterizations being made at the intersections of contemporary activities centered on NEOs. With respect to the trajectory of this dissertation, this is the heliospheric ecology being constituted through space analogue argumentation, optimizations of space biomedical ecobiopolitics, design quests to define the concept of habitability.

I begin by discussing how NEOs became a part of a detected solar system environment, scientifically and socially, providing the grounds for NEOphile reasoning and action. Following astronomical and geological discovery processes that ended up linking them to planetary catastrophe, NEOs became simultaneously perceived as astronautical destinations and "natural hazard" deflection targets for interdisciplinary risk-management. I illustrate how these perceptions solidify into parallel projects of environmentalist action through two American-initiated NEO informational and policy movements. First is the international Association of Space Explorers' United Nations petition to organize a NEO deflection and impact mitigation project as a futuristic environmental policy. I chase my discussion of this with a report from the "asteroid underground:" the NEOphiles' traveling presentation to promote their "crewed mission to a NEO" study. As the NEOphiles remake NEOs from threatening objects into objects of astronautical discourse about how to preserve and enhance human evolution, they create a narrative about the co-evolution of astronautical tools and a human species. As if providing an answer to claims that it will take multiple Earths to sustain American forms of prosperity, the NEOphiles depict an open field of extraterrestrial resources that can preserve American ideals on multiple fronts, from extrepreneurialism to national security to the essential humanness of engaging in extreme struggle. The NEOphiles' sense that there is a social as well as evolutionary drama playing out in their mission concept advocacy casts NEOs as ecological "fear"[7] objects that make more technoscientifically objective what Kathleen Stewart and Susan Harding have analyzed as the American apocalyptic/millennial sensibility[8] of human struggle, salvation, and sustainability -- connecting the fate of NASA as an institution with humans as a species.

Another goal I have here is to foreground the spirited life of an astronautical study. Both forms of NEO activism I describe in the chapter are organized around "white papers," documents that establish a technical proposal. NASA "Phase I" studies, like the one that launched the NEOphiles, are both legendary and notorious things within the agency, wherein they can end up languishing in hard drives or lining office walls, as I describe in Chapter 2, or propagating follow-on studies that establish new projects or programs. The physicist and space exploration advocate Freeman Dyson famously ascribed NASA's contemporary loss of innovative agility to a culture divided: there is a visionary and risk-taking "paper NASA" in which "adventurous on paper" innovation supports far future visions. In Dyson's view, "paper NASA" cannot compete with the "real NASA."[9] "Real NASA" is the "intensely conservative" and risk-averse side of the agency dedicated to preserving bureaucratic and political structures like the Shuttle and Space Station programs -- the "bureaucratic nonsense" that irritates NEOphile Rob Landis. By showing how such a boundary is both important to cultural imaginaries of how the agency works within NASA but also its artificiality, I aim to give "paper NASA" a measure of realness here, and to show that, as Joan Fujimura describes in her study of future imaginaries among genomic scientists,[10] the collective imagination and action that NASA studies inspire are not separate from technoscientific actuality.

"Paper NASA" activities also indicate how technocratic narrative production is not monolithic but shaped by alternative narratives about why, how, and where to "get into space." Leaving aside the fact that it would be possible to argue that NASA *mostly* produces documents, I would revise Dyson's idea: competitive frictions between "paper" and "real" NASA are *actual* NASA.[11] In the case of the NEOphiles, "paper NASA" fosters an internal critique of real NASA that is, as is the NEEMO analogue program, driven by concerns about the agency's future as well as how to protect at-risk American values and lifeways based on imagining environments as materially and transcendentally prospective. Out of this critique come proposals for politics and economies of survival, freedom, and optimized humanness that are informed by technical theorizations of the environmental and ecological.



Un missionnaire du moyen âge raconte qu'il avait trouvé le point où le ciel et la Terre se touchent...

Engraving by astronomer and comet-hunter Camille Flammarion for his book *L'atmosphère: météorologie populaire* (1888)

"Not your father's solar system:" new objects, detection regimes, and the remaking of boundaries

In the 20th century, accepted notions of what constitutes the "solar system," in astrophysical dynamical and planetary geological terms, were coming undone. Unraveling was an orderly Copernican solar system fabric made up of an empty space ruled by planets, ordered by orbits, resolved of primordial chaos, and within which the Earth abides as a separate and unique kind of place. What exactly outer space was made up of remained a problem of debates between vacuists and plenists, but the celestial mechanicists of the early 19th century eschewed the Cartesian proposition of a matter-filled space full of resistance and focused on the Newtonian notion of a vacuum-filled space in which orbits reflect calculable and observable laws of force and motion. They were sure that calculative anomalies in the Copernican solar system model would be reconcilable as the missing planets were found, but the increasingly powerful astronomical observing technologies and techniques used to resolve these problems turned up new problems in the form of a solar system full of non-planetary objects and matter. What emerged was a post-Copernican solar system full of matter in motion that required understanding that the Earth obtains in an environment that is neither sedate, predictable, nor separate from it – one that required surveillance as much as contemplation.

The appearance of non-planetary bodies in the nineteenth and mid-twentieth century herald a regime of "detection" derived from practices of astronomical observation, calculation, and classification. Science studies scholar and biologist Hans-Jörg Rheinberger has described laboratory experimental systems as the "smallest integral working units of research"[12] and their purpose as materializing new questions and "epistemic things" that can re-make ways to know research objects and situate them contextually. Astronomical observational systems do this as well, elaborating new techniques for detection and cross-disciplinary data sharing that bring to light new objects, events, processes and especially new kinds of cosmological orders and contexts to be accounted for and characterized. "Detection" regimes slip easily into modes that merge the notion of becoming aware with the engagement of mysteries, the interpretation of matter out of place, and even the solving or prevention of crimes. The observation of non-planetary and non-cometary objects and eventually a ninth, unruly planet materialized new kinds of boundary crossings, both environmental and disciplinary, that eventually coupled observation with detection practices, putting asteroids and comets into the category of things not just to be watched or reacted to but to be watched out for.

Orbital disorder

Between 1800 and 1930, astronomers with telescopes worked to correct two disturbing problems of orbital harmony. To detect the planet that must occupy the geometrically disorderly gap between Mars and Jupiter, the late eighteenth century Vereinigte Astronomische Gesellshaft ["United Astronomical Society"] set up a "Celestial Police" that included William Herschel, Charles Messier, and Johanne Bode, whose astronomical rule it was (now ruled coincidental by astronomers) that required a planet to be there. In 1801 a non-member of the Police, Italian astronomer Giuseppe Piazzi, sifted through evidence to track down a "minor planet" called "Ceres" that seemed to satisfy the problem. In 1930, American amateur astronomer Clyde Tomball discovered the so-called "Planet X," the mysterious and hidden entity that must be perturbing Uranus's orbit. However, stronger telescopes and new observing regimens continued to turn up ambiguous-looking and behaving solar system objects.

In the late 19th century, comprehensive observational star charting and the introduction of long-exposure photography century for capturing light from the distantly strange and beautiful "Messier" objects, later identified as galaxies and nebulas, revealed tiny, moving, but non-planetary objects of indeterminate origin and orbit. On photographs they appeared as unlovely smears. These were the overexposed motion trails of objects soon to be known, because of their numbers and out-of-place appearance, as the "vermin of the sky.[13] German astronomer Maximillian Wolf's "blink stereomicroscope," which juxtaposed two photographs of a section of the sky so that the eye could flicker between them to discern differences of location and brightness that indicated motion, allowing astronomers to detect rather than directly observe these "asteroid" or moving "star-like" objects and to then systematically catalogue them, although such traveling objects were not immediately assumed to be related to meteorites.[14] Clyde Tombaugh also used this blink technique to image far-away Pluto, imagined to be a large object with gravitational power. Eventually, its confirmed smallness and oddly canted orbit that at times fell inside Neptune's ended up disqualifying it as a serious planetary perturber, and eventually, as a planet at all. From the mid-twentieth century to the present, the neatly defined properties and parameters of a sedate solar system were being recalculated and re-characterized to include problematic objects.

Astronomers of the mid-twentieth faced a solar system with unstable outer objects, an unknown boundary, and new classes of objects, both visible and theoretical, which vastly outnumbered planets. From the mid 19^{th} century, astronomers had catalogued asteroids they referred to as occupying, with the "planet" Ceres, a "belt" between Mars and Jupiter. In 1950, the number of catalogued asteroids topped 2,000 with 54 identified as outside the main belt region, and new searches were on for a "Planet X" that must exist beyond Pluto. In trying to account for the newly documented speed and behavior of comets, Dutch astronomer Jan Oort argued for the existence of a "cloud" of comets with long-term orbits at a distance of 20,000 astronomical units (1 AU is the distance from the Earth to the sun) in 1950. In 1951 Dutch-American astronomer Gerard Kuiper theorized that primordial material from the early solar system should exist past Pluto, as far as 50 to 100 AUs, consisting of an estimated 10^{12} small objects that never coalesced into one planet. The search for "planetoid" objects beyond Pluto resulted in the definitive discovery of a "Trans-Neptunian" space and class of objects (TNOs), into which Pluto was installed as a TNO "dwarf planet" in 2006. The path from Pluto's discovery to its "demotion" from planet to dwarf planet reflected a shift, as Lisa Messeri has recently argued, from commonly held astronomical and public agreements about the nature of the solar system and the idea of a "planet." Disagreements on what counts as a "planet" – orbital characteristics vs. shape and composition? – created a fractured classificatory model, with dynamicists and morphologists trying to reconcile their particular kinds of data. In the end, "planets" emerged as rare, orderly, and geologically complex and other kinds of objects as prolific, disorderly, old, and simple and "primitive."[15] When "planet" was redefined and Pluto was reclassified, the IAU also divided the broad category of non-planetary "small bodies" into two groups: dwarf planets (the TNOs Pluto, Haumea, Makemake and Eris and the large asteroid Ceres) and "small bodies" (the remaining TNOs, asteroids, and all comets).

Today, small bodies are ubiquitous. At the time of this writing, the number of registered small bodies totals over 400,000, and they continue to be detected and comprehensively sub-classified according to locations, morphologies, and orbital behaviors that put them all over the place. Between the late 19th and late twentieth century, astronomers had considered and dismissed theories that the asteroids of the asteroid belt were simply the remains of a broken up planet, determining instead that all the small bodies of the solar system were captured bits of early, undifferentiated solar system matter moving around over time. All small bodies had been and were being pushed and pulled by interaction with each other and planets and set in motion through collision with those objects and each other, and, as a result, they continue to be subject to becoming dislodged and creating new collisions. This characteristic informed the International Astronomical Union's 2006 declaration that "small bodies," as opposed to planets, have not "cleared" their orbital neighborhoods of most threats. Indeed, the spatial boundary of an individual small body within over the duration of the heliosphere's existence is, conceivably, the whole heliosphere. Unlike planets, small bodies could be threats.

To muddy the heliospheric waters even more, the contemporary IAU definition of "small bodies" could technically include meteoroids of vanishing smallness, suggesting the image of a heliosphere criss-crossed by material in motion that is not observable and extremely hard to detect. Boundary crossing "small bodies" of all sizes are thus not only "fossil" remains of solar system formation and the forensics of collisionary action; they provide contemporary evidence of a still-active solar system and inscribe, with their orbits and presence, the heliosphere's dynamic material space.

All told, the astronomical imaginary of a serene solar system gave way to imaginaries of a space that is more or less orderly and more or less material. This re-imagined solar system ended up precipitating the 20th century's attention to past, contemporary, and future processes of planetary and small body impact and collision. In addition, the boundary between Earth and space gained a new temporal and spatial permeability, illustrated as an aesthetic argument in the 1888 woodcut by astronomer Camille Flammarion (see above). That boundary is both calculable as an artifact of atmospheric attenuation and imaginable in social and cultural terms, opening the question of what such a permeable boundary means in calculations of natural risk and models of ecology based on nested and extending spheres. Also attenuating since the late nineteenth century were disciplinary boundaries between astronomy and other sciences, that came together exactly over efforts to define and know ambiguous boundary spaces like atmospheres and mysterious features like craters.

Small bodies and an extended ecosphere

Along with twentieth century astronomical efforts to catalogue, classify, and track the prolific non-planetary objects now known as "small bodies" came parallel, and eventually interconnected, astronomical and geological theorizations about the existence and role of cosmic collisions in planetary and biological history. Earth's own history and future became subject to comparative reasoning about the ecological boundaries of life's beginnings, ends, and extensibilities. From the mid-century onward, asteroids became objects of astronautical theorizations about an environmentally active terrestrial near-Earth space, a zone of extended ecological risk and speculation.

Sightings of meteors and comets and the use and collection of meteoric material on Earth have a long history, but until the late nineteenth century, astronomers and geologists didn't have or seek evidence to associate meteoritic and cometary Earth-crossings with significant geologic features or events. This was in part due to the conditions of evidence. As a geological and biological active planet, most of Earth's large impact craters are hidden by water, erosion, or growth. Any Earthly crater formations, and those subsequently located on other planets through telescopes, were interpreted as originating in a planet's own geology, and usually as volcanic. In 1876, British astronomer Richard Proctor suggested an unpopular "impact model" of lunar crater creation. This idea was reanimated by American astronomer Grove Carl Gilbert in

1892 and later by mining geologist Daniel Barringer in the early 20th century, both of whom were captivated by Arizona's Coon Mountain – later renamed Meteor Crater. In 1907, the fears of publics and astronomers like Flammarion (who wrote a history of the Earth from Halley's comet's perspective and two books on comets as spiritual messengers[16]) that Halley's comet would bring dangerous gases or "impregnate" the atmosphere and "snuff out" all life were marginalized as unscientific superstition.[17] However, the mysterious Tunguska Siberian impact "event" of 1908 called broader attention, despite lack of a crater, to the prospect that atmosphere-crossing cosmic objects could be large and environmentally destructive. Non-endogenic geological events were not just historical but could happen now. Attempts to understand collision evidence brought together disciplines that eventually constituted formal collaborative forums and spaces for what became "planetary science."

By the mid-twentieth century, astronomical evidence for a small-body filled and disrupted solar system emerged alongside new geological arguments that the moon's craters were largely the result of impacts. Major proponents of the lunar impact theory were German geologist Alfred Wegener and American geologist and oceanographer Robert Dietz, early and mid-century theorists, respectively, of a continentally "drifting" and shattered Earthly surface and subsurface world. In 1953, the journal *Meteoritics* further institutionalized, via scholarship focused on the boundary crossing consequences of meteorites and the opportunity to investigate non-terrestrial material, the new interdisciplinary domain of planetary science (the journal later became *Meteoritics and Planetary Science)*. These cross-disciplinary interactions were steps toward breaking barriers to the production of comparative and generalizable knowledge about the Earth and other planets, signaling the appearance of what Peter Galison calls "trading zones" [18] for astronomy and geology. Along with concepts like "planet,"[19] this zone shared the terminology and data of "detection," "collision," and "impact" to analyze and argue with.

"Astrobiology" was another emerging 1950s disciplinary hybrid within which comets, meteorites, and impacts provided theory-building material in the effort to detect life or its signs beyond Earth. Since its beginnings, astrobiology offered interested life scientists an opportunity to theorize about how the most extreme environmental and spatial boundaries might be relevant to a planet's, including Earth's, biological processes. In 1958 a Lowell Observatory astronomer who also worked at RAND introduced a 1958 book of collected papers from an interdisciplinary conference, *Problems in astronomy and biology*. He praised the trend in productive "de-specialization" pioneered by meteorologists, astronomers, and nuclear physicists collaborating on problems they increasingly recognized as common.[20] NASA aerospace physician Hubertus Strughold wrote the collection's keynote review of these shared problems. Strughold, who was interested in both the burgeoning field of ecology and the implications of astrobiology for aerospace biomedical work, declared that

> Actually the scope of the problems common to astronomy and biology is much bigger when we include human physiology in planetary ecological considerations and the human factor involved in astronomical observations.... Astrobiology is actually ecology, and extends geographic ecology into a general planetary ecology....An approach to the question of life on other planets in our solar system, from the standpoint of general physical ecology, leads us to a zonal aspect.[21]

In considering the relationship between the domain in which to detect extraterrestrial life and in which terrestrial life can be supported, Strughold takes on the question of how to think about ecological boundaries.

Strughold invokes as the best descriptor of life's ultimate environmental boundaries a neologism introduced that very year by ecologist Lamont C. Cole: *ecosphere*. Strughold imagines calculating the perimeters of an intra-solar systemic "belt" that would satisfy the requirements for a local life "zone," based on requirements that water can be liquid, radiation can be mitigated, and photosynthesis can occur. This would constitute an "ecosphere" of material and dynamic systems within which Earth occupies a habitable sweet spot and Mars and Venus sit at the "ecological fringes."[22]

By the early 1960s, futurists working within NASA research networks incorporated the growing body of detected asteroids into visions of extendible human ecologies and ecospheres. Among the most productive and philosophical of these was a General Electric employee and NASA Geminii program rocket engineer, Dandridge Cole, a Swedenborgian school educated grandson of a Swedenborgian bishop who wrote several treatises on the potential military, colonial, economic, and, "ultimate" evolutionary uses of "planetoids" and asteroids. Attempting to look, as one of his book titles declares, "beyond tomorrow" as Earthly "living conditions implode around us,"[23] Cole subscribes to the commonly held astronautical assumption that spaceflight is a developmental maturation of the human species. However, Cole's technical theorization of the future of human evolution is based on two assumptions about biological and social evolutionary limits: both the modern human body and contemporary centrally governed capitalist societies with their specializations and complexities had reached their "ultimate" forms. The only evolutionary option for human beings is to externalize their internal biological complexity and spatially internalize social complexity to make it manageable. He called this process "Macro Life."[24] Cole explains that the ongoing development of closed loop ecological macro life systems on Earth (at General Electric, for example) and even the enclavist social experiments of "religious fanatics" (which should be encouraged as legitimate "sociological" and "civil defense" "experiments" and not penalized)[25] will eventually enable small human units to enclose themselves inside raw material-rich asteroids and extend into space, allowing for the continued reproduction, dispersal, and interconnected development and growth of human society. Cole declared this to be both the next logical stage of multi-cellular life and the "extreme example of the ultimate human social organization toward which evolutionary trends have been pointing for millennia," where some trends are "as old as life" and some "as old as the universe itself."[26] What then continues to evolve off-world is a temporally and spatially boundless human techno-social body that Cole distinguished as the "Astro Life" version of Macro Life. Astro life will be tasked with the problem of sorting out the next stages of "efficient" political "freedoms" through the success or failure of self-contained social and ecological "pilot models" that contend effectively with "environmental forces" and permit reasoned "prophecy" about better ways to live.[27]

Cole's Macro Life concept emerges as another kind of astrobiological theorization of human biological and social evolution, based on taking advantage of asteroids as manipulable and mobile resources – miniaturized versions of Spaceship Earth. Interlocutors I worked with may or may not have been familiar with Strughold or Cole, and in fact the NEOphiles were not familiar with Cole until I called their attention to him, but people doing NASA technical studies turn up such authors and their ideas during the course of bibliographic searches for technical papers proposing new concepts and designs. Within NASA, old ideas persist and re-enter discourses. As I argued in Chapter

2 and Chapter 3, I found broad tacit understandings among NASA interlocutors that (in Strughold's words) "astrobiology is ecology," that there is a broadly life-relevant heliospheric "eco"sphere, and that, as a correlative, human ecology is not bounded by Earth's atmosphere but by the circumstances and technologies of habitability. I found these tacit understandings to be key elements an implicit, explanatory cosmological model common to space life sciences practitioners as well as engineers, astronauts, and technologists working with environmental life-support problems and systems. For both NEO impact and mission activists, the scalable ecospherical concepts that asteroids validate through anthropocentric interpretations of their threat or potential are the basis for a heliospheric ecological model that goes without saying.

Lucky stars

In 1981, a watershed planetary science publication in the journal *Science* sketched for a broader public sphere the outlines of a NEO-illuminated heliospheric ecology by offering a definitive solution to a mystery that bridged the boundaries of astronomy, geology, *and* biology. What was the relationship between a thin band of sediment occurring at 65.5 Ma (mega anum, i.e., millions of years ago) and the mass animal and plant species extinctions that mark the boundary between the Cenozoic and Mesozoic eras? The answer presented not just a case for the existence of a grand cosmic impact on Earth, but the beginning of scientifically acceptable theorizations about the historical ecological *roles* of those impacts. Physicist and Nobel laureate Luis Alvarez, partnered with his geologist son Walter and two scientists in the Energy and Environment Division of the Lawrence Berkeley Laboratory, found that the boundary sediment in question contained an unusual abundance of iridium, 6.3 parts per billion, which indicated an extraterrestrial origin.[28] Using data from the Krakatowa volcano eruption and astronomical estimations of size range among the detectible "earth crossing asteroid" population, Alvarez and colleagues concluded that a 10 ± 4 kilometer asteroid must have impacted Earth at that time, creating, besides local catastrophic damage, atmospheric disruptions that stopped photosynthesis, disrupted food chains, causing widespread extinctions. They suggest also that other passages of extraterrestrial material through the Earth's atmosphere, such as cometary ice, might have been other extinction event boundary-makers.

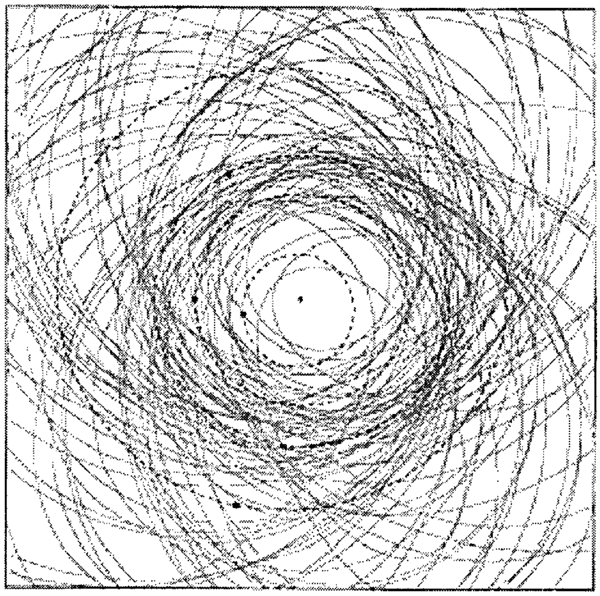
Astrobiology's origins as a way of theorizing and detecting the existence of life on other planets later became, with NASA's controversial 1995 announcement that a Martian meteorite contained fossil organisms, a way to theorize a cosmic "panspermia" in which life travels via space rocks.[29] In my discussions about this event with a senior planetary scientist at JSC, he indicated that the NASA announcement of prebiotic fossil "life" in the ALH 8001 Martian meteorite was made with scientific hopes but also with political hopes of boosting the agency's funding troubles during the Clinton administration.[30] In this way, the meteorite straddled the political boundary between President Bush Sr's failed first lunar return plan of the early 90's and the agency's future uncertainties. Lately, astrobiologists are refining the "panspermia" concept through experiment and theory. The conditions of "lithopanspermia" (panspermia via meteorite transfer) were tested in an attempt to replicate the survival of microorganisms on an simulated "host planet,"[31] and panspermia has taken on a less gender-laden but more religiously evocative label, "exogenesis," that simultaneously highlights distinctions between indigenous and alien life but also expands the space of a biologically rich and ecologically interconnected "creation." The exogenesis theory includes speculations that it wasn't intra-solar system meteorites but interstellar comets that "seeded" life on Earth. In advance of a paper to be published in *Meteoritics and Planetary Science*, "Stardust" mission Principal Investigator Don Brownlee announced that the first sample return from a comet's tail ("Wild 2") contained the amino acid glycine, possibly indicating that "some of life's ingredients formed in space."[32] Keeping in mind that comets travel from the edges of the heliosphere and may have been captured from interstellar space, a broader life-relevant "space" opens up. With data to drive exogenesis speculations comes a challenge to classical *de facto* Darwinian abiogenetic and ecopoetic models for life's beginnings. All of this provides a way for astrobiology and planetary science to move beyond boutique status to become fields that claim authority about life at spatial and temporal extremes. The subtitle of 2003's *The life and death of planet Earth* by paleontologist Peter Ward and Brownlee extends this authority to knowledge about life's ends: *the new science of astrobiology charts the ultimate fate of the world.*[33]

Alvarez *et al*'s work has withstood criticism and stands as a generally accepted explanation for "the end of the dinosaurs," spawning not just other attempts to link impact events with biological catastrophe but also to view Earth's interaction with extraterrestrial material as something other than totally inconsequential or grandly momentous.

NEOphile and physician Seth Jackson alerted his colleagues to one such new explanatory model of Earthly evolution in a cosmic context 2008. He emailed to the group an article from *Nature* that cites a controversial new theory by a team of Swedish geologists that aimed to synchronize: astronomical and geological evidence of a solar system "late bombardment" period around 400 - 300 Ma, geological evidence of abundant meteorite fragments, and the jump in biological diversity visible in fossils from the Ordovician Period. The theory claims that this bombardment caused new species to emerge from pressures to adapt and survive.[34] Scientifically contested evolutionary ideas like this make it into the space community press, to such websites as Space.com, which asked in an article in 2001: "Were those who came to travel to the Moon and ponder their very origin the logical and inevitable victors in the most important of all Darwinian struggles? Or did we just get lucky?" The article, called "Reinventing Darwin Again,"[35] features the anti-"'Neo-Darwinist" claims of a UK social anthropologist and computer scenario programmer (a Planetary Society "volunteer") who claim that impacts "guided" human evolution by giving *homo sapiens* the "cosmic luck" needed for their genetic "adaptive advantage" to flourish in a changed post-impact climate. In theoretical arenas like this, prickly debates started in the nineteenth century about the relative importance of gradual or catastrophic change in biological history continue, enhanced by contemporary attractions to the profound sublimities, game spaces, and generativeness of extremity. Interactions between Earth and the rocky inhabitants of extreme space are viewed as agonistically life-enhancing rather than just threatening. This is the kind of claim that inspires NEO-centered theories about what collision-prone asteroids and comets can do if they are controlled -- the ultimate spatial act of environmental mastery.

As asteroids became known as the solar system's hostile and generative "primitive bodies," their material primitivism and disorderly behavior became a target for astronautical efforts to detect and calculate their prospective economic value. Soon after Alvarez *et al*'s article, the 1983 IRAS (Infrared Astronomical Satellite) mission began to return systematic spectral data on 1811 asteroids, confirming ways to classify them according to their composition. These classifications are determined by the analysis of asteroid "albedo" (reflection): metallic, silicate, and carbonaceous. Using such data, University of Arizona planetary geologist John S. Lewis used these data to generate speculations about asteroid material trade value. His claims followed on 1960s asteroid resourcing speculations exemplified by Dandridge Cole's dramatic claim that it would be possible to extract "$50,000,000,000,000 from the Asteroids" and solve the space program's budget woes forever.[36] Lewis became in the 1990s a spokesperson for commercial asteroid mining, arguing that evidence of pure undifferentiated metals promised "untold riches" that would finally justify space exploration.[37] Such predictions perpetuate the colonial lure of the pure primitive as a resource for social engineering, this time of a purely non-living primitive body. At space development conferences and in speaking with NEOphiles, I heard acknowledgements that asteroid mining might create untold inequalities as a consequence, but, as with many social sticking points in the astronautical hybrid of technical and romantic objectification, this problem was framed as a new challenge for humans along the road to an inevitable future – a challenge that other people will have to solve. As with enthusiasms for harnessing cosmic energy from the moon or space, asteroid mining proponents view the terrestrial incorporation of cosmic wealth as a kind of manna that is in theory available to everyone, spreadable like the perpetual shower of cosmic dust that bombards Earth (after all, iridium is a form of platinum). NEO wealth is imagined as a way to transform global wealth ecology and improve its systemic baselines and boundaries, as if an extraterrestrial source of wealth might be objectively different, tinged with heavenly meaning and pointing to providential progress, "lifting," in the words of one advocate I heard at a conference, "everyone up."

Despite late twentieth and early twenty-first century circulations of subtly positive and hopeful astronautical theories about small body-Earthly interaction, impact threat remains the topic that garners the most attention across scientific and social boundaries. The evidence of interstellar rock and dust accretions on Earth, of prolific solar system bodies with disorderly orbits, and of craters on planets and moons all signal the contemporary existence of serious meteoric and cometary threats. With Cold War policies for military-industrial technology expansion came accepted assumptions that national security and weapons development required and enabled the capacity to expand spatially and temporally, and asteroid and comet impact threat mitigation was identified as a prospective investment site for multidisciplinary and multi-institutional collaboration. With the cataloguing of asteroid and cometary orbital behaviors and theories about the history of an impacted Earth came projects to calculate the risk variables and develop the technologies necessary to manage a future impact-threatened Earth. Starting in the 1990s, popular scientific articles about asteroid and cometary threats often contain generation-boundary observations that "it's not your father's solar system." Another frequent opener is: "Earth exists within a cosmic shooting gallery." A boundary between heliospheric perception and planetary protectionary action was being bridged.



Inner solar system and orbits of 100 largest known NEOs (1992)'
Courtesy NASA (R. P. Binzel)

"In a cosmic shooting gallery:" NEOs and the risk ecosphere

With interdisciplinary data sharing and theorizing, astronomical and geological characterizations of Earthly asteroid impact risk gained new calculative dimensions. Data on historical craters continues to accumulate, and sustained scientific and political impetus to conduct asteroid surveys yields continuing evidence of a larger than previously imagined "small body population" occupying the inner solar system, within which are many with Earth-crossing orbits. What emerged at the turn of the twenty first century is a growing class of asteroids and comets known to increasing numbers of people as Near Earth Objects, some now even known publicly by name. NEOs have characteristics that are not just astronomical or geological but useful for making headlines as well as social predictions and policies, setting the parameters for a terminological and data trading zone about heliospheric risk. This zone includes academic astronomers, geologists, biologists, as well as the military, scientific and security arms of government institutions like NASA and, now, impact activist groups.

In 1991, JPL asteroid astronomer Don Yeomans wrote an article for the Planetary Society's journal *Planetary Report* called "Killer rocks and the celestial police" that re-defines the solar system's small bodies as murderous and elevates the historical "celestial police" role to the level of a global threat surveillance service.[38] The contemporary celestial police, exemplified today by an animated searching eyeball graphic on JPL's "NEO Watch" website, do not just observe but monitor the cosmos for threats to Earthly environmental and social order. This is an Earthly order with radically re-imagined spherical boundaries that matter to nations and international relations. These boundaries include zones of human-made orbital debris but also extend in theory to the comets of Oort cloud and beyond, where life-threatening interstellar neutral hydrogen atoms push into the heliosphere when it passes through clouds of galactic clouds. This is an environmental sphere that environmental sociologist Tim Ingold claims does not exist anymore when he critiques the alienation inherent in environmentalist discourses about a "global environment."[39] He claims that discourses about the "global" environment encourage a sense of perceptual detachment from a superficial globe-object, a perception he exemplifies by describing how the orbiting astronaut's gaze displaces the Western early modern and still existent non-Western understanding of human environmental existence that inheres "within" a space. This assessment ignores a subtle yet persistent political traffic in astronomical and astronautical spherical environmental theorizations. The sense of existing "in a cosmic shooting gallery" manifests one such environmental sphere.

In this section, I describe the emergence of NEO surveillance and policy regimes that are formalizing both the terms of Earthly planetary risk and the extreme spatial and temporal boundaries of a NEO-human relationship. These are the terms with which NEO activist groups engage the problems of impact as well as the potentialities of exploration.

Crossing into policy

During the nineteen fifties, astronomical and geological scientists interested in small body behavior and impacts began routine data sharing and interaction with Cold War era nuclear test scientists and human space program lunar reconnaissance surveyors. The long career of "astrogeologist" Gene Shoemaker illustrates these productive boundary intersections. The Alvarez impact theory team, the B612 Foundation, and the NEOphiles all had professional connections with Shoemaker before his death in 1994. In the manner of memorializing scientific knowledge and practice geneaologies as patrilineal, Shoemaker is the acknowledged "father of planetary geology and a NEOphile referred to Shoemaker as the "godfather" of what would become contemporary impact theories and deflection planning. When he started work for the US Geological Survey in the late nineteen fifties, Shoemaker compared the structure and mechanics of craters caused by meteorites with nuclear explosions. He was also aiming to become the first geologist on the moon but was preemptively disqualified for having Addison's disease. Dedicated early on to the idea that impact was a fundamental force in solar system evolution, Shoemaker founded the 1973 Planet-Crossing Asteroid Survey at the Palomar Observatory that would become the model for tracking "near Earth" planetary crossing objects. During the early nineties, the group of objects known as "earth crossers" became formally known (although my interlocutors do not agree about precisely when and how) as "Near Earth Objects," officially opening the door to inclusion in that definition long-period comets from the heliospheric edges and even the host of human-made objects stretching from low Earth orbit to geosynchronous satellite space.

In 1992, Shoemaker sat with Edward Teller, the father of the H-Bomb, at a round table discussion about the use of nuclear weapons to mitigate near Earth asteroid threats.[40] This meeting signaled the dual concern of these asteroids and comets to scientists and the military, and the criss-crossing of military dual use and national catastrophe preparedness technology proposals.[41] At the first International Academy of Astronautics Planetary Defense conference in 2007 it had become commonplace among military planners to call NEO mitigation "planetary defense," and to characterize Earth's location in space not only as within a "shooting gallery" full of "speeding bullet[s]" but also to counter astrobiological notions of Earth's orbit as life-sustaining by calling it also "hazardous."[42] While the quantification of the NEO risk in such military environmental terms legitimated discussions about using Strategic Defense Initiative weaponry that might be politically opposed if the "enemy" was another nation, there is later, in NGO NEO mitigation activism, an alternative narrative that argues that appropriate anti-NEO technology cannot be weaponizable. Scientific evidence that weapons used against incoming NEOs would increase their threat (an exploded NEO on target for Earth is not necessarily a neutralized NEO) has led to the proliferation of designs for non-weaponized NEO mitigation. These are the technologies at the heart of the pro-spaceflight and universalized notions of humanitarianism that motivates international NEO activism, as I will detail further on.

The time between the 1980s and the end of the 2000s was a turning point for NEOs, in which they moved beyond the domains of science, science fiction, and futurism and into national policy circles. In meetings like NASA's 1981 Colorado workshop "Collision of Asteroids and Comets with the Earth: Physical and Human Consequences," new characterizations of an Earth/space relationship began to suggest a hierarchy of heliospheric elements ordered by their immediate relevance to human life, putting NEOs along with the sun and Moon as objects of consequence. NEOs also had by this time their own internal classification system. They are numbered according to the year and order of discovery and grouped according to which planetary orbits they pass: Mars (in which case such NEOs are called "Atens"), Venus ("Amors"), and Earth ("Apollos"). When their orbits were completely confirmed, they can receive a name like those of the main belt, after a mythological figure or whatever the discoverer(s) chose. The shocking discovery and close Earthly pass of an object logged as 1989FC in 1989 that qualifies for inclusion in the NEO subgroup "Potentially Hazardous Objects" lead to a new provision in NASA's authorization bill to organize workshops that could conduct two studies: one to develop a systematic NEO detection program, the other to determine new asteroid moving or destruction technologies. Unlike the moon, which waxed and waned as a cosmic policy object, NEOs became engageable as an uncertain but ever-present threat. The detection study released a workshop report that stated the importance of Earthly impacts to the "ecosphere" as well as the importance of using technological ingenuity to avoid them, calling this a "gestalt shift" in how humans should think about their relationships with the NEO "population." [43]

The detection study became the congressionally mandated NASA Spaceguard Survey, which orders NASA to detect NEOs and characterize the threat environment. The survey is named for a science fiction asteroid watch program imagined by Arthur C. Clarke,[44] establishing what astronomer and NEO expert Stephen Ostro has noted as the ongoing "blurred lines between science, futuristic thinking, and science fiction" when it comes to engagements with NEOs.[45] As is evident in the sophisticated astronautical visionary theorizing of NASA's Dandridge Cole, those second two "lines" had long been blurred, with asteroids portrayed not only as ultimate modern threats to be heroically opposed, like nuclear war or alien invasion, but as sites for roguish off-world colonizing, Gold Rush style prospecting for daring male groups, or havens for political dissenters.[46] In asteroid action movies and in asteroid science fiction stories, the disorderly roughness of asteroids and the penetrating threat of "deep impact" are matched by the rough masculinity (it is oilrig "roughnecks" who drill into an asteroid and nuke it in the movie "Armageddon") of heroes who can combat these rocky worlds or tough out a life on them.

Space guard's charge is to detect "asteroids larger than 1–2 km" which would cause "global scale events," understood to be the consequences of impact and structure and infrastructural collapse.[47] Therefore, the Spaceguard survey attaches NEOS to national and Earthly futures by using orbit and mass data to calculate a "quantitative estimate of the impact hazard as a function of impactor size (or energy)." In addition, the survey should also continually "advocat[e] a strategy to deal with such a threat."[48] These early 1990s activities and the dramatic and shocking 1994 impact of Jupiter by the Shoemaker-Levy comet (named after Gene Shoemaker) also created another reclassification of NEOs as environmental objects. That first eye-witnessed large planetary impact in modern astronomical history precipitated the re-labeling of NEOs as "natural hazards," underscoring the socially meaningful contiguousness of Earthly and non-Earthly nature. In 2007, that meaning was elaborated in another study project, objectifying even further the quantitative and qualitative features of a NEO/human boundary made collapsible through collision.

The extended nature of hazard

In the course of a conversation on the hot grounds of JSC one summer, NEOphile Seth Jackson gave me a citation for a newly edited, post-conference article collection, *Comet/Asteroid impacts and human society: An interdisciplinary approach.*[49] The volume's editors, Swedish astronomer Hans Rickman and Canadian geologist and environmental catastrophe expert Charles Bobrowsky, received a request and grant in 2004 from the International Council for Science to assemble a multidisciplinary "retreat" in Spain to address on an "open platform" the "potential psycho-social and physical consequences of a catastrophic comet or asteroid impact on Earth."[50] The editors state as their goal the wholesale delineation of "fact from fiction" about comet/asteroid impacts (CAIs) and to delimit the "restrictive vision" that discussions of "natural hazards" usually have.[51] By "restrictive," the authors mean disciplinary and theoretical. With contributions from astronomers, geologists, environmental social scientists, and development specialists, the argumentative thread that holds the volume together is that while scientific knowledge of CAIs is increasing, political knowledge and social action focused on this rare but catastrophic risk is not keeping up. What is needed is an *un*restricting of the kinds of scientific, technical, and discursive boundaries that limit a broader understanding of an impact-vulnerable planet Earth in a broader cosmic ecological context. In keeping with Star and Griesemer's description of how boundary objects function to strengthen institutional ecologies, NEOs in this work institutionalize new associations that remake ecological boundaries and spaces.

As a collaborative volume with a cosmological agenda and scope, it takes as its empirical foundation the total history of a progressing cosmic-level human/environment relationship put constantly in the balance by CAIs. The objective parameters of this relationship can, as its sections declare, be grouped in terms of "Anthropology, Archaeology, Geology," "Astronomy and Physical Implications," and "Socio-Economic and Policy Implications." The form and continuance of the human/NEO relationship is now contingent upon -- and even determined by -- CAI *and* the human response to it, objectively and subjectively. Following Bruno Latour's description of how matters of fact become matters of concern[52] through discursive contests in which facts are remodeled and given new entailments by struggles for attention and legitimacy, this volume materializes what might be called an extreme post-Cold War "space of concern." This space is made up of social, political, *and* ecological facts- and concerns-in-the-making about impact detection, mitigation, and communications responsibility and impact vulnerability.

Comet/Asteroid impacts and human society, is as much a way to communicate impact risk facts and consequences as to establish the broad heterogeneous scope of a field that can make visible, in scientific terms translatable to sociopolitical domains, Earth's nearly invisible but epic existence within a space of extraterrestrial bombardment. Sociologist Ulrich Beck's description of a "world risk society" in which traditional ideas about the spatial and temporal bounds of risk and of what counts as an enemy and as defense are unsettled, the NEO threat creates the demand to master the danger of a "worlds risk society" in which humans are called to account for not just the globally figurative but extraterrestrially literal interconnectedness of worlds.[53]

Within the volume are also members of the NEO activist network, such as Ames NEO expert Dave Morrison and geologist, David Kring, who is developing an "impact theory of life" from his position as a staff scientist within JSC's collaborative Clear Lake neighbor, the Lunar and Planetary Science Institute. With his collaborator Richard Grieve, the "threshold" of CAI object size and frequency "for disrupting human civilization" is "much less" than that needed for mass extinctions.[54]

The Grieve and Kring article joins other articles in the volume that trace the human understanding of human/NEO impact from superstition to the "civilized" domain of science and social policy. The phrase "human civilization" acts as a placeholder for all kinds of totalistic imaginations of a species-wide "human" evolutionary, social, and economic status that is assumed to be gaining in complexity and interconnectedness so that the species as a whole is more vulnerable on a planetary scale. Although several of the authors in the "Socio-Economic and Policy Implications" section problematize this universalized concept of vulnerability and worry about how CAI preparedness and response could exacerbate global inequalities,[55] there is a general consensus among the authors that policy makers who attempt to deal with the CAI threat as "global" must deal with a "low-probability" but potentially "unprecedented"[56] natural risk that falls outside collective historical memory[57] and must be communicated to publics who are "innumerate,"[58] disconnected from the cosmos by urbanization,[59] and distrustful of space militarization.[60] Although most of the volume's contributors label CAIs as categorically celestial, cosmic, or even natural, they acknowledge that these threats are marked by the modern global astropolitics of outer space knowledge, access, technocratic control and contests, and military and commercial investment.

The characterization of CAI risk in universal terms that are haunted by social particularities is not only the concern of scientific organizations and government institutions but also a new arm of NGO NEO activism. This activism takes as its solution making sure that the NEO threat is not just labeled as natural, but that, in the astronautical age, a devastating evolution-altering impact is understood as ultimately social.

Unnatural catastrophe

> I'm convinced more than ever that this is a sort of intelligence test for us. The dinosaurs failed that test and nearly every species that preceded them.
>
> --NEOphile email

On a fall day in 2007, I sit one of the NEOphiles, an astronaut and NEO science expert, in a crowded Clear Lake cantina. With ensembles of lunching JSC employees providing a background chorus, this ex-serviceman/scientist/astronaut responds expressively to one of my standard questions "is space a part of nature?" by making the referential shift that I had become used to – where "nature" becomes "environment:"

> You know, I'm a product of down here, so it's obviously strange when you get to space, but I never got a sense of being outside my comfort zone, I always thought in my weeks in space, I always viewed my presence there as unusual in human experience, but something that human beings were perfectly capable of enduring or even enjoying, I think it's just an expansion of the envelope that we've already inhabited and there's no, there's nothing about us that prevents us from thriving in that environment as well, in fact it's so aesthetically stimulating to be there, that it's a great pleasure to be in space, every time you look up from what you're doing you get a sense of awe or marvel, at the scenery, and just the freshness of the experience of looking out at space, black space, looking down at the beautiful

> earth, it's so refreshing. [...] I've never worked harder than when I've been up there, and so I wouldn't want to live there at the long term at that kind of pace, but if we could have a more normal home life work life existence up there, I think people would find it to be tremendously satisfying. So, I don't see from my point of view, a separate kind of dimension or world that we couldn't dream of inhabiting. I view it just as an expansion of our environment and people are so adaptable, in general, in terms of going to the poles of the earth and to the bottoms of the oceans, living on the frontier for the last few millennia, always trying to get to these very harsh places, by the standards of the day, that space is just another category of frontier, it's very natural for me to think of humans living there for the long run. We might think of it as very exotic today, but I don't think it's gonna be that way in fifty years.

The depiction is familiar to me: Earth is not a separate nature from space, just "down here" relative to orbit. Further, space living in its arduousness is invigorating, in conditions that are simply unusual, in an environment expandable and normalizable through technology-enhanced adaptations. During the interview, I asked the astronaut to clarify a phrase I heard him make about the NEO/human relationship in a presentation at NASA Headquarters several months earlier. The meeting was one of the NEOphiles' ongoing pitches to publics and decision-makers, which I had been watching in various venues, to promote their crewed NEO mission Phase I study concept. In his talk the astronaut summoned the powerful image of humans "manipulating with their own hands and machines something that could destroy us." He explained:

> Well, Rusty Schweickart has said it many times, and I agree with him, we're alive at the time when we actually have just developed the technology to prevent us from being snuffed by an asteroid, and we've been subject to extinction for as long as humanity's been around, with absolutely no ability to do anything about it and for the first time in history, our species is actually able to turn off a process that has been running the solar system since it began, so it's actually a pretty historic moment, to actually think of altering the way the solar system operates, in a way that preserves our ability to survive. So, our technology has actually caught up with the dynamics of this process and we're on the verge of being able to manipulate our way into some survival, in the way that the dinosaurs didn't have the capacity to do. So rather than being subject to the whims of celestial dynamics, we're now able to make sure that we don't get waxed by this process, bombardment that's been going on. And I think it'll be very satisfying to actually

> have people nudging these bodies around or operating around them and really demonstrate that we have the capacity. It'll be quite momentous.

Here the momentous interaction with a NEO is processual, rational – engineered in fact. Although the NEOphile astronaut and Schweickart are pursuing different missions to a NEO -- Schweickart's to move one aside and the NEOphile to explore one -- they share a vision in which human evolution is a matter of pitting technoscientific planning against cosmic whims and luck, of manipulating our way to survival.

In this view of "threat mitigation" as an act of evolutionary fitness, NEOs occupy critical event boundaries. They appear between life and death writ large as evolution and extinction, at shifts in the history of so-called "dominant" forms of life, suggesting that humans will be confronted with chances to affect their odds for survival. If as JPL NEO expert Donald Yoemans notes in a New York Times op-ed piece, "We owe our very existence and current position atop the food chain to these celestial visitors,"[61] then visiting *them* to alter their trajectories is a type of environmental engineering with entailments that go beyond the boundaries of Earth-centered environmental discourses. As the NEOphile astronaut puts it, NEO mitigation is not just an act of Earthly "defense" but "altering the way the solar system operates." This is not only a cosmological re-vision of what the solar system is and the human place within it, but an expectation that human evolution is contingent upon a hands-on approach to solar system environmental operations. Recalling my introduction by another astronaut to astronautics as an "operational culture" during the NEEMO 9 mission, here I am introduced to what is at stake in the decision to make or not to make human operational boundaries heliospheric. While other contemporary visions of environmental engineering are burdened by reflexive concerns about the misuses of technology on Earth, Schweickart warns that contemporary technologies have now rendered a NEO catastrophe prospectively unnatural and that the refusal to confront it in space amounts to an evolutionary failure. From a regime of detection emerges a proposed regime of deflection.

"We invite you to join this ultimate environmental project:" NEO mitigation as international environmental policy

My astronaut lunch partner and Schweickart are both members of the Association of Space Explorers, and both have been committed since the early 2000s to politicizing astronautics as a human evolutionary tool. In 2008 the B612 Foundation became part of a global NEO mitigation coalition headed by the NEO committee arm of the Association of Space Explorers (ASE), which is an organization made up of "350 people from 35 nations" who have flown in space. Members of the ASE are elite survivors of extreme risk and have gained the perspectival objectivity of the orbital "overview effect" (see Chapter 1); as a result of these distinctions, the ASE has "observer status" in the United Nation's Committee for the Peaceful Uses of Outer Space. While the ASE petition reflects what social scientists Lakoff and Collier describe as "a profusion of plans, schemas, techniques, and organizational initiatives that respond to new kinds of perceived threats to collective security,"[62] their activism also promotes astronautical theorizations of human/environment interaction and evolution. The environment they are concerned with is not just global but heliospheric, and they reframe the terms of human survival as tied to astronautically-enabled success or failure. This is an environmental imaginary that the B612 Foundation, ASE NEO committee, and the NEOphiles share, although the Foundation's mission concept solution is not crewed but robotic. Their goal with such a mission is to "significantly alter the orbit of an asteroid in a controlled manner by 2015."

The B612 Foundation website invites visitors to "join" in the "ultimate environmental project" that they launched because of their dissatisfaction with the "current lack of action" to protect the Earth from Near Earth Asteroids.[63] As the 72-year-old Schweickart told a *Wall Street Journal* reporter about the "campaign" he runs from his Sonoma California wine country home, "You are looking at the world's expert in deflecting asteroids, and that is just inexcusable."[64] Like the NEOphile crewed mission campaign, the B612 Foundation began at Johnson Space Center. In early 2001, following the decade in which NEOs were made calculable and characterizable through detection surveys and policy white papers, a group of astronauts and experts, including early NEO policy leader David Morrison, got together at JSC to have an informal meeting about ways to deflect a NEO. Their stated task was to think of non-weaponized ways to push, pull, or otherwise alter the orbit of a NEO heading for Earth, and to develop a technology demonstration mission to do so. This meeting became the basis for the creation of the B612 Foundation, named for the asteroid on which French author Antoine de St. Exupéry's Little Prince lived. In keeping with the story's depiction of a prince wise beyond his mortal appearance, the Foundation's name evokes the value of thinking about the NEO problem from a transcendentally evolved perspective.[65] As Chair of the Foundation, Schweickart represents his and the Foundation's goals at public and governmental forums as an expert characterizer of what the website calls "the current environment." The website explicitly states that this environment is not the quiescent "old solar system" but a dynamic solar system in which the Earth and its "sister planet" the moon inhabit a "neighborhood" heavily populated with Earth crossers.[66]

In 2007, Schweickart gave one of his many Congressional testimonies, calling into question the utility of thinking about NEOs as "natural hazards" or as military targets, and in doing so redefines the social concept of "responsibility" in evolutionary terms. For a 2007 Space and Aeronautics Subcommittee of the House Committee on Science and Technology hearing on the NEO threat, Schweickart summed up his Foundation's perspective in the form of a testimony, revealing frustration with current national efforts. He ended with this statement:

> In closing I would suggest a personal perspective based on having spent the last 6 years of my life studying this issue. NEOs are part of nature. A NEO impact is a natural hazard in much the same way as are hurricanes, tsunamis, floods, etc. NEO impacts are deceptively infrequent, yet devastating at potentially unimaginable levels. NEOs are however not our enemies. We do not need to "defend" against NEOs, we need to protect ourselves from their occasional impact, as we do with other natural hazards.
>
> Unlike other natural hazards, however, NEO impacts can be predicted well ahead of time and actually prevented from occurring. If we live up to our responsibility, if we wisely use our amazing technology, and if we are mature enough, as a nation and as a community of nations, there may never again be a substantially damaging asteroid impact on the Earth. We have the ability to make ourselves safe from cosmic extinction. If we cannot manage to meet this challenge, we will, in my opinion, have failed to meet our evolutionary responsibility.[67]

He and his ASE associates took this idea of species responsibility global. The ASE's UN petition presents a kind of universal moral imperative for developing authoritative technocratic schemes of rational planning and political pre-agreements about mechanisms of response, mitigation, and trust.

By the time the ASE UN petition was drafted, the news media had become a zone for NEO detection and near-miss reporting, including ongoing controversies over calculating the threat of 99942 Apophis. The asteroid, spotted in 2004, was named after an Egyptian light-eating god of utter destruction -- who in turn was named after an evil alien character on the science fiction series Stargate SG-1 who crosses spatial boundaries with a timegate to destroy and enslave. While its orbit was being confirmed, 99942 Apophis was graded on the Torino asteroid threat scale as a potential threat in 2036, if it passed through a kind of mathematical "stargate" called a "keyhole" in 2029. JPL scientists reported that if the NEO, now classed more specifically as a PHO (potentially hazardous object), passed through this orbital time/space plot it would collide with a TNT equivalent of 880 megatons. Framed by popular cultural precedents that depict asteroids as destroyers as well as global uniters, Apophis quickly became a boundary object of thought and practice, its threat made calculable and debatable within the domains of eschatology (999 upside down is 666, the mark of the beast), numerology ("It is expected to pass Earth the first time on April 13, 2029 -- a Friday the 13th. What's more, 2 + 0 + 2 + 9 = 13" [68]), military science, meterology, geology, and public policy. In 2009, Apophis was downgraded to a non-existent threat for its pass on 2029 and to a practically non-existent threat in 2036, but its behavior when it passes Earth on both dates, as close as some geosynchronous satellites, will determine how much of a threat it may be on future passes. In this case, the play of scientific odds reframes the idea of meteors and comets as auguries. Interpretation of their meaning now extends from simply sighting them to making sense of their probablistic existence as trackable threats in deep space. The meaningful politics of their existence is linked to the politics of "taking responsibility" for them as objects of disorder and consequence that starts from the moment of discovery and continues with each orbital pass.

The ASE petition for the UN to take responsibility for NEOs, which is at the time of this writing still in committee, sets out the legal and policy basis for doing so by reinterpreting a key article of the 1967 Outer Space Treaty. This reinterpretation reframes space as an environmental extension of Earth that requires surveillance and globally coordinated management. The Outer Space Treaty, on which the US is signatory, represents space as a human commons of scientific and economic potential. Article 9 of the Treaty states that space exploration must follow planetary protection protocols "so as to avoid (…) adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and (…) shall adopt necessary measures for this purpose."[69] In an imaginative move, the B612 coalition rescopes this planetary protection requirement by linking this article to a companion treaty resolution on remote sensing "which calls upon states to promote by means of their remote sensing activities the protection of Earth and mankind, and share relevant information, whether it concerns a threat to the Earth's natural environment or resulting from natural disasters."[70] Although the coalition admits that this particular resolution was "not drafted with a view to asteroid threats, [it] should be interpreted *a fortiori* to entitle measures to be taken to avoid serious and adverse changes to the environment of Earth stemming from an asteroid threat."[71] The coalition recommends specific actions that stem from the B612 Foundation's early work to design integrated detection and deflection systems, such as increasing NEO surveillance and building a non-weaponized robotic "gravity tractor" that could prod the asteroid away from the "keyhole" space, or if possible, alter the location of ground zero, an alternative fraught with controversy.

The political ecology of NEO mitigation

In the coalition's petition, the impacted or unimpacted Earth becomes a unit of co-constituted ecological and social selection, testing the capacity of some social groups to rationally control the various elements of catastrophe. While effacing national differences and highlighting the interests of "humans" as a planetary species, the ASE document writers admit that a NEO deflection project such as the gravity tractor may only turn, in Schweickart's words, an "act of God" impact into an "act of humankind" pathway of impact points. Schweickart described this problem in a 2004 paper, "The Real Deflection Dilemma,"[72] a response to early 1990s articles by Carl Sagan and other concerned scientists that a "deflection dilemma" exists in which nations that can deflect away *from* could also deflect *to*, effectively weaponizing a NEO. Referring to the increasing sophistication of deflection technology designs and modeling scenarios, Schweickart dismisses the weaponization option, reiterating that new models reveal its imprecision in an era of surgical strike technologies. The "real dilemma arises in that otherwise uninvolved people and property across international boundaries"[73] are at risk, making international NEO impact cooperation mandatory. Although his dismissal of a NEO weapon may not be justified and in an interview elsewhere a reporter quotes him as admitting that "Washington" is still focused on "the nuclear option."[74] In his deflection scenario modeling as an alternative to the nuclear option, NEOs become political ecological boundary objects on a global scale.

Here, based on regimes of calculation and modeling, the general term "impact" becomes a probabilistic calculation of possible impact points and their consequences across boundaries. Each point has the potential to be deflected from or to according to the exercises of technological and political power. The intended or unintended shifting of impact points from one national space to another will create what the petition admits is an escalation of the potential for NEO mitigation projects to become "more political and difficult."[75] The *Wall Street Journal* article on Schweickart's description of the UN petition sums up Schweickart's preference for pre-negotiated calculations, to allay fears that the U.S. will use NEO deflection as a basis for weaponizing space and to assert a form of "cool" scenario-based reasoning to trump politics being "heated" up by an incoming NEO:

> Now suppose the impact line for an asteroid begins over Country A, extends through Country B and ends at Country C. To nudge the asteroid so that it misses Earth completely, you first have to push it in one direction or another -- in effect, toward either A or C. That means that residents of either A or C will bear a slightly greater risk if the rescue effort doesn't push the asteroid quite hard enough. Naturally, the citizens of A and C, and their political leaders, will be screaming for the asteroid to be pushed in the other country's direction and out of their backyard. Mr. Schweickart says the only fair way to proceed is to have a decision-making formula drawn up well in advance, thus unaffected by the political heat of an actual crisis.[76]

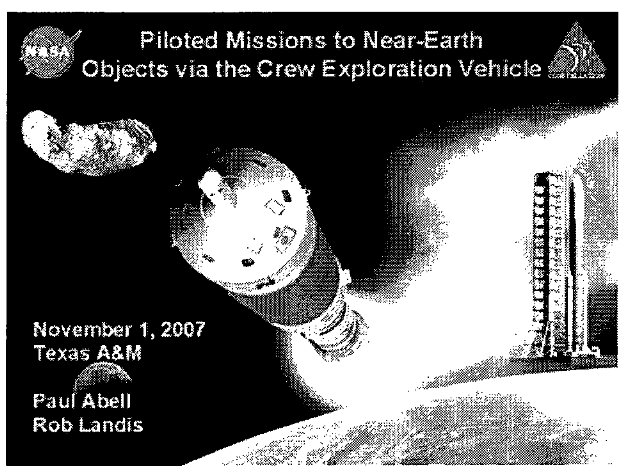
In the UN petition, the authors nervously skirt the fact that impact mitigation investors will have an advantage over noninvestors, going on to recommend that an appropriate plan would calculate in advance "the basis of the value of human life and property, independent of national political power or influence" and enforce that agreement as necessary.

In this "rational" scheme, each nation bears an individual responsibility to recognize and pre-negotiate its survival. Following established theorizations of CAI risk in universalistic terms that erase disconnections and the inequalities of interconnections, the ASE petition describes preserving the Earthly biosphere as the responsibility of a "complex and interconnected human society" [77] with the obligation and unprecedented capacity to avoid becoming "victims" of this kind of environmental catastrophe. In this plan, NEO defense is a form of responsible environmental policy and engineering, with "species" and "biosphere" salvation as an ultimate imperative. Haunting the ASE document is the geographics of sacrifice and the fate of the evolutionarily un-elect, made "not to survive" through decision-support technologies in which survival is based on the means to negotiate how "human life and property" is characterized in ways that appear "independent of national political power or influence." Like the heroic plan of an asteroid impact action movie, the ASE's goal is to unite humanity under the universalistic umbrella of a shared threat space And, like those movies, mitigation of resulting geographic inequalities, vulnerabilities, and power hierarchies is another story – a problem for other times and spaces. While NEO impact advocates have a passion for making impact a social rather than natural problem, they are not equally vocal about the unnaturalness of social inequalities.

These planet-level logics of calculative responsibility are at work in what Sheila Jasanoff has called the earthly politics of global environmental governance and its resistance. However, NEO mitigation astropolitics dramatically rescales such discourses from the "global" to the "evolutionary" level, opening up new ways to quantify and characterize the means by which a "civilization" or the "species" can become extinct or avoid extinction. As Stephen Collier and Andrew Lakoff have argued, catastrophe preparedness logics, especially those centered on rare risk with catastrophic consequences, can reveal extreme and powerful re-orderings of value that are not based on humanistic units of preservation such as bodies, communities, societies, or nations, thereby leading to schemas that value the saving of vital infrastructures over humans *per* *se.*[78] If undertaken, a United Nations NEO impact mitigation program based on plotting impact paths have to characterize spaces in terms of their contribution to preventing "civilization" disruption and extinction, which may necessitate different units of calculation than "nations." The document itself points to the need to remap the Earth in terms of protection-worthy spaces and those that must "absorb risk." This situates the Earth and NEOs together within a cosmic telos of human fitness and destiny. In this way NEOs serve as boundary objects that not only "inhabit intersecting social worlds and satisfy the informational requirements of each,"[79] according to Star and Griesemer's formulation of the concept, but they also make it possible to translate into social and political terms reasons for managing the intersection of terrestrial and extraterrestrial ecologies.

Within astronautical advocacy networks that include and go beyond the B612 Foundation and the ASE, NEO deflection is not the only astronautical "ultimate environmental project" imagined to have the power to save and sacrifice. While the ASE was drafting its petition, NEOphile supporter and Ames Research Center Director Pete Worden, announced collaboration of NASA and the software mogul Cisco Systems to create a cybernetic and satellite based "planetary skin" "massive global environmental monitoring" and "decision support"[80] system for subscriber governments and organizations. Like in the case of the space biosuit, this scheme redefines the basic idea of what skin is in the extreme. It also brings space-based surveillance forward as a different kind of total space power, conjuring the image of a grotesquely unbounded panoptic tegument-sensor.[81] In 1998, space reporter and advocate James Oberg predicted that asteroid deflection would be an "extreme case" within an "entire spectrum of deliberate human intervention in Earth's biosphere" which will "be one of the most intense ideological and philosophical conflicts of the next century."[82] Oberg presented this prediction to the U.S. Space Command, the highly-funded but little known military astronautics arm of the Air Force, which he predicts will be among the few organizations positioned to mount space-based environmental engineering missions as well as to counter "naïve" and "ideological" "hands off the Earth" strategies that have generated international treaties that prevent "deliberate environmental modification." In this way, NEO deflection and and space-based environmental engineering proposals remake the upper boundaries of current global "Earthly politics."

The broader cosmic ecological imaginary that underwrites the B612 coalition's UN petition is one in which NEOs are not just threats to avoid but globally incorporable resources. As objects to seek out as well as watch out for, they promise revitalization, enhancement, fitness in the form of wealth, or even havens for escaping a natural or social doomsday. This imaginary more deeply sutures together the fate of human beings with the fate of civil human space exploration programs.



Powerpoint presentation cover slide

NEOphilia

> Late last night coming home from [the airport], a guy on the bus with me asked what I did at NASA ...of course the NEO thing came up and this business dude was hooked. Hooked.
>
> --NEOphile email

NEO Study Disclaimer:

- This is only a Phase 1 technical feasibility study.
- NASA has not endorsed this mission concept yet.

From the time I began to attend their presentations through 2009, the NEO crewed mission study authors opened their powerpoint presentations with this disclaimer on a NASA-logo emblazoned slide. When I first encountered flight controller Rob Landis, small body astronomer Paul Abell, flight surgeon Jim Logan, trajectory analyst Dan Adamo, astronaut Tom Jones and the rest of the local NEOphile network in 2006, this slide communicated the conceptual nascence and institutional liminality of their crewed NEO mission concept. The study is detailed, including the outline of its "concept of operations." The "con-ops," as a patient manager in the Engineering Directorate (a woman ready to retire who wrote procedures for developing them) explained to me, tells a story. However, this was a controversial alternative narrative – a story that was, according to some NASA colleagues and administrators, a "waste of time" to tell.

Nevertheless, by late 2009, the disclaimer read as ironic, the "yet" pointing to NASA's resistance to a Constellation mission option that had gained its own legs through what might be called NEOphile "presentation activism." The scope of this activism was exemplified by one NEOphile's exhausted calculation that he flew 100,000 miles between 2008 and 2009 to do his job but also to network the NEO mission concept -- a travel distance of astronautical magnitude. The study authors' idea to use Constellation's Apollo-style crew capsule to send two or three astronauts on a NEO exploration and sample-return mission had some official support from supervisors who permitted NEOphile civil servants and contractors to make their traveling presentations, but it eventually secured game-changing levels of endorsement from a variety of outside institutional authorities and publics. This despite having no official political mandate, agency-level public affairs representation, or paid working groups. The mission concept's rise to national and international prominence was evident as it landed on the table as a debatable mission option during the 2009 Augustine Commission's review of NASA's programs. However, the study gained both fame and notoriety by impacting the heart of a larger astronautical debate about where both NASA and the whole venture of human space exploration is "going," technically and philosophically.

From a NEOphilic perspective, NEOs are boundary objects for what NEOphile astronaut Tom Jones calls a "natural progression" of human space exploration. While NEOphiles agree with most space exploration advocates that Mars is the ultimate planetary destination, their advocacy troubles the assumption that Mars or planets in general are heliospheric destinations with the most immediate or long-term Earthly benefit. The crewed NEO mission option incorporates multiple arguments about the importance of NEOs to humanity, adds in NASA instrumentalist environmental discourses about the facts and potentials of human ecology, and ends up elaborating a more comprehensive understanding about the whole nature of the NEO/human relationship than occurs within the bounds of astrobiological and geological theories. The NEO mission concept also expands the salvation-from-NEO discourse by adding new at-risk entities salvageable *by* NEOs: NASA itself and human space exploration. With NEOs as things that objectify new spatial boundaries for environmental exploitation, human space exploration progress gets mapped onto human evolutionary progress in the extreme. Darwinian selection works through technology on a heliospheric scale. As Jones writes in one of his regular "The View from Here" columns for *Aerospace America*, the apogee of this progress is "a multiplanet species."[83]

Study in action: 2007 - 2008

I met JSC flight controller and NEOphile Rob Roy Landis in fall 2006 at one of the weekly "Exploration Faithful" one-hour informal get-togethers at JSC's Building 37. That building houses the Astromaterials Research and Exploration Science (ARES) office, including planetary scientists, orbital debris specialists, and the Earth science group that provides astronauts with multi-disciplinary Earth-observation training. On Thursday mornings a large ARES office conference room opens up to anyone with a JSC badge and Dr. Wendell Mendell presides over his ongoing multi-decade "tag up" ("meeting" in NASAese). The Exploration Faithful group started as a way to maintain a forum for keeping "exploration" (NASA shorthand for human as opposed to robotic science missions) alive after President Bush Sr.'s Space Exploration Initiative died in the early nineties. It is often full of lively intergenerational, interdisciplinary, and political debates and has had many well-known participants, including an intern who stole and tried to sell lunar samples online. In this room, no exploration topic is taboo, although the NEO mission topic eventually went from being considered an interesting novelty to a magnet for debate. Landis was an Explorogroup regular with an unusual NASA resume full of both robotic and human mission operations experience, and when I met him he had just worked to complete the Phase I study. Like the persistent Scottish rebel he is named after, he consistently brought up NEOs and the mission study during Explorogroup meetings, stirring up the interest but also ire of lunar-dedicated scientists, who often display their own topological passions by referring to themselves as "lunatics." Although they do not use the term "topophilia,"[84] planetary scientists are well aware that their ties to places they have never been to but dwell in through work and observation are intellectual and affective. Debates within exploration and science circles about the value of destinations evince topophilia as well as topophobia, since the stakes are funding, legitimacy, and missions to places that make people's careers and dreams.[85]

As with other Phase I NASA studies "A Piloted Orion Flight to a Near-Earth Object: A Feasibility Study,"[86] the feasibility being tested is both technical and political. Landis has a master's degree in astronomy and has been interested in NEOs as scientific and exploration objects for years, an interest that he shopped among a scattered group of NASA civil servants and contractors. In an email to me in which he outlined the Phase I study's social history, Landis notes that during a NASA Advisory Committee Meeting in Washington, D.C., he suggested to attendees that Constellation hardware could be used to fly a crew to a NEO, as a mission option to fill the gap between flights to the International Space Station and Mars.[87] Jeff Hanley, JSC-based Manager of the Constellation Program Office authorized a white paper study as part of its Advanced Programs research, and Ames' Center Director Pete Worden agreed that his center would lead the study. In summer 2006, Ames engineer and celestial mechanics specialist David Korsmeyer began to manage the study across multiple centers.

Like the NEEMO organizers described in Chapter 1, NEOphiles who read space history were aware of the emergence of national spaceflight programs out of advocacy groups and value small working groups as technical, philosophical, and political units. When they emerged in the late nineteenth century, these largely white and male societies were active in creating an association between modernity and spaceflight and promoting, as one historian writes in a recent NASA history publication, the "Americanist narrative" of "frontier pioneering, continual progress, manifest destiny, free enterprise, and rugged individualism."[88] Such powerful colonial narrative elements exist, however, alongside varieties of American astronautical tropes of progress and fulfillment, such as that expressed by astronaut Nicole Stott who spoke with me about her hopes for family life in space places or when African American astronaut Yvonne Cagle autographed a portrait for me with the phrase "Space for All." The NEOphiles' and others' understanding of the value of the NEO crewed mission concept align Americanist as well as pluralistic American expectations for pushing boundaries.

With a network that crossed NASA center boundaries, the NEO mission study began to attract attention for its claims that NEOs could uniquely facilitate NASA's exploration strategy. In 2007, the study gained support within NASA, and then entered the broader world of scientific and technical meetings and conferences through papers given by Landis and others on the team. Although the study is authored with care so as not to explicitly advocate visiting NEOs before the moon, its characterization of the benefits of NEO exploration places NEOs level with the moon, or upon reflection, even above it. It brings NEOs out of their solar system position as pre-historical, peripheral, and menacing objects into the terrestrial bounds of human spaceflight justification debates. As a result NEOs become more than space rocks. In words favored by NEOphiles in their presentations and talks, NEOs are "stepping stones" that are "realistic intermediate destinations" for moving toward Mars and out into the solar system. This metaphor also underscores the way that NEOs, as detectible and trackable object/points, more deeply objectify "space" as a zone of interconnected sites in consequential relation to one another.[89]

Between 2006 and 2008 the "The Phase I Study" I followed was, to borrow again Anne-Marie Mol's idea that singular objects can be made ontologically multiple through expert practices, a "study multiple."[90] As soon as the study team completed their work, their products began to travel as a "viewgraph" (digital slide) presentation. A critical feature of "paper NASA," "viewgraph presentation" and "viewgraph engineering" are common but also commonly critiqued forms of NASA technical communication.[91] Nevertheless, my interlocutors displayed their study widely in presentation form, which mirrored their white paper document.[92] If the Phase I Study was never just "paper," the purpose of the slide presentations was also not just to disseminate technical information. The "Phase 1" category gave the authors license to speak speculatively and with a kind of conceptual freedom about their hopes for NEOs as political, environmental, and astro-ecological "stepping stones" with evolutionary significance.

Stepping stones for evolution

In fall 2007 the NEOphiles were perfecting their presentation activism. I went to watch NEOphile astronomer Paul Abell and Rob Landis give the study's powerpoint talk to an audience at the Lunar and Planetary Institute (LPI) near Johnson Space Center. LPI is a small, low brick building complex northwest of Johnson Space Center. Opened in

1968 as a planetary science research center that also provided support for JSC's lunar operations, LPI was originally co-operated by Rice University and the National Academy of Science and is now managed by the Academy's Universities Space Research Association consortium of 100 member universities with space science and engineering programs. That fall, "impact theory of life" originator David Kring was managing LPI's new web-based lunar science information portal, and other scientists at the institute were engaged projects focused on planets as well as on small bodies, from comets and Kuiper belt objects to interstellar dust. Abell and Landis had alerted JSC and LPI colleagues, from scientists and engineers to managers, about the NEO crewed mission talk and in the late afternoon an assortment of people began to arrive and settle into the LPI's small auditorium.

This is the first version of a presentation I would see again at NASA Headquarters and Rice University, and that I would review on my own computer after NEOphiles sent me versions from talks given elsewhere, including one given at a science fiction convention. All of these presentations drew from a repository of slides shared among the NEOphiles and their manager-stakeholders. Part of what allows "paper NASA" groups to assemble and take ownership of alternative narratives about how and where to explore is that such information-loaded slides are also considered proprietory and guarded from unauthorized use or distribution – particularly to the press. The many NASA presentations I saw over the years were formally government property and subject to export control and other kinds of distribution restrictions, but also to informal social understandings about how people secure the right to share, use, and publish their presentation-based knowledge.

After the lights dimmed, Abell explained the disclaimer slide and then situated the study within NASA's internal intellectual history. Abell announced in his calm and resonant voice that "this is a very sensitive topic to NASA" and added that JSC managers had been briefed about it but that it had not been presented at Headquarters. Joking about the popular conception of asteroids as alien threats, he averred "we have no plans to wage war on asteroids," and then anchored the mission concept with a bibliographic slide that legitimated the mission concept something invented long before the Vision for Space Exploration. The study authors created bigger historical bounds for their idea, linking it to an Apollo era study to mount a Saturn V rocket mission to the asteroid 433 Eros in 1975 and ending with two recent studies done during the Space Exploration Initiative in the early 1990s, including a 1994 paper by astronaut and study team member Tom Jones. Abell then specified the constraints that the study labored under: to prove that the mission is possible without major modifications to Constellation's current launch and crew capsule architecture.

Abell's technical knowledge of and even advocacy for human mission operations is unusual for an astronomer, however, Abell and Landis had been working on this project in many venues, including during observation runs at the Mauna Kea Observatories complex. Abell had explained to me that within the social hierarchy of astronomers, cosmologists are on the top and planetary astronomers fall at the bottom, indicating that NEO astronomers occupy an even less exalted spot. While his description validates philosopher Hans Blumenberg's diagnosis that post-Copernican astronomical thought maintains the ascendancy of philosophy and theology in the form of cosmology,[93] it also shows how astronomers and astronautics practitioners tend to orient themselves to the greater goals of their practice in two ways, by grounding themselves in the epistemological aspirations of observation, or by enabling the project of human spaceflight. One orientation celebrates the rewards of making things visible and detectable; the other, as my notes and transcriptions evince through differences in the use of language by scientists committed to robotic exploration and others to human exploration, is saturated with visions and dreams of extended forms of human being and becoming. Although some of my interlocutors occupied both commitments, more often than not they leaned toward one or the other.

Despite having an astronautically literate audience before him, Abell still had to preface his description of the mission by explaining what NEOs *are* at the most basic levels. This involved re-educating the audience about how to understand the open-ended human ecology being imagined by the mission. This task also immediately distinguished this talk from any others focused on a mission to the moon or Mars. During the time I followed the NEOphiles and watched reactions to their presentations and ideas, some would complain about what they called an "astronomical illiteracy" among NASA civil servants and contractors as well as the public. This was an artifact of the slow adoption of the new "not your grandfather's solar system" model of heliospheric dynamics and materials, and the NEOphiles knew they were introducing many audience members to the idea that there are cosmic objects out there with orbits similar to the Earth's. NEOphiles often reported that people they spoke with didn't know what Near Earth objects or asteroids are, or assumed that they were simply those objects in the asteroid belt that are closest to Earth. Also, within JSC "NEO" was confused with "LEO" (low earth orbit), which, NEOphiles reported, led to questions from people who wanted to know why in the world NASA would want to explore anything in "Near Earth Orbit?" NEOphiles groused that NASA people "should know better," but it was clear that NEOs were still "new" things in a broad public sense. As Star and Griesemer describe, boundary objects have to "reconcile" differences in meanings and worldviews,[94] and in this case, what had to be communicated and reconciled was not only what kind of objects NEOs were but how solar system object interactions and boundaries should be imagined. As a result, the study and its presentations became ways to communicate to NASA employees and publics about the contemporary solar system, and to situate NEOs *within* the conceptual boundary of cosmic things that are significantly meaningful to Earthly nations and human beings.

To do this, Abell presented slides that put NEOs into context using illustrations that quantify and classify NEOs as near, prolific, and without predictable boundaries. Abell pointed out that NEOs vary in size, showing the Japanese Space Agency's Hayabusa mission target, the asteroid Itokawa, as about the size of the Golden Gate. NEOs can be round, made up of rubble, and have rocks on them that represent the size of things that have made holes on earth (slide: Meteor crater). Abell's next slides illustrated how NEOs are detected and classed as threats, but followed on with other slides that touted NEOs as destinations for humans in terms of science, political understandings of the solar system neighborhood, and exploration resource economies. The slide that sets up this contextual understanding is dramatic: with a series of clicks, the presenter visually modifies the normal image of the inner solar system environment. To the simple black and white graphical image of a sun orbited by four planets, Landis adds more and more colored dots representing an increasing "NEO population" until the blank space is full of color, driving home with the double cognitive and emotional impact of a kind of "settlement Earth" – we – "surrounded" by a frontier of hostility and opportunity. This visualization is not astronomically contemplative, but is geared toward action that is both scientific and political by invoking a scenario of environmental vulnerability that demands the joint production of NEO detection knowledge and interactive engagement.

This slide represents the basic NEOphile argument: the observational technologies that specify where and what NEOs are also provide ways to calculate their accessibility and benefit for scientific, planetary defense, and economies. In this argument, NEOs are not just targeting the Earth for impact and justifying the deployment of detection and deflection regimes, but are emerging incorporably "target rich" in numbers and materials. The presentation brings 1960s and present NEO advocacy together by citing the value of NEOs as "undifferentiated" solar system objects with material that can provide clues to solar system formation, raw materials for Earthly markets as well *in situ* use value. A water rich asteroid, Abell explains, could be mined for rocket fuel and life support materials; this installs in the audience's minds the notion of asteroids as resource-providers, not resource users. This provides for a way to refute the charge that space exploration will never be able to support itself.

In these ways, the study and its presentations argue that the defense from, exploration of, and exploitation of NEOs go naturally together. With enthusiastic claims about the dual practicality of NEO detection and exploration, the crewed mission study vision asks audiences to rethink the cognitive, emotional, and environmental givens that make Earth and space appear separate and ecologically distinct, and how a "human presence" on a NEO is a significant step toward infrastructurally resourcing the heliosphere for science, markets, and movement away from environmental limitations. In conversation with NEOphiles, I was unsurprised to find that like other NASA interlocutors, they had read or were reading controversial anthropologist Jared Diamond's works and cited them as evidence for their case that accessing NEOs would forestall Earthly social and ecological collapse.

After following with a discussion of the robotic precursor missions needed to better characterize the best target for a NEO mission, Abell describes the technical and operational details of the mission. Some details are familiar to an astronautical audience that knows lunar and low Earth orbit mission operations. However, others are unusual: the astronauts will need less fuel to get to the right NEO than to the moon (this is economical), they will not land but hover beside it and engage with it remotely or on tethers (this is unusual and invokes a cool image of rock climbing and SCUBA diving), and they will probably stay for a 7 – 10 days in order to "ride" the NEO orbit back to a place that can get them home with the least fuel needs (this is innovative and resourceful), perhaps the astronauts will extract some minerals or water to see if they can do it (this is demonstrative). NEO smallness, their nearness, their tiny gravities, their accessibility, their richness all adds up as value. Abell and others call them "stepping stones," a metaphor used often in astronautics to indicate the place that makes it possible to extend, expand, and progress to the next place.

As such, NEOs are like another alternative destination with a long NASA and space advocacy history that began to be revisited during the aughts: "Lagrange" or "libration" points. These are not things or objects but mathematical points of balance that occur in the gravitational dynamics created by three objects in space, also called the "three body problem." If one of those objects is a spacecraft in motion, these points can be used to re-map the solar system topologically for spacecraft trajectory plotting, turning a problem into an equation in momentum transfer. NASA mathematicians and mission designers propose making mission trajectories in terms of an "interplanetary superhighway" that can be plotted by taking advantage of libation point gravitational dynamics that create "low-energy" pathways for spacecraft through the solar system. JPL mathematician Martin Lo describes this "highway" as

> a vast infrastructure provided by the Solar System just like the Jet Streams in the atmosphere or the Great Currents on Earth. As all natural resources, once discovered, it must be developed, mined, and harvested.[95]

Interplanetary superhighway / courtesy NASA

An artist's rendering of the interplanetary superhighway re-characterizes the heliosphere. Planets are not presented in terms of their solar orbits or even their relative orbital distances from one another but as if they are stations on a subway map, with gravitational "halos" made into "tubes" through which vehicles can move between them. The NEOphiles' trajectory plots are standard and do not follow this superhighway, but like the interplanetary highway advocates, the NEOphiles ask their audiences to rethink nearness and farness and the solar system resource landscape differently, as asteroids become closer than they appear.

Abell and Landis cap the presentation by bullet-pointing the interconnected importance of NEOs to "Exploration," "Science," and "General Public" – categories that reflect the Vision for Space Exploration's major categories with which NASA administrators try to "sell" the lunar return scenario. The two NEOphiles highlight the value of the human explorer *qua* human, and remind the audience that there is an already existing human/NEO relationship calling for deliberate rather than accidental knowledge and prospective management. Beginning with "Exploration," Abell invoked the perspectival change ("we will be leaving Earth behind") as well as the opportunity for the efficiency testing of hardware and humans confronting isolation and severe radiation exposure. The astronauts would be protected by water and their own urine, they would have protective sleeping bags in which to "ride out" a galactic cosmic ray storm, images that caused laughter but evoked the dual image of a frontiersman and what one NASA engineer I came across had dubbed the "econaut," an intensively ecologically aware and integrated astronautical human.

Continuing with the "Science" rationale, Landis contrasts his experience as a flight controller with the Mars Rovers to remind the audience about the efficiency of the human capacity for *in situ* scientific performance of data collection. The human explorer being represented here is the one that Explorogroup lunar scientist Wendell Mendell heralds as the distinctive performer of what geologists call "ground truthing:" the confirmation of remote sensing data with data collected by bodies on the "ground." As Abell explains later, unlike robots, "humans can look at a context and make a judgment," cementing the idea that humans distinguish themselves by being environmentally aware in ways that machines cannot be – and echoing the words of another NASA Ames human/computer integration expert who told me “robots are not explorers.” In addition, Abell and Landis consider data collection for resource prospecting and basic knowledge production as complementary forms of scientific activity -- what a lunar scientist on a listserve would dub “frontier science.”[96] For “pro-human” exploration advocates, the human/robot difference is expressed in terms of the embodied human capacity to judge and render experience-based truth and to evaluate a landscape for habitability or use, thereby reminding the audience that *in situ* human data collection and fieldwork evaluations are not a pre-scientific but wholly scientific acts.

For the “General Public” rationale Abell and Landis reminded the audience of what it would mean to leave the Earth/moon system, to explore inner solar system space, to make progress toward Mars, and to characterize a “potentially hazardous object” up close. Landis drives this home: any NEO that can be visited is close enough to count as a PHO. Abell ends the talk by putting the NEO mission into the realm of the real: “Can we do it? Yes, we can do this.”

Announcing to the audience that they were going to be the world premier audience for a video, Abell and Landis play a quick animation of the whole mission, made for free, Abell reports, by a private graphic arts company excited about the mission concept. The animation launches, accompanied by a tinny midi-file soundtrack and occasional astronautical communication loop, pushing the presentation into the hyperreal world of astronautical visualizations. It is not of the quality usually displayed by the work of Frassinito and Associates, a long-time “visualization” contractor whose mostly anonymous work as the graphic face of NASA comes out of an unassuming office I visited as the Constellation vehicles were being designed. However, it enacts the founding astronautical expectation voiced by President Kennedy that "a man" will be sent and returned "safely to Earth." After the animation played, the question and answer session is dominated by requests for information about the NEO hazard and the mission's risks, including concerns that visiting a NEO might nudge it toward an Earth impact, which Abell discounted, saying that it would be a prime opportunity to test out theories about using gravitational attraction to alter a NEO's orbit – integrating the B612 Foundation's objective into a human mission.

Landis takes a moment to invoke Apollo 8's landmark view of the whole Earth from the moon, the "whole other picture" of the tiny Earth that invokes Carl Sagan's hopes for species-wide enlightenment from the image of the Earth as a "pale blue dot." Landis turns this perspective into an extreme challenge, saying that this is the pre-Mars mission that answers a fundamental question:

> Are we really in this space exploration business or are we a bunch of candy-ass sunshine explorers?

The audience erupts with laughter, but the implication, styled by an ex-Air Force cadet's rough interrogative, is clear: the NEO option is an exploration alternative whose adoption or dismissal says something about "we" in the form of the U.S. space program and human beings. Space artist Pat Rawlings' beautifully detailed painting "Summit" (opening graphic in this chapter) portrays two NASA astronauts as the opposite of candyass, two daring and agile rock-climber geologists on the "NEO I" mission, one hanging off a net, rock in hand, habitat module waiting nearby and seemingly larger than Earth.

The NEOverse and the Flexible Path

After the Obama administration's review of a human spaceflight "Program of Record" (formerly known as Constellation) in crisis because of "goals that do not match allocated resources,"[97] the NEO mission option's campaign success was evident. In the Augustine Commission's task to "[Seek] a Spaceflight Program Worthy of A Great Nation," the NEO mission concept became the centerpiece in one of three options to make NASA's program, in the commission's words, "sustainable." An alternative to the two other lunar mission options, the "Flexible Path" option would take crews to a non-planetary sites without "deep gravity wells" – such as NEOs, the moons of Mars, or Lagrange points – to "extend our presence in free space."[98]

> The Flexible Path represents a different type of exploration strategy. We would learn how to live and work in space, to visit small bodies, and to work with robotic probes on the planetary surface. It would provide the public and other stakeholders with a series of interesting "firsts" to keep them engaged and supportive. Most important, because the path is flexible, it would allow for many different options as exploration progresses, including a return to the Moon's surface or a continuation directly to the surface of Mars.

This is the American cultural concept of "flexibility" that Emily Martin finds in the discursive valorization of a fit human immune-response system, scaled up to the level of the heliospheric. The Flexible Path offers a nimble mission system architecture that is innovative and variable, is virtuously responsive to environmental change (in outer space or in budgets), and permits forward motion to the ever-receding high ground from which to claim technical and political prestige. This prestige comes in the form of an environmentally adaptive flexibility that transcends the standard territorial stability that comes with planting footprints and flags on planetary soil.

In the two years between Abell and Landis's talk and the Augustine Commission's recommendations, the NEOphiles collected a digital library about the rise of NEOs and the NEO mission in media. It included Gregg Easterbrook's article "The Sky is Falling" about NASA's irresponsible attitude toward the NEO threat in *The Atlantic* (included in *Best American Science Writing of 2009*),[99] a cover story on the crewed mission option in the July 2008 Smithsonian Air & Space magazine,[100] and Star Trek science consultant André Bormanis's piece for the Planetary Society's *Planetary Report* called the "Million Mile Mission"[101] that is as much about the "asteroid underground's" struggle to get their concept recognized as it is about the concept itself. In my conversations with NEOphiles, we would play with "neo" as prefix or referent, such as playing with the link between the NEOphile efforts and science fiction movie series "The Matrix," featuring the savior character "Neo" who is "called" to save humanity from enslavement as biological energy sources and virtual reality inhabitants for a computer operating system. The NEO mission also invokes Protestant Christian understandings of the relationship between callings, salvation, and heavenly promises and reward. However, the NEOphiles see "salvation" not as liberation from technology, but as an increase in the capacity of humans to systematically reduce their technological and environmental vulnerabilities. Those ideas took an explicitly American historical form in shape of a NEO mission study called "Plymouth Rock" sent to Landis for review by engineers at Lockheed Martin in 2009. Reflecting on this rich social and symbolic field coalescing around NEOs, Landis had came to refer to this alternative space of transcendentalism, randomness, material and ideational synergies, grassroots enthusiasms, and, eventually, the emergence of political and industrial endorsement for the mission, as "the NEOverse."

The "NEOverse" is in many ways an apt interpretive metaphor. It not only describes the study's constitution, through work and struggle, of an alternative mission advocacy space but also points to how NEO deflection and mission activism to gain (in a term sometimes used by NEOphiles) "converts" perpetuates new millennial and universalizing visions of human pasts and futures. It indicates the discursive space in which NEOs moved from peripheries to the center of American security and space policy debates, signaling the imaginative contours and social configurations of a planet in crisis and a human-inhabited solar system. As a kind of "alternate universe," it represents the NEO-centered critique of NASA's scientific and exploration programs, legitimating NEO activists' rendering of NEOs as central to human evolutionary next steps. This alternative is not just the result of what Bruno Latour calls a longer network[102] but what Steven Epstein calls a "credibility struggle." In such struggles, people gain support for their scientific and technical ideas and claims not just by having knowledge that appears to be empirically credible within the domain of science, but credible in the face of controversy *about* science[103] -- in this case, credibility in the face of controversy about the future of American human space exploration. The NEOphiles kept track of this controversy, sending out space community commentaries and articles with titles like "Will NASA survive the next 50 years?" The NEOphiles were delighted to report the number of times they began to hear that their mission might "save NASA." In this way, the "NEOverse" appears politically ecological in the sense that Tom Jones portrays it, as a "natural progression" for the future of human missions based on technical theorizations of survival concerned with sustainable exploration-based economies, unlimited environmental extensions, and rational acts of salvation and sacrifice signaling an evolving humanity. In the ecological scientific method of reframing seemingly harmful things as beneficial in other perspectives, NEOs become something more, and more meaningful, than proto-meteorites of doom.

In sum, while NEOs seem to fit neatly into the now comprehensive scholarship on new rationalizations and strategies to control risk and disorder,[104] they are paradoxical risk objects that inspire grand acts of risk-control and risk-taking, and the extension of and escape from risk-governed spaces. NEOs objectify astronautical arguments about how to view cosmic environmental boundaries and the meaning of space technologies of all kinds, adding to data about space weather and orbital debris that objectifies the idea of a "near earth" and even "far earth" environment in need of management.[105] Imagined by their exploration advocates as "stepping stones" to predicted futures in far off-spaces, NEOS are not just referents for the "spatial" but also (to paraphrase spatial historian Paul Carter) the environmental "forms and fantasies through which a culture declares its presence."[106] NEOs beckon minds and bodies outward and onward in ways that re-envision what it means to live in and be transformed by the solar system. NEOecology is an alternatively bounded human ecology, making it possible to circumvent the deep ecology of Spaceship Earth's given requirements and limitations. The passion to engage with NEOs, as I have hoped to illustrate, goes beyond goals to ensure terrestrial safety or expand national territory. It extends a desire, imagined as innate and ever-emergent but grounded in American national and exploratory discourses, to fulfill and be fulfilled by the vitalistic and liberatory promise of the extreme. A promise-dream of being wholly and permanently present, now, in the multi-spatial environment of space.

------//------

[1] I take this self-designation from email salutations; some members also use the term "NEOphytes." This is an informal designation that not all members of the network use, nor is it a designation that the group uses for any official purpose. However, it provides a way to refer to the group/network and their commonly held passion for NEOs.

[2] Star and Griesemer (1989).

[3] Thomas Gieryn's (1983) analysis of how science is always engaged in work to demarcate boundaries between the work it does and other modes of knowledge production, in part based on the difference between the demarcation of the objective from the subjective (see note 5 below), is also relevant to the processes I am describing, especially because it shows how there are gradations and demarcations within the "boundary of science." NEOs were within the authoritative bounds of science, but only tangentially as "astronomical science" objects, which changed when they crossed over into the "environmental science" and "exploration science" boundaries. However, it is precisely the role of the NEO as object in the work of objectifying boundaries and making them objective, on a scalar level in particular, that I am interested in here.

[4] In a review article and introduction to the first part of a special issue of *Revue d'Anthropologie des Connaissances* revisiting the "boundary object" concept as a way to understand shared objects within environmental management issues, Trompette (2009) calls attention to the concept's genesis as a response to the delineation of "ecologies" more broadly thought of as "worlds" than institutions. However, Trompette and the contributors involved in this special issue are still focused on the ecological properties of objects at work, and not on the constitution of ecologies *qua* ecologies. Nevertheless, Trompette usefully points out that Star was a student of Anselm Strauss and as such is interested in the relational creation and negotiation of social environments. This legacy reflects Strauss's importation of ecological metaphors to create "social worlds/arena theory" as a collectivist and interactionist response to positivist organizational theory, in a way that also has the effect of operationalizing "environment" in a way that does not encourage describing it on "its own terms" (Clarke 1991: 124). This is the unproblematized notion of environment and ecology at work in the Star and Griesemer analysis, but their work does inspire questions about how "ecologies" of all kinds are constituted as such through the same interactive and organizationally-focused processes.

[5] Daston (1992: 117). NEOs in this way close the gap on the "overview effect" and its technical/romanic "objectivity" presented in Chapter 1. As with that example, Lorraine Daston's (1992) essay on the process by which "objectivity" is purged of moral and situated perspectival knowledge provides a guidepost for understanding what technical objectivity has become in official and formal discourses and practices. However, astronautical objectivity, as I have attempted to show, is a combination of idealized objectivity and a "from space" perspective considered to be universally and transcendentally "human" in combined epistemological, ontological, emotional, and moral terms.

[6] Nussbaum (2002:388).

[7] See Davis (1998) on the making of modern American "fear ecologies" co-created by environmental crises, development, and media of millenial imaginaries.

[8] Stewart and Harding (1999).

[9] Dyson (2000), introduction to 3rd edition of O'Neill *et al* (2000) *The high frontier: human colonies in space.*

[10] Fujimura (2003).

[11] I mean to underscore the term "actual" in the sense described by Paul Rabinow (2003), as an orienting framework for an anthropology of the contemporary and its ethnographic pursuit its objects of study as apparatuses, problematization, conjunctures, and events. By referring to an actual NASA, I am opposing the idea that "paper NASA" should be understood as ideal and intangible and contained within a "real" NASA, but instead that both are part of the apparatus of technoscientific contest.

[12] Rheinberger (1997: 28).
[13] Barnes-Svarney (1996:23).
[14] Edberg and Levy (1994:102)
[15] Messeri (2009).
[16] See Flammarion and Stableford (2002 [1873)].
[17] Sheehan (1995).
[18] Galison (1997).
[19] Messeri (2009).
[20] Wilson (1958:41).
[21] Strughold (1958: 43).
[22] Strughold (1958: 44).
[23] Cole (1961: 53).
[24] Cole (1961). Science fiction writer George Zebrowski named and based his 1979 novel on this concept, subtitling it "a moble utopia."
[25] Cole (1961: 49).
[26] Cole (1961: 18).
[27] Cole (1961: 50, 58, 60).
[28] Alvarez *et al* (1980: 1110).
[29] See Helmreich (2009: 260 – 263).
[30] Interestingly, the speech that Clinton made to announce this finding was re-mixed in the movie "Contact" as a speech announcing the receipt of an alien communication.
[31] Horneck et al (2008).
[32] http://stardust.jpl.nasa.gov/news/news115.html
[33] Ward and Brownlee (2003).
[34] Schmitz *et al* (2008).
[35] Britt (2001).
[36] Reported as Cole (1963), but unverifiable.
[37] Lewis (1996).
[38] Yeomans (1991).
[39] Ingold (2000).
[40] Dave Morrison, developer of the Ames Research Center "Asteroid and Comet Impact Hazards," (http://impact.arc.nasa.gov/index.cfm), reports this story in a "News Achive" section entitled "Edward Teller (1908-2003) and Defense Against Asteroids" and indicates that these notes on "Teller at Los Alamos, January 1992" are"by David Morrison with Clark Chapman (adapted from an unpublished book manuscript)."
[41] Mellor (2010) recently discusses the ways that asteroid research and military cooperation legitimate the idea of war in space and the development of spacebased weapons and platforms for testing Strategic Defense Initiative systems otherwise opposed politically. Certainly, these proposals bring space scientist and military groups together and perpetuates "the politics of fear" at the heart of US defense policy, as Mellor indicates. However, as I argue further on, there is also scientific and political pushback against the utility of such weapons, and, as I indicate, the story of the proposal to develop nonweaponized NEO mitigation, and to secure international collaboration to do so, is a counter narrative with as many political and social implications for increasing the understanding of scientific, military, and governmental interaction.
[42] Garretson and Kaupa (2007:1).
[43] Morrison (1992: 1.1).
[44] Clarke (1973) Rendezvous with Rama.
[45] Stephen Ostro interview in a 2008 documentary "Planetary Defense."
[46] Classic science fiction with these themes include Jack Williamson's two-novel story of asteroid capitalists (1950, 1951) and Robert Heinlein's (1952) Swiss-family Robinson on an asteroid tale reprinted in 2009, a more recent example is Ben Bova's solar system "Grand Tour" Asteroid Wars mini-series (*Rock Rats* [2002] and *The Silent War* [2004]).
[47] Morrison (2007: 163).
[48] Morrison (2007: 163).
[49] Bobrowsky and Rickman (2007).

[50] Bobrowsky and Rickman (2007: vi).
[51] Bobrowsky and Rickman (2007: vi).
[52] Latour (2004 and 2008).
[53] Beck (1999).
[54] Ibid.
[55] Hewitt (2007).
[56] Chapman (2007).
[57] Morrison (2007).
[58] Morrison (2007).
[59] Hartwell (2007).
[60] Slovic (2007).
[61] Yoemans (2009).
[62] Collier and Lakoff (2008). This quote is available on page 30 of their pre-published online document, available on http://anthropos-lab.net/wp/publications/2008/01/collier-and-lakoff.pdf
[63] http://www.b612foundation.org/about/welcome.html
[64] Gomes (2008: B1).
[65] In *Esalen, America and the Religion of No Religion*, Jeffrey Kripal (2007) documents Schweickart's participation in the California group's project to engineer and promote transcendental consciousness.
[66] http://www.b612foundation.org/info/current_environment.html
[67] Schweickart (2007:13).
[68] Boyle (2009).
[69] Schweickart et al (2008: 46).
[70] Schweickart et al (2008: 46).
[71] Schweickart et al (2008: 46).
[72] Schweickart (2004).
[73] Schweickart (2004:1).
[74] Gomes (2008: B1).
[75] Schweickart et al (2008: 16).
[76] Gomes (2008: B1).
[77] Schweickart et al (2008: 1).
[78] Collier and Lakoff (2008: 27).
[79] Star and Greisemer (1989: 508).
[80] http://blogs.cisco.com/ciscotalk/green/comments/skin_care/
[81] Bakhtin (1984).
[82] Oberg (1998).
[83] Jones (2009).
[84] See Bachelard 2004 and Tuan (1990).
[85] See Ruan (2007).
[86] Korsmeyer et al (2007). This is the title of the study as presented by David Korsmeyer at the International Astronautical Congress in 2007.
[87] Personal correspondence.
[88] William Bainbridge (1983 [1976]) pioneered the view of spaceflight advocacy as a social movement. NASA recently collected perspectives on space flight and exploration advocacy in its conference collection, Societal Impact of Spaceflight. See: Billings (2007), Siddiqi (2007),
[89] See Lakoff (2000).
[90] Mol (2002).
[91] For the story of how graphical representation expert Edward Tufte blamed "viewgraph engineering" as a contributing factor in the Challenger launch decision tragedy see Robison *et al* (2002); accessed online in an earlier form as: "Representation and Misrepresentation: Tufte and the Morton Thiokol Engineers on the *Challenger*" Online Ethics Center for Engineering 8/29/2006 National Academy of Engineering Accessed: Friday, January 22, 2010 <www.onlineethics.org/Resources/Cases/RB-intro/RepMisrep.aspx>
[92] Landis *et al* (2007).
[93] Blumenberg (1987).
[94] Star and Griesemer (1989: 506)
[95] Lo (2002: 18).

---

[96] Lunar Listserv, 2010.
[97] Augustine Commission (2009: 9).
[98] Augustine Commission (2009: 15).
[99] Easterbrook (2008); Easterbrook (2009).
[100] Klesius (2008).
[101] Bormanis (2007).
[102] Latour (1987).
[103] Epstein (1996: 3).
[104] Much of this scholarship can be traced to Ulrich Beck's (1992) much used and equally critiqued sociological definition of "risk society" as the condition in which risk becomes "uninsurable," and his description of "reflexive modernization" as a sensibility that the field of current and future risks is largely anthropogenic. Two recent explorations of on natural hazard mitigation and preparedness cultures (Collier and Lakoff 2008, Collier 2008) take this idea outside its analytic frameworks, looking at how efforts to work with risk reframe notions of what is "at risk" (infrastructures and not humans) and go beyond the archival and calculative to engender collective "enactments" of preparedness that end up also being enactments of the shared features of contemporary collective life. NEO activism an example in this vein, in that it exceeds the bounds of risk management and becomes a heterogeneous project to know the past and plan for the future of collective planetary life.
[105] See also: Portree (1993).
[106] Carter (1988: xxii).

Conclusion

Off a Cliff

As I finished this dissertation, Jeff Volosin, a former Headquarters engineer and policy official with a history in NASA and who was deeply involved in Constellation when I met him in 2007 wrote in the online space community information clearinghouse, *SpaceRef*:

> I mean no disrespect - but - I am tired of listening to [...] all of [the] whiney, Baby Boomer, Cold Warrior, Manifest Destiny driven individuals who are still trying to live out their 1950's childhood dreams - at taxpayer expense.
>
> Like many of you, for the past 25 years, I have played my own minor role in a vibrant NASA. I have watched as NASA has pushed back the limits of robotic exploration of the solar system with ever more complex and capable probes. In addition, I have seen NASA greatly expanded our view of the Earth - helping us better understand how our environment is changing and how human activities and natural processes contribute to that change. In contrast, human spaceflight has, just during my career, driven off a cliff. [....] Maybe our (by "our" I mean those of us directly supporting or passionately connected to NASA) problem is that we can't let go of our collective childhood dream. ...[...] humans were always front and center in this vision - well not just humans - Americans. So - in some ways - I hate to shake off this dream as much as anyone - but - would it be sacrilegious to say it - maybe this vision no longer applies to the world that exists in the 21st century. [...] These individuals didn't know how computer and robotic technologies would evolve - how virtual presence would provide large numbers of humans with opportunities to experience all sorts of environments through surrogates - without the need for a human to always be directly involved on the pointy-end of exploration. [...] NASA for the 21st century is waiting to be defined - let's all try to focus on shaking off that past - and using the creativity, inspiration and capability of the younger generations of this Agency and this country - to go boldly - and I mean boldly - into the future.
>
> Ad Astra Per Aspera!!!![1]

Volosin was not sad to see Constellation, the human spaceflight program he helped to launch, come to an end, but he still invokes one version of the decades-old human space exploration motto, "through adversity, to the stars."

As anthropologist Robbie Davis-Floyd noted in interviews with human spaceflight principals during the short-lived early 1990s lunar return program that Constellation was supposed to resurrect for the twenty-first century, astronautics advocates such as Volosin, whether they lean toward robotics or human space exploration, connect the human future in general to the future of human environmental engagements and mastery.[2] In her interviews, Davis-Floyd describes how astronautics practitioners justify their vision of human extension into the solar system by labeling it an "opportunity to become the greatest cultural project in human history by evolving us into a spacefaring global community living compassionately within planetary limits."[3]

Today, human space exploration is at a crossroads, and it's difficult to tell if the astronautical vision of ecological order and mastery will continue to involve spacefaring humans or not. As Wendell Mendell, lunar scientist and a NASA sage known affectionately as the "Obi Wan Kenobi" of Johnson Space Center, told me: "We are trying to move a huge machine into the future, but we don't have mechanisms for attaching people to it." As a result, the goals and purpose of embodied human space exploration and of human- (versus science) centered space remote sensing regimes are being called into question on fundamental terms. While Volosin labels this a welcome shift away from the designs of territorial empire, an equally experienced NASA manager told me once that NASA's new exploration directions were being laid out by elites she did not recognize at lobbying events, who appeared to operate outside of the old military-industrial complex network from which NASA was born. It is tempting to see something natural and even progressive in a shift away from embodied, government-funded space exploration projects and the established elites who controlled it for political purposes.

However, it is not clear such a shift can or will happen. In addition, it is important to ask questions about the emergent forms and politics of such a shift: What does it mean when national policies begin to define extreme environment exploration and monitoring as exclusively scientific, remote, and virtual? What is the significance of the concurrent American political and economic focus on virtual "participatory exploration," virtual warfare, and remote or virtual environmental management technologies? What will the human "experience" of the space/cosmic environment become? As I ended this dissertation project, these were the questions I can imagine investigating next, along with the question of what significance space environments like the Moon and Mars have for contemporary American national future-visions and policies.

In this dissertation, I have attempted to portray outer space as a spatial and temporal "American extreme," and to analyze how that extreme is made technoscientifically, cosmologically, and futuristically relevant to the environmental understanding of what it means to be American and human. My fieldsite was not just NASA centers but also the lifespan of a human spaceflight program, Constellation. Although Constellation was on the chopping block for cancellation in early 2010, the outer space extreme continues to be incorporated as a site within which to scale up the production of knowledge about humans as environmental and ecological beings. Whether or not government-funded exploration will involve humans at its (in Volosin's words) "pointy end," American remote sensing technologies will continue provide the authoritative vantage point from which to observe, characterize, and manage a total human planetary and cosmic environment. Meanwhile, the future of human spaceflight is likely to be worked out in entrepreneurial sectors and within internationally networked venues. A dated enterprise in its current form that is understood to have fallen short of expectations and dreams, NASA human spaceflight today occupies both a domain of extreme privilege but is also on the way to being temporarily or permanently "parked" at the margins of contemporary spatial politics. As a now formally-designated aspect of American "folk-life," American human spaceflight occupies what Kathleen Stewart calls a "space at the side of the road." Its discourses and activities carry the mark of historical authenticity but are also commonly regarded as tangential or peculiar, chronically in search of justification, part of the past, something that is on the edge of the cliff, where cliffs are extreme sites at which people confront unknown horizons, total ends or beginnings that are voluntary or involuntary, material and spiritual transformations. Whether or not human spaceflight totally falls "off the cliff" in the U.S. to become a thing of the past, an astronautical road forward, toward more powerful means of knowing and managing a human environment understood as planetary and also greater than the planet, will go on.

In this dissertation, I have argued that cosmology and ecology have been and continue to be co-constituting in American astronautics. I have supported that with evidence from participant observation, interviews, non-participant observation, and archival research. I examined the legitimation of extreme environments as truth-making and progress-manifesting spaces, the "ecobiopolitics" of space biomedicine's attempts to manage humans as environmental sub-systems, the making of "habitability" as a key elaborating concept for work on comprehensively environmentally integrated and sustainable space habitats that are understood to be relevant to the terrestrial future, and on the ways Near-Earth asteroids and comets have become both astronomical and environmental objects, implicated the heliosphere as domain of environmental politics, policy, and essential truths about humans as cosmically ecological beings.

In all of these NASA endeavors, during a time of deep uncertainly for the future of human spaceflight, it was clear to astronautics boosters of either the human or robotics sides or both, that they shared a fear that if human space exploration (embodied or otherwise) goes "off a cliff," so do humans. This idea is tied to science-fiction-inspired and scientifically-informed American worries about the end of planet Earth; within astronautics this fear is complex, tied to fears about national and ecological failures, either by human hands or by the inevitable end of the Earth's habitability in the heliosphere. But it is also tied to the romance of seeking the high-ground and knowledge achieved through challenge and environmental adaptation. In her converstations with astronautics advocates, Robbie-Davis Floyd was asked by an interlocutor, Mark Craig, a senior NASA engineer-manager I also came to know, what she thought about "the future of humans in space." She responded that she got "carried away" and reinterpreted the question for him: "The real question is not 'What is the future of humans in space?' but 'What is the future of humans?'" To which Craig responded: "Yes, of course." Regardless of one's understanding of what astronautics has to do with that future, it is the logic of these connections, the imbrications of human ecology and cosmology in American astronautics, that I have tried to illuminate in this dissertation.

------//------

[1] Volosin (2010). http://www.spaceref.com/news/viewnews.html?id=1378
[2] Davis-Floyd (2000).
[3] Davis-Floyd (2000: 433).

Bibliography

Abrams, M. H. 1971. *Natural supernaturalism; tradition and revolution in romantic literature*. New York: Norton.

Ackmann, M. 2003. *The Mercury 13 : the untold story of thirteen American women and the dream of space flight*. New York: Random House.

Adams, C. 2002. "Sociokinetic analysis as a tool for optimization of environmental design," in *Isolation: NASA experiments in closed-environment living, Science and technology series*. Edited by H. W. Lane, R. L. Sauer, and D. L. Feeback, pp. 165 - 175. San Diego, California: Univelt, for American Astronautical Society.

— 2003. "An interview with Constance Adams, architect for the TransHab inflatable space station module," in *Hobby Space: http://www.hobbyspace.com/AAdmin/archive/Interviews/Systems/ConstanceAdams.html*.

Agamben, G. 1998. *Homo sacer : sovereign power and bare life*. Stanford, Calif.: Stanford University Press.

Alder, K. 2007. Introduction: Thick Things. *Isis* 98:80-83.

Alvarez, L. W., W. Alvarez, F. Asaro, and H. V. Michel. 1980. Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science as Culture* 208:1095-1108.

Anonymous. 2008. "Humans vs. robots," in *Air & Space Magazine*: Smithsonian.

Arendt, H. 2006. "The conquest of space and the stature of man," in *Between past and future: eight exercises in political thought*. New York: Penguin Books.

Aristotle, and G. A. Kennedy. 2007. *On rhetoric : a theory of civic discourse*, 2nd edition. New York: Oxford University Press.

Art Center College of Design (Pasadena, C. 2003. "Reach," in *NASA Means Business student competition 2003*. Edited by T. S. G. Consortium.

Ashcroft, F. M. 2000. *Life at the extremes*. Berkeley: University of California Press.

Atwill, W. D. 1994. *Fire and power : the American space program as postmodern narrative*. Athens: University of Georgia Press.

Augustine Commission. 2009. "Review of human spaceflight plans committee." Washington, D.C.: White House Office of Science and Technology Policy.

Bachelard, G., and M. Jolas. 1994. *The poetics of space*. Boston: Beacon Press.

Baer, H. 2009. A field report on the critical anthropology of global warming: a view from a transplanted American downunder *Dialectical Anthropology* 33:79 - 85.

Bainbridge, W. S. 1983. *The spaceflight revolution : a sociological study*, Repr. edition. Malabar, Fla.: Krieger.

Bakhtin, M. M. 1984. *Rabelais and his world*, 1st Midland book edition. Bloomington: Indiana University Press.

Bass, D. S., R. C. Wales, and V. L. Shalin. 2005. "Choosing Mars time: analysis of the Mars Exploration Rover experience," NASA: http://ti.arc.nasa.gov/m/pub/878h/0878%20(Wales).pdf.

Baudrillard, J. 1994. *Simulacra and simulation. The Body, in theory.* Ann Arbor: University of Michigan Press.

BBC. 2004. "Space Odyssey: Voyage to the Planets." DVD.

Beck, U. 1992. *Risk society : towards a new modernity.* London ; Newbury Park, Calif.: Sage Publications.

Beer, G. 1983. *Darwin's plots : evolutionary narrative in Darwin, George Eliot, and nineteenth-century fiction.* London ; Boston: Routledge & Kegan Paul.

Bell, L. 1991. "IDEEA ONE: The First International Design for Extreme Environments Assembly." *University of Houston Hilton: November 12 - 15, 1991.*

Benjamin, M. 2003. *Rocket dreams : how the space age shaped our vision of a world beyond.* New York: Free Press.

Berleant, A. 1992. *The aesthetics of environment.* Philadelphia: Temple University Press.

Bernard, H. R. 1998. *Handbook of methods in cultural anthropology.* Walnut Creek, Calif.: AltaMira Press.

Bijker, W. E., T. P. Hughes, and T. J. Pinch. 1987. *The social construction of technological systems : new directions in the sociology and history of technology.* Cambridge, Mass.: MIT Press.

Billings, L. 2007. "Overview: ideology, advocacy, and spaceflight -- evolution of a cultural narrative," in *Societal Impact of Spaceflight.* Edited by S. J. Dick and R. D. Launius, pp. 484 - 499. Washington, D.C.: National Aeronautics and Space Administration.

Blumenberg, H. 1987. *The genesis of the Copernican world. Studies in contemporary German social thought*. Cambridge, Mass.: MIT Press.

Bobrowsky, P. T., and H. Rickman. 2007. *Comet/asteroid impacts and human society : an interdisciplinary approach*, 1st edition. Berlin ; New York: Springer.

Bormanis, A. 2007. Worlds beyond. *The Planetary Report* 27.

Boston, P. 1999. "The search for extremophiles on Earth and beyond: What is extreme here may be just business-as-usual elsewhere." Edited by A. A. Magazine: Astrobiology Web: http://www.astrobiology.com/adastra/extremophiles.html.

Bova, B. 2002. *The rock rats*, 1st edition. New York: Tor.

— 2004. *The silent war*, 1st edition. New York: Tor Books.

Bowker, G. C., and S. L. Star. 1999. *Sorting things out : classification and its consequences. Inside technology*. Cambridge, Mass.: MIT Press.

Boyer, D. 1995. The corporeality of expertise. *Ethnos* 70: 243-266.

Boyle, R. 2009. Flying up to meet asteroids: A proposed NASA mission to intercept an ill-omened rock in the sky. *Popular Science* PopSci: The Future Now (blog): Posted 03.25.2009: http://www.popsci.com/military-aviation-amp-space/article/2009-03/flying-meet-asteroids.

Brosius, J. P. 1990. *After Duwagan : deforestation, succession, and adaptation in Upland Luzon, Philippines. Michigan studies of South and Southeast Asia ; no. 2*. [Ann Arbor]: Center for South and Southeast Asian Studies, University of Michigan.

Buell, L. 1995. *The environmental imagination : Thoreau, nature writing, and the formation of American culture*. Cambridge, MA: Belknap Press of Harvard University Press.

Burrough, B. 1998. *Dragonfly : NASA and the crisis aboard MIR*, 1st edition. New York, NY: HarperCollinsPublishers.

Campbell, M. B. 1999. *Wonder & science : imagining worlds in early modern Europe*. Ithaca: Cornell University Press.

Canguilhem (tran. John Savage), G. 2001. The Living and Its Milieu. *Grey Room* 3:7 - 31.

Carroll, J. M. 2000. *Making use : scenario-based design of human-computer interactions*. Cambridge, Mass.: MIT Press.

Carsten, J., and S. Hugh-Jones. 1995. *About the house : Lévi-Strauss and beyond.* Cambridge ; New York: Cambridge University Press.

Carter, P. 1988. *The road to Botany Bay : an exploration of landscape and history*, 1st American edition. New York: Knopf.

Casper, M. J. 1998. *The making of the unborn patient : a social anatomy of fetal surgery.* New Brunswick, N.J.: Rutgers University Press.

Casper, M. J., and L. J. Moore. 1995. Inscribing bodies, inscribing the future: gender, sex, and reproduction in outer space. *Sociological Perspectives* 38:311-333.

Center for Cultural Studies and Analysis. 2004. "American perception of space exploration: A cultural analysis for NASA." Philadelphia, PA: Center for Cultural Studies & Analysis. http://esdepo.gsfc.nasa.gov/docs/files/NASA_Analysis.pdf.

Certeau, M. d. 1984. *The practice of everyday life*. Berkeley: University of California Press.

Chang, K. 2009. "Recovered Pieces of Asteroid Hold Clues to Early History . New York: New York Times: www.nytimes.com/2009/03/26/science/space/26asteroid.html.

Chapman, C. 2007. "The asteroid impact hazard and interdisciplinary issues," in *Comet/asteroid impacts and human society: an interdisciplinary approach.* Edited by P. T. Bobrowsky and H. Rickman, pp. 145 - 162. Berlin ; New York: Springer.

Clarke, A. 1991. "Social worlds/arenas theory as organizational theory," in *Social organization and social process : essays in honor of Anselm Strauss*. Edited by D. R. Maines, pp. 119-158. New York: Aldine de Gruyter.

Clarke, A. C. 1973. *Rendezvous with Rama*, [1st edition. New York,: Harcourt Brace Jovanovich.

Clarke, A. E., J. K. Shim, L. Mamo, J. Ruth Fosket, and J. R. Fishman. 2003. Biomedicalization: technoscientific transformations of health, illness, and U.S. biomedicine. *American sociological review* 68:161 (34 pages).

Cohen, E. 2004. *Contemporary tourism : diversity and change*, 1st edition. *Tourism social science series*. Boston: Elsevier.

Cole, D. 1961. Macro-Life. *Space World* 1:44-46.

— 1961. Social and political implications of the ultimate human society. *The American Astronautical Society.*

— 1963. $50,000,000,000,000 from the Asteroids. *Space World* 4:1-8.

Collier, S. J. 2008. Enacting catastrophe: preparedness, insurance, budgetary rationalization. *Economy and Society* 37:224 - 250.

Collier, S. J., and A. Lakoff. 2005. "On regimes of living," in *Global assemblages: technology, politics, and ethics as anthropological problems*. Edited by A. Ong and S. J. Collier, pp. 22 -39. Malden, MA: Blackwell.

— 2008. "The vulnerability of vital systems: how "critical infrastructure" became a security problem," in *Securing 'the homeland' : critical infrastructure, risk, and (in)security*. Edited by M. Dunn Cavelty and K. S. Kristensen. Milton Park, Abingdon, Oxon ; New York: Routledge.

Collins, H. M. 1992. *Changing order : replication and induction in scientific practice*. Chicago: University of Chicago Press.

Conley, V. A. 1997. *Ecopolitics : the environment in poststructuralist thought. Opening out*. London ; New York: Routledge.

Cook, P., and Archigram (Group). 1973. *Archigram*. New York,: Praeger Publishers.

Cooper, H. S. F. 1987. *Before lift-off : the making of a space shuttle crew. New series in NASA history*. Baltimore: Johns Hopkins University Press.

Coyne, R. 1999. *Technoromanticism : digital narrative, holism, and the romance of the real*. Cambridge, Mass.: MIT Press.

Csordas, T. J. 1994. *Embodiment and experience : the existential ground of culture and self. Cambridge studies in medical anthropology ; 2*. Cambridge ; New York: Cambridge University Press.

Cutting, A. 2009. Ashes in orbit: Celestis Spaceflights and the invention of post-cremationist afterlives *Science as Culture* 18:355–369.

Daston, L. 1992. Objectivity and the escape from perspective. *Social Studies of Science* 22:597 - 618.

— 2004. *Things that talk : object lessons from art and science*. New York; Cambridge, Mass.: Zone Books, MIT Press [distributor].

Davis, M. 1998. *Ecology of fear : Los Angeles and the imagination of disaster*, 1st edition. New York: Metropolitan Books.

Davis-Floyd, R. 2000. "Commercializing outer space: the SATWG stories," in *Para-sites: a casebook against cynical reason*. Edited by G. Marcus. Chicago: University of Chicago Press.

Davis-Floyd, R., and J. Dumit. 1998. *Cyborg babies : from techno-sex to techno-tots.* New York: Routledge.

de Laet, M., and A.-M. Mol. 2000. The Zimbabwe bush pump. *Social Studies of Science* 30:225-263.

Deleuze, G., and F. Guattari. 1987. *A thousand plateaus : capitalism and schizophrenia.* Minneapolis: University of Minnesota Press.

Dethloff, H. C. 1993. *Suddenly, tomorrow came...: a history of the Johnson Space Center. Nasa Sp ; 4307.* Washington, D.C. and Houston, Tex.: National Aeronautics and Space Administration, Lyndon B. Johnson Space Center.

Diprose, R. 2008. Biopolitical technologies of prevention. *Health Sociology Review* 17:141-150.

Douglas, M. 1982. *Natural symbols : explorations in cosmology*, 1st Pantheon paperbacks edition. New York: Pantheon Books.

Dovey, K. 2005. "The silent complicity of architecture," in *Habitus : a sense of place* 2nd edition. Edited by J. Hillier and E. Rooksby, pp. xiv, 427 p. Aldershot, Hants, England ; Burlington, VT: Ashgate.

Downey, G. L., and J. Dumit. 1997. *Cyborgs & citadels : anthropological interventions in emerging sciences and technologies*, 1st edition. *School of American Research advanced seminar series.* Santa Fe, N.M.: School of American Research Press.

Driver, F. 2001. *Geography militant : cultures of exploration and empire.* Oxford, UK ; Malden, Mass., USA: Blackwell Publishers.

Driver, F., and L. Martins. 2005. *Tropical visions in an age of empire.* Chicago: University of Chicago Press.

Dunbar, K. 1995. How scientists really reason: scientific reasoning in real-world laboratories. *Journal of Applied Developmental Psychology* 21:49-58.

du Preez, A. 2009. The sublime and the cultures of the extreme: an exploration. *Communicatio* 35:201 - 218.

Dyson, F. 2000. "Introduction," in *The high frontier : human colonies in space*, 3rd edition. Edited by G. K. O'Neill and D. Gump, pp. 183 p. Burlington, Ont., Canada: Apogee Books.

Earle, S. 2002. "Testimony of Sylvia Earle explorer-in-residence, National Geographic Society and founder Deep Ocean Exploration and Research, Inc (based n meeting transcript)," in *U.S. Commission on Ocean Policy* Northwest Regional Meeting edition. Seattle, Washington.

Easterbrook, G. 2008. "The sky is falling " in *The Atlantic*, vol. 301: June, pp. 74 - 84.

— 2009. "The sky is falling," in *The best American science writing*, 2009. Edited by N. Angier, pp. 288 - 305. New York: Harper Perennial.

Edberg, S. J., and D. H. Levy. 1994. *Observing comets, asteroids, meteors, and the zodiacal light. Practical astronomy handbook series ; 5*. Cambridge [England] ; New York: Cambridge University Press.

Elliott, C. 2003. *Better than well : American medicine meets the American dream*, 1st edition. New York: W.W. Norton.

Epstein, S. 1996. *Impure science : AIDS, activism, and the politics of knowledge. Medicine and society*. Berkeley: University of California Press.

Fabian, J. 2002. *Time and the other : how anthropology makes its object*. New York: Columbia University Press.

Finkelstein, V. 1980. *Attitudes and disabled people : issues for discussion*. New York, N.Y.: International Exchange of Information in Rehabilitation.

Finney, B. R., and E. M. Jones. 1985. *Interstellar migration and the human experience*. Berkeley: University of California Press.

Finney, G. 2008. "Faro Cricket: inner space," in *Squob*: September 8, 2008. http://squob.com/travel_trailers/faro-cricket-inner-space/.

Flammarion, C., and B. M. Stableford. 2002. *Lumen. The Wesleyan early classics of science fiction series*. Middletown, Conn.: Wesleyan University Press.

Fortun, K. 2001. *Advocacy after Bhopal : environmentalism, disaster, new global orders*. Chicago: University of Chicago Press.

Fortun, M. 2005. For an ethics of promising, or: a few kind words about James Watson. *New Genetics & Society* 24:157-174.

Foss, S. K. a. C. L. G. 1995. Beyond persuasion: a proposal for an invitational rhetoric. *Communication Monographs* 62:1 - 18.

Foucault, M. 1973. *Madness and civilization; a history of insanity in the Age of Reason*. New York,: Vintage Books.

— 1994. *The birth of the clinic : an archaeology of medical perception*. New York: Vintage Books.

— 1995. *Discipline and punish : the birth of the prison*, 2nd Vintage Books edition. New York: Vintage Books.

Fraser, T. M. 1968. "The intangibles of habitability during long duration space missions. NASA CR-1084."

Frickel, S. 2004. *Chemical consequences : environmental mutagens, scientist activism, and the rise of genetic toxicology*. New Brunswick, N.J.: Rutgers University Press.

Fujimura, J. 2003. "Future Imaginaries: Genome scientists as sociocultural entrepreneurs," in *Genetic nature/culture: Anthropology and science beyond the two-culture divide*. Edited by A. H. Goodman, pp. 176-195. Ewing, NJ: University of California Press.

Fuller, R. B. 1973. *Earth, inc*. Garden City, N.Y.,: Anchor Press.

Galison, P. 1997. *Image and logic : a material culture of microphysics*. Chicago: University of Chicago Press.

Garb, Y. 1985. The use and abuse of the whole Earth image. *Whole Earth Review* 45:18-25.

Garretson, P., and D. Kaupa. 2007. "Planetary defense: potential Department of Defense mitigation roles," in *1st IAA Planetary Defense Conference: Protecting Earth from Asteroids*. Washington, D.C.

Gauthier, D. J. 1995. Martin Heidegger, Emmanual Levinas, and the politics of dwelling, Dissertation: Louisiana State University and Agriculture and Mechanical College.

Gelernter, D. H. 1997. *Machine beauty : elegance and the heart of technology*, 1st edition. *MasterMinds*. New York: Basic Books.

Gieryn, T. 1983. Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists. *American Sociological Review* 48.

Godin, B. 1997. The rhetoric of a health technology: the microprocessor patient card. *Social Studies of Science* 27:865-902.

Gomes, L. 2008. "Keeping the Earth asteroid-free takes science, soft touch," in *Wall Street Journal*.

Gray, L. 2008. "Making some connections," in *Houston Chronicle*, pp. 1 - 3. Houston.

Griesemer, J. R. 1990. Modeling in the museum: on the role of remnant models in the work of Joseph Grinnell. *Biology and Philosophy* 5:3-36.

Grieve, R. A. F., and D. A. Kring. 2007. "The geologic record of destructive impact events on Earth," in *Comet/asteroid impacts and human society : an interdisciplinary approach*, 1st edition. Edited by P. T. Bobrowsky and H. Rickman, pp. 3 - 24. Berlin ; New York: Springer.

Gusterson, H. 1996. *Nuclear rites : a weapons laboratory at the end of the Cold War.* Berkeley: University of California Press.

Hacking, I. 1986. "Making up people," in *Reconstructing individualism: autonomy, individuality, and the self in Western thought* Edited by T. C. Heller, M. Sosna, and D. E. Wellbery, pp. 222-236.

Hallyn, F. 2000. *Metaphor and analogy in the sciences*. Dordrecht ; Boston: Kluwer Academic Publishers.

Handberg, R. 2003. *Reinventing NASA : human space flight, bureaucracy, and politics*. Westport, Conn.: Praeger.

Haraway, D. J. 1991. *Simians, cyborgs, and women : the reinvention of nature*. New York: Routledge.

— 1995. "Cyborgs and symbionts: living together in the New World Order," in *The Cyborg Handbook*. Edited by C. H. Gray, pp. xi - xx. New York: Routledge.

Harding, R. 1989. *Survival in space : medical problems of manned spaceflight*. London ; New York: Routledge.

Hargrove, E. C. 1986. *Beyond spaceship earth : environmental ethics and the solar system*. San Francisco: Sierra Club Books.

Harper, K. M. 2001. Introduction: the environment as master narrative: discourse and identity in environmental problems. *Anthropological Quarterly* 74:101-103.

Hartwell, W. T. 2007. "The sky on the ground: celestial objects and events in archaeology and popular culture," in *Comet/asteroid impacts and human society: an interdisciplinary approach*. Edited by P. T. Bobrowsky and H. Rickman, pp. 71 - 87. Berlin ; New York: Springer.

Heidegger, M. 1975. *Poetry, language, thought*, [1st edition. New York,: Harper Colophon.

Heinlein, R. A. 2009. *The rolling stones*. New York: Baen Books.

Helmreich, S. 1998. *Silicon second nature : culturing artificial life in a digital world.* Berkeley: University of California Press.

— 2006. The signature of life: designing the astrobiological imagination. *Grey Room* 23:66-95.

— 2009. *Alien ocean : anthropological voyages in microbial seas.* Berkeley: University of California Press.

Henderson, K. 1999. *On line and on paper : visual representations, visual culture, and computer graphics in design engineering. Inside technology.* Cambridge, Mass.: MIT Press.

Henry, H., and A. Taylor. 2009. Re-thinking Apollo: envisioning environmentalism in space. *Sociological Review* 57:190 - 203.

Hersch, M. 2009. Checklist: the secret life of Apollo's 'fourth crewmember'. *Sociological Review* 57:6-24.

— 2009. High fashion: The women's undergarment industry and the foundations of American spaceflight. *Fashion theory: The journal of dress, body & culture* 13:345-370.

Hesse, M. B. 1966. *Models and analogies in science.* [Notre Dame, Ind.]: University of Notre Dame Press.

Hewitt, K. 2007. " Social perspectives on comet/asteroid Impact (CAI) hazards: technocratic authority and the geography of social vulnerability " in *Comet/asteroid impacts and human society: an interdisciplinary approach.* Edited by P. T. Bobrowsky and H. Rickman, pp. 399 - 415. Berlin ; New York: Springer.

Hitt, D., O. K. Garriott, and J. Kerwin. 2008. *Homesteading space : the Skylab story.* Lincoln: University of Nebraska Press.

Hogle, L. F. 2005. Enhancement technologies and the body. *Annual Review of Anthropology* 34:695-716.

Horneck, G., D. Stöffler, S. Ott, U. Hornemann, C. S. Cockell, R. Moeller, C. Meyer, J.-P. de Vera, J. Fritz, S. Schade, and N. A. Artemieva. 2008. Microbial rock inhabitants survive hypervelocity impacts on Mars-like host planets: first phase of lithopanspermia experimentally tested. *Astrobiology* 8:17- 44.

Ingold, T. 2000. *The perception of the environment : essays on livelihood, dwelling & skill*. London ; New York: Routledge.

Institute of Medicine (U.S.). Committee on Creating a Vision for Space Medicine during Travel Beyond Earth Orbit., J. Ball, and C. H. Evans. 2001. *Safe passage : astronaut care for exploration missions*. Washington, D.C.: National Academy Press.

Jablonski, N. G. 2006. *Skin : a natural history*. Berkeley: University of California Press.

Jasanoff, S., and M. L. Martello. 2004. *Earthly politics : local and global in environmental governance. Politics, science, and the environment*. Cambridge, Mass.: MIT Press.

Jones, T. D. 2009. The view from here: planetology and the future of our speces. *Aerospace America* 47:20 - 22.

Jordanova, L. J., R. Porter, and British Society for the History of Science. 1979. *Images of the Earth : essays in the history of the environmental sciences*. Chalfont St. Giles: British Society for the History of Science.

Kamler, K. 2004. *Surviving the extremes : a doctor's journey to the limits of human endurance*, 1st edition. New York: St. Martin's Press.

Keating, P., and A. Cambrosio. 2000. Biomedical Platforms. *Configurations 8, no* 3:337-387.

— 2003. *Biomedical platforms : realigning the normal and the pathological in late-twentieth-century medicine. Inside technology*. Cambridge, Mass.: MIT Press.

Keller, E. F. 2002. *Making sense of life : explaining biological development with models, metaphors, and machines*. Cambridge, Mass.: Harvard University Press.

Kennedy, K. 2009. "Vernacular of space architecture," in *Out of this world : the new field of space architecture*. Edited by A. S. Howe and B. Sherwood. Reston, VA: American Institute of Aeronautics and Astronautics.

Kennedy, K., and C. Adams. 2004. "ISS TransHab: An inflatable habitat" (unspecified conference abstract obtained from source).

Kirby, D. 2010. The future is now: diegetic prototypes and the role of popular films in generating real-world technological development. *Social Studies of Science* 40:41-70.

Klerkx, G. 2004. *Lost in space : the fall of NASA and the dream of a new space age*, 1st edition. New York: Pantheon Books.

Klesius, M. 2008. The million mile mission. *Air & Space Magazine*:6.

Kohler, R. E. 2002. *Landscapes & labscapes : exploring the lab-field border in biology*. Chicago: University of Chicago Press.

Korsmeyer, D. J., R. R. Landis, and P. A. Abell. 2007. "Into the beyond: A crewed mission to a Near-Earth Object," in *International Astronautical Congress*. Hyderabad, India.

Koselleck, R. 1985. *Futures past : on the semantics of historical time. Studies in contemporary German social thought*. Cambridge, Mass.: MIT Press.

Kosslyn, J. S. a. S. 2005. Mini-cog rapid assessment battery: developing a "blood pressure cuff for the mind". *Aviation Space and Environmental Medicine* 76:B192 - B197.

Kosut, M. (forthcoming). "Extreme bodies/extreme culture," in *Fleshed Out: Key Readings in Social and Cultural Studies of the Body*. Edited by L.-J. Moore and M. Kosut: New York University Press.

Kotarba, J. 1983. Social control function of holistic health care in bureaucratic settings: The case of space medicine. *Journal of Health and Social Behavior* 24:275-288.

Krauss, L. M. 2009. "A One-Way Ticket to Mars " in *The New York Times*.

Kripal, J. J. 2007. *Esalen : America and the religion of no religion*. Chicago: University of Chicago Press.

Kroll-Smith, S., S. R. Couch, and B. K. Marshall. 1997. Sociology, extreme environments and social change *Current Sociology* 45:1-18.

Kuhn, T. S. 1996. *The structure of scientific revolutions*, 3rd edition. Chicago, IL: University of Chicago Press.

Lakoff, G., and R. E. Nâuänez. 2000. *Where mathematics comes from : how the embodied mind brings mathematics into being*, 1st edition. New York, NY: Basic Books.

Lambright, W. 1994. The political construction of space satellite technology. *Science, technology, and human values* 19:47 - 49.

Lambright, W. H., and A. G. Schaefer. 2004. he political context of technology transfer : NASA and the international space station. *Comparative Technology Transfer and Society* 2:1 - 30.

Landecker, H. 2007. *Culturing life : how cells became technologies*. Cambridge, Mass.: Harvard University Press.

Landis, R. R., D. J. Korsmeyer, P. A. Abell, and D. R. Adamo. 2007. "A piloted Orion flight to a Near-Earth Object: A feasibility study," in *American Institute of Aeronautics and Astronautics Space 2007 Conference*. Longbeach, California.

Larson, W. J., and L. K. Pranke. 2000. *Human spaceflight : mission analysis and design. Space technology series*. New York: McGraw-Hill.

Latour, B. 1987. *Science in action : how to follow scientists and engineers through society*. Cambridge, Mass.: Harvard University Press.

— 1996. *Aramis, or, The love of technology*. Cambridge, Mass.: Harvard University Press.

— 2004. Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry* 30:225-248.

— 2008. *What is the style of matters of concern?* Amsterdam: Van Gorcum.

— 2009. "Spheres and networks: Two ways to reinterpret globalization." Harvard Graduate School of Design

Latour, B., and S. Woolgar. 1986. *Laboratory life : the construction of scientific facts*. Princeton, N.J.: Princeton University Press.

Launius, R. 1999. NASA history and the challenge of keeping the contemporary past. *The Public Historian* 21:63-81.

— 2003. Public opinion polls and perceptions of US human spaceflight. *Space Policy* 19:163-175.

— 2005. "Heroes in a vacuum: The Apollo astronaut as cultural icon," in *43rd AIAA Aerospace Sciences Meeting and Exhibit*. Reno, Nevada.

Launius, R. D., and H. E. McCurdy. 1997. *Spaceflight and the myth of presidential leadership*. Urbana: University of Illinois Press.

Lavery, D. 1992. *Late for the sky : the mentality of the space age*. Carbondale: Southern Illinois University Press.

LaViolette, P. 2006. Green and extreme: free flowing through seascape and sewer. *Worldviews* 10 178-204.

Law, J. 2002. *Aircraft stories : decentering the object in technoscience. Science and cultural theory.* Durham, NC: Duke University Press.

Law, J., and M. Callon. 1988. Engineering and sociology in a military aircraft project: a network analysis of technological change. *Social Problems* 35:284-297.

Lawrence, D., and S. M. Low. 1990. The built environment and spatial form. *Annual Review of Anthropology* 19:453-505.

Le, C. 1986. *Towards a new architecture.* New York: Dover Publications.

Lewis, J. S. 1996. *Mining the sky : untold riches from the asteroids, comets, and planets.* Reading, Mass.: Addison-Wesley Pub. Co.

Limerick, P. N. 1994. "The adventures of the frontier in the twentieth century," in *The frontier in American culture : an exhibition at the Newberry Library, August 26, 1994 - January 7, 1995* Edited by R. White and P. N. Limerick. Chicago and Berkeley: The New Berry Library and University of California Press.

Little, P. E. 1999. Environments and environmentalisms in anthropological research: facing a new millenium. *Annual Review of Anthropology* 28:253-84.

Lo, M. 2002. "The interPlanetary superhighway and the origins program." *IEEE Aerospace Conference Proceedings, 2002*, pp. 7-3543- 7-3562 7.

Lock, M. M. 2002. *Twice dead : organ transplants and the reinvention of death. California series in public anthropology.* Berkeley: University of California Press.

Logsdon, J. 1986. The decision to develop the space shuttle. *Space Policy* May:104 - 119.

Lovelock, J. 2000. *Gaia : a new look at life on earth.* Oxford ; New York: Oxford University Press.

— 2006. *The revenge of Gaia : earth's climate in crisis and the fate of humanity.* New York: Basic Books.

Low, S. M., and D. Lawrence-Zuñiga. 2003. *The anthropology of space and place : locating culture. Blackwell readers in anthropology ; 4.* Malden, MA: Blackwell Pub.

Luhmann, N. 2000. *Art as a social system.* Stanford, Calif.: Stanford University Press.

Lyotard, J.-F. 1984. *The postmodern condition : a report on knowledge. Theory and history of literature ; v. 10.* Minneapolis: University of Minnesota Press.

Lytkin, V., B. Finney, and L. Alepko. 1995. Tsiolkovsky - Russian cosmism and extraterrestrial intelligence. *Royal Astronomical Society Quarterly Journal* 36:369 - 376.

Mackenzie, D. A. 1990. *Inventing accuracy : an historical sociology of nuclear missile guidance. Inside technology*. Cambridge, Mass.: MIT Press.

Magarrell, E. 1992. *Blameless Lives*. Washington, DC: The Word Works.

Marburger, J. 2006. "44th Robert H. Goddard Memorial Symposium keynote address," in *Robert H. Goddard Memorial Symposium*. Greenbelt, Maryland.

Marcus, G. 1998. *Ethnography through thick and thin*. Princeton, New Jersey: Princeton.

Martin, E. 1994. *Flexible bodies : tracking immunity in American culture from the days of polio to the age of AIDS*. Boston: Beacon Press.

Masco, J. 2006. *The nuclear borderlands : the Manhattan Project in post-Cold War New Mexico*. Princeton, N.J.: Princeton University Press.

McCarthy, E. a. V. A. O. 2007. After Writing Culture: An interview with George Marcus on research imaginaries, collaboration, and critical data. *After Culture/Emergent Anthropologies* 1:35-54: http://emergentanthropologies.net/afterculture/index.php/afterculture/article/view/3/30].

McCurdy, H. E. 1993. *Inside NASA : high technology and organizational change in the U.S. space program. New series in NASA history*. Baltimore: Johns Hopkins University Press.

McDougall, W. A. 1997. *The heavens and the earth : a political history of the space age*, Johns Hopkins paperbacks edition. Baltimore, Md.: Johns Hopkins University Press.

McGuirk, K. 1997. A. R. Ammons and the whole earth. *Cultural Critique* 37:131-158.

McKibben, B. 2010. *Eaarth : a survivor's guide*, 1st edition. New York: Time Books.

Meleschko, G. I., Y. Y. Shepelev, M. M. Averner, and T. Volk. 1993. "Biological life support systems," in *Space biology and medicine*, vol. 2. Edited by A. E. Nicogossian, S. R. Mohler, O. G. Gazenko, and A. I. Grigoryev. Washington D.C.: AIAA.

Mellor, F. 2010. Colliding worlds: asteroid research and the legitimization of war in space. *Social Studies of Science* 37:499–531.

Messeri, L. R. The problem with Pluto: conflicting cosmologies and the classification of planets. *Social Studies of Science.*

Mirmalek. 2009. Working time on Mars. *Kronoscope* 8:159 - 178.

Mody, C. 2005. The sounds of science: Listening to laboratory practice. *Science, technology, & human values* 30:175-198.

Mol, A. 2002. *The body multiple : ontology in medical practice. Science and cultural theory.* Durham: Duke University Press.

Morrison, D. 1992. "The Spaceguard Survey: Report of the NASA International Near-Earth-Object Detection Workshop." *NASA International Near-Earth-Object Detection Workshop, 1992.*

— 2007. "The impact hazard: advanced NEO surveys and societal responses," in *Comet/asteroid impacts and human society : an interdisciplinary approach*, 1st edition. Edited by P. T. Bobrowsky and H. Rickman, pp. 163 - 173. Berlin ; New York: Springer.

Morsiani, P., A. Zittel, T. Smith, and C. H. Butler. 2005. *Andrea Zittel : critical space.* Munich ; New York: Prestel.

Muir, J. 1993. *Travels in Alaska. Penguin nature library.* New York: Penguin Books.

Mukerji, C. 1989. *A fragile power : scientists and the state.* Princeton, N.J.: Princeton University Press.

Mullane, R. M. 2006. *Riding rockets : the outrageous tales of a space shuttle astronaut.* New York: Scribner.

Myers, N. 2009. "Performing the protein fold," in *Simulation and its discontents.* Edited by S. Turkle, pp. 171 - 202. Cambridge, Mass.: The MIT Press.

NASA Langley Research Center, N. I. o. A., TEDx. 2009. "Space to Create." *TEDx, Ferguson Center for the Arts on the campus of Christopher Newport University, 2009.*

Nash, L. L. 2006. *Inescapable ecologies : a history of environment, disease, and knowledge.* Berkeley: University of California Press.

National Aeronautics and Space Administration. 1995. "Man-Systems Integration Standards," vol. Revision B. http://msis.jsc.nasa.gov/.

— 2004. "Vision for Space Exploration." http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf.

— 2005. "Bioastronautics Roadmap: A Risk Reduction Strategy for Human Space Exploration." NASA Johnson Space Center, Houston, Texas. http://bioastroroadmap.nasa.gov/index.jsp.

— 2008. "Space Life Sciences." http://slsd.jsc.nasa.gov/.

National Research Council. 2007. "Building a better NASA workforce: Meeting the workforce needs for the national Vision for Space Exploration." Washington, D.C.: National Academies Press.

Novas, C., and N. Rose. 2000. Genetic risk and the birth of the somatic individual. *Economy and Society 29, no* 4:485-513.

Nussbaum, M. 2002. "Objectification," in *The philosophy of sex : contemporary readings*, 5th edition. Edited by A. Soble and N. Power, pp. 381 - 419. Lanham, Md.: Rowman & Littlefield.

Nye, D. E. 2003. *America as second creation : technology and narratives of new beginnings*. Cambridge: MIT Press.

Oberg, J. 1998. "Planetary climate modification and the US Space Command -- as-yet unrecognized missions in the post-2025 time frame " in *Futures Focus Day Symposium sponsored by Commander-in-Chief, US Space Command.* Colorado Springs, Colorado.

Ohanian, M., and J.-C. Royoux. 2005. *Cosmograms*: Lukas & Sternberg.

Olson, V. 2010. The ecobiopolitics of space biomedicine. *Medical Anthropology* 29:2.

O'Neill, G. K., D. Gump, Space Studies Institute., and Space Frontier Foundation. 2000. *The high frontier : human colonies in space*, 3rd edition. Burlington, Ont., Canada: Apogee Books.

Ortner, S. B. 1973. On key symbols. *American Anthropologist* 75:1338-1346.

Paine, T. O. 1990. "Biospheres and solar system exploration," in *Biological Life Support Systems: Commercial Opportunities*, vol. NASA Conference Publication #3094. Tucson, Arizona.

Pandolfo, S. 1997. *Impasse of the angels : scenes from a Moroccan space of memory.* Chicago: University of Chicago Press.

Paxson, H. 2008. Post-Pasteurian cultures: The microbiopolitics of raw-milk cheese in the United States. *Cultural Anthropology* 23:15 - 47.

Penley, C. 1997. *NASA/TREK : popular science and sex in America*. New York: Verso.

Pepper, S. C. 1942. *World hypotheses, a study in evidence*. Berkeley and Los Angeles,: University of California press.

Perelman, C. 1982. *The realm of rhetoric*. Notre Dame, Ind.: University of Notre Dame Press.

Petryna, A. 2002. *Life exposed : biological citizens after Chernobyl. In-formation series*. Princeton, [N.J.]: Princeton University Press.

Pinch, T. 1991. "How do we treat technical uncertainty in systems failure? The case of the space shuttle Challenger," in *Social responses to large technical systems : control or anticipation*. Edited by T. R. La Porte, pp. 137-52. Dordrecht ; Boston: Kluwer Academic Publishers.

Pitts, B., C. Brensinger, J. Saleh, C. Carr, P. Schmidt, and D. Newman. 2001. "An astronaut 'Bio-Suit'system: exploration-class missions." Boston, Mass: MIT.

— 2001. *Astronaut Bio-Suit for exploration class missions: NIAC Phase I Report, 2001*. MIT.

Pitts, J. A. 1985. *The human factor: Biomedicine in the manned space program to 1980*. National Aeronautics and Space Administration.

Porter, D. 1999. *Health, civilization, and the state : a history of public health from ancient to modern times*. London ; New York: Routledge.

Portree, D. S. F. 1993. "Orbital debris and near-earth environmental management: a chronology." Washington, D.C.: NASA reference publication 1320: NASA.

Poynter, J. 2006. *The human experiment : two years and twenty minutes inside Biosphere 2*. New York: Thunder's Mouth Press.

Prentiss, R. 2005. The anatomy of a surgical simulation: The mutual articulation of bodies in and through the machine. *Social Studies of Science* 35:837-866.

Rabinow, P. 1992. "Artificiality and enlightenment: from sociobiology to biosociality," in *Incorporations*. Edited by J. C. a. S. Kwinter, pp. 234 -52. New York: Zone.

— 1995. *French modern : norms and forms of the social environment*, University of Chicago Press edition. Chicago: University of Chicago Press.

— 1996. *Making PCR : a story of biotechnology*. Chicago: University of Chicago Press.

— 2003. *Anthropos Today*. Princeton, New Jersey: Princeton University Press.

Rapp, R. 1999. *Testing women, testing the fetus : the social impact of amniocentesis in America. The anthropology of everyday life*. New York: Routledge.

Rappaport, R. A. 1984. *Pigs for the ancestors : ritual in the ecology of a New Guinea people*, A new enl. edition. New Haven: Yale University Press.

Redfield, P. 2000. *Space in the tropics : from convicts to rockets in French Guiana*. Berkeley: University of California Press.

Reichhardt, T. 2002. *Space shuttle : the first 20 years*. New York: DK Pub.

Rheinberger, H.-J. 1997. *Toward a history of epistemic things : synthesizing proteins in the test tube. Writing science*. Stanford, Calif.: Stanford University Press.

Robinson, M. 2009. "The explorer gene," in *Time to eat the dogs: On science, history, and exploration* http://timetoeatthedogs.com/2009/09/28/the-explorer-gene/.

— 2009b. "Interview with Felix Driver," in *Time to eat the dogs: On science, history, and exploration*

Robinson, M. F. 2006. *The coldest crucible : Arctic exploration and American culture*. Chicago: University of Chicago Press.

Robison, W., R. Boisjoly, D. Hoeker, and S. Young. 2002. Representation and misrepresentation: Tufte and the Morton Thiokol Engineers on the Challenger. *Science and Engineering Ethics* 8:59-81.

Rose, N. 2007. *The politics of life itself : biomedicine, power, and subjectivity in the twenty-first century*. Princeton, NJ: Princeton University Press.

Ruan, X., and P. Hogben. 2007. *Topophilia and topophobia : reflections on 20th century human habitat*. New York: Routledge.

Rus, M., and C. M. Frieze. 2007. "Garret Finney: the thinker," in *House and Garden*, vol. June. New York, New York: Condé Nast.

Sadler, S., and Archigram (Group). 2005. *Archigram : architecture without architecture*. Cambridge, Mass.: MIT Press.

Schensul, S. L., J. J. Schensul, and M. D. LeCompte. 1999. *Essential ethnographic methods : observations, interviews, and questionnaires. Ethnographer's toolkit ; 2*. Walnut Creek, Calif.: AltaMira Press.

Schmitz, B., D. A. T. Harper, B. Peucker-Ehrenbrink, S. Stouge, C. Alwmark, A. Cronholm, S. M. Bergström, M. Tassinari, and W. Xiaofeng. 2008. Asteroid breakup linked to Great Ordovician Biodiversification Event. *Nature Geoscience* 1:49 - 53.

Schweickart, R. L. 2004. "The real deflection dilemma," in *Planetary Defense Conference: Protecting Earth from Asteroids*. Orange County, California

Schweickart, R. L., T. D. Jones, F. von der Dunk, and S. Camacho-Lara. 2008. "Asteroid threats: a call for global response," Association of Space Explorers Committee on Near-Earth Objects.

Schweitzer, A., and P. Cicovacki. 2009. *Albert Schweitzer's ethical vision : a sourcebook.* New York: Oxford University Press.

Serres, M., and B. Latour. 1995. *Conversations on science, culture, and time. Studies in literature and science*. Ann Arbor: University of Michigan Press.

Shapin, S., S. Schaffer, and T. Hobbes. 1985. *Leviathan and the air-pump : Hobbes, Boyle, and the experimental life : including a translation of Thomas Hobbes, Dialogus physicus de natura aeris by Simon Schaffer*. Princeton, N.J.: Princeton University Press.

Shaw, D. B. 2004. Bodies out of this world: The space suit as cultural icon. *Science as Culture* 13:123-44.

Sheehan, W. 1995. *The immortal fire within : the life and work of Edward Emerson Barnard*. Cambridge ; New York: Cambridge University Press.

Shelley, C. 2003. *Multiple analogies in science and philosophy. Human cognitive processing, v. 11*. Amsterdam ; Philadelphia: John Benjamins Pub.

Sherwood, B. 2009. "What is space architecture," in *Out of this world : the new field of space architecture*. Edited by A. S. Howe and B. Sherwood, pp. 3 - 6. Reston, VA: American Institute of Aeronautics and Astronautics.

Shirley, D., and D. Morton. 1998. *Managing Martians*, 1st edition. New York: Broadway Books.

Shostak, S. 2004. Environmental justice and genomics: acting on the futures of environmental health. *Science as Culture* 13:539 - 562.

Showalter, D., and T. B. Malone. 1972. "The development of a lunar habitability system: NASA CR - 1676." Washington, D.C.: NASA.

Siddiqi, A. 2007. "Making spaceflight modern: a cultural history of the world's first space advocacy group," in *Societal Impact of Spaceflight*. Edited by S. J. Dick and

R. D. Launius, pp. 513 - 537. Washington, D.C.: National Aeronautics and Space Administration.

Singer, M. 1989. The limitations of medical ecology: The concept of adaptation in the context of social stratification and social transformation. *Medical Anthropology* 10:223-234.

Slovic, P. 2007. "Perception of risk from asteroid impact," in *Comet/asteroid impacts and human society: an interdisciplinary approach.* Edited by P. T. Bobrowsky and H. Rickman, pp. 370 - 382. Berlin ; New York: Springer.

Smith, A. 2005. *Moondust : in search of the men who fell to Earth*, 1st U.S. edition. New York: Fourth Estate.

Solan, V. J. 2004. 'Built for health': American architecture and the healthy house1850--1930, Yale University.

Speybroeck, L. v., G. v. d. Vijver, and D. d. Waele. 2002. *From epigenesis to epigenetics : the genome in context. Annals of the New York Academy of Sciences ; v. 981.* New York, N.Y.: the New York Academy of Sciences.

Star, S. L., and J. R. Griesemer. 1989. Institutional ecology, 'translations,' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology. *Social Studies of Science* 19:387- 420.

Stenuit, R. 1966. *The deepest days.* New York,: Coward-McCann.

Stepan, N. 1991. *The hour of eugenics : race, gender, and nation in Latin America.* Ithaca: Cornell University Press.

— 2001. *Picturing tropical nature.* Ithaca, N.Y.: Cornell University Press.

Stewart, K. 1996. *A space on the side of the road : cultural poetics in an "other" America.* Princeton: Princeton University Press.

Stewart, K., and S. Harding. 1999. Bad endings: American apocalypsis. *Annual Review of Anthropology* 28:285-310.

Stone, T. L. 2009. *Almost astronauts : the true story of the "Mercury 13" women*, 1st edition. Somerville, Mass.: Candlewick Press.

Strughold, H. 1958. General review of problems common to the fields of astronomy and biology. *Publications of the Astronomical Society of the Pacific* 70:43 -53.

Strydom, P. 2002. *Risk, environment, and society : ongoing debates, current issues, and future prospects. Issues in society.* Buckingham [England] ; Philadelphia: Open University Press.

Stuster, J. 1996. *Bold endeavors : lessons from polar and space exploration.* Annapolis, Md.: Naval Institute Press.

Suchman, L. A., J. Blomberg, J. E. Orr, and R. Trigg. 1999. Reconstructing technologies as social practice *American Behavioral Scientist* 43:392 - 408.

Suchman, L. A., J. Blomberg, and R. Trigg. 2002. Working Artefacts: Ethnomethods of the prototype. *British Journal of Sociology* 53:163-179.

Suedfeld, P. 2006. Space memoirs: value hierarchies before and after missions — a pilot study. *Acta Astronautica* 58:583-586.

Sunder Rajan, K. 2006. *Biocapital : the constitution of postgenomic life.* Durham: Duke University Press.

Taylor, G. J. 2008. "Designing for space: Core77 visits NASA's industrial design team," in *Core 77: Design Magazine and Resource*: http://www.core77.com/blog/featured_items/designing_for_space_core77_visits_nasas_industrial_design_team_by_glen_jackson_taylor_11565.asp#more.

Thompson, R. S. 2007. "The air conditioning capital of the world: Houston and climate control," in *Energy metropolis : an environmental history of Houston and the Gulf Coast.* Edited by M. V. Melosi and J. A. Pratt, pp 88 – 104. Pittsburgh, Pa.: University of Pittsburgh Press.

Thomson, R. G. 1997. *Extraordinary bodies : figuring physical disability in American culture and literature.* New York: Columbia University Press.

Topham, S. 2003. *Where's my space age? : the rise and fall of futuristic design.* Munich ; New York: Prestel.

Toulmin, S. E. 2003. *The uses of argument*, Updated edition. Cambridge, U.K. ; New York: Cambridge University Press.

Trompette, P. 2009. Revisiting the notion of boundary object (translated by Dominick Vinck). *Revue d'anthropologie des connaissances* 3:3 - 25.

Trotti, G., and Trotti and Associates Inc. 2007. *NIAC Phase 1 Final Report.*

Tsing, A. L. 2005. *Friction : an ethnography of global connection.* Princeton, N.J.: Princeton University Press.

Tuan, Y.-f. 1990. *Topophilia : a study of environmental perception, attitudes, and values*, Morningside edition. New York: Columbia University Press.

Turkle, S. 2009. *Simulation and its discontents*. Cambridge, Mass.: The MIT Press.

Vailly, J. 2008. The expansion of abnormality and the biomedical norm: neonatal screening, prenatal diagnosis and cystic fibrosis in France. *Social Science & Medicine* 66:2532-43.

Vaughan, D. 1996. *The Challenger launch decision : risky technology, culture, and deviance at NASA*. Chicago: University of Chicago Press.

Verne, J., and W. Butcher. 1998. *Twenty thousand leagues under the seas*. Oxford ;: New York : Oxford University Press.

Vidler, A. 1992. *The architectural uncanny : essays in the modern unhomely*. Cambridge, Mass.: MIT Press.

Vogler, A. 2005. "The universal house: An outlook to space-age housing," in *Concept house: toward customized industrial housing*. Edited by M. Eekhout, pp. 77 - 87: TU Delft: http://www.spacearchitect.org/pubs/ConceptHouse-2005-Vogler.pdf.

Vogler, A., and A. Vittori. 2009. "Space architecture for the mother ship: bringing it home," in *Out of this world : the new field of space architecture*. Edited by A. S. Howe and B. Sherwood, pp. 393 - 404. Reston, VA: American Institute of Aeronautics and Astronautics.

Waligora, J., D. Horrigan, and A. Nocogossian. 1991. The physiology of spacecraft and space suit atmosphere selection. *Acta Astronautica* 23:171-177.

Ward, P. D. 2009. *The medea hypothesis : is life on earth ultimately self-destructive?* Princeton: Princeton University Press.

Ward, P. D., and D. Brownlee. 2003. *The life and death of planet Earth : how the new science of astrobiology charts the ultimate fate of our world*. New York: Times Books.

Watts, P. 1999. *Starfish*, 1st edition. New York: Tor.

Weber, M., H. H. Gerth, and C. W. Mills. 1958 [1946] *From Max Weber: Essays in sociology*. New York: Oxford university press.

Weddle, P. 1978. *Argument : a guide to critical thinking*. New York: McGraw-Hill.

Weitekamp, M. A. 2004. *Right stuff, wrong sex : America's first women in space program. Gender relations in the American experience*. Baltimore: Johns Hopkins University Press.

Whatmore, S. 2002. *Hybrid geographies : natures, cultures, spaces*. London ; Thousand Oaks, Calif.: SAGE.

White, F. 1987. *The overview effect : space exploration and human evolution*. Boston: Houghton Mifflin.

Whitehead, I., and G. Finney. 2004. "Garrett Finney brings space habitability down to earth," in *Architectural Record*: http://archrecord.construction.com/people/profiles/archives/0204profile.asp.

Wiley, A. S. 1992. Adaptation and the biocultural paradigm in medical anthropology: A critical review. *Medical Anthropology Quarterly* 6:216 - 236.

Williamson, J. 1950. *Seetee shock*. New York,: Simon and Schuster.

— 1951. *Seetee ship*, [pseud. 1st edition. New York,: Gnome Press.

Wilson, A. G. 1958. Introduction (Symposium paper: Problems common to the fields of astronomy and biology). *Publications of the Astronomical Society of the Pacific* 70:41-43.

Winter, F. 2001. "The 'Trip to the Moon' and othe rearly spaceflight simulation shows, ca. 1901 - 1015: Part I," in *History of rocketry and astronautics : proceedings of the Twenty -Eighth and Twenty-Ninth History Symposia of the International Academy of Astronautics*, vol. AAS history series ; v. 23. Edited by D. C. Elder, K. Dougherty, International Academy of Astronautics, and American Astronautical Society. San Diego, Calif.: Published for the American Astronautical Society by Univelt, Inc.

Wong, D. T. 2009. "Human factors interface with systems engineering for NASA human spaceflights " in *Human Systems Integration Symposium*. Annapolis, Maryland.

Yeomans, D. K. 1991. Killer rocks and the celestial police - the search for near-earth asteroids. *Planetary Report* 11:4 - 7.

— 2009. "The Lure of Rocks From Outer Space," in *The New York Times*, pp. http://roomfordebate.blogs.nytimes.com/2009/03/06/the-lure-of-rocks-from-outer-space/.

Young, A., and National Air and Space Museum. 2009. *Spacesuits within the collections of the Smithsonian National Air and Space Museum*. Brooklyn, N.Y.: PowerHouse Books.

Zabusky, S. E. 1995. *Launching Europe : an ethnography of European cooperation in space science*. Princeton, N.J.: Princeton University Press.
