

MAKING CERTAIN:  
INFORMATION AND SOCIAL REALITY

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## **ABSTRACT**

Elliott Ayers Hauser: Making Certain: Information and Social Reality  
(Under the direction of Ryan Shaw)

This dissertation identifies and explains the phenomenon of the production of certainty in information systems. I define this phenomenon pragmatically as instances where practices of justification end upon information systems or their contents. Cases where information systems seem able to produce social reality without reference to the external world indicate that these systems contain facts for determining truth, rather than propositions rendered true or false by the world outside the system. The No Fly list is offered as a running example that both clearly exemplifies the phenomenon and announces the stakes of my project. After an operationalization of key terms and a review of relevant literature, I articulate a research program aimed at characterizing the phenomenon, its major components, and its effects. Notable contributions of the dissertation include:

- the identification of the production of certainty as a unitary, trans-disciplinary phenomenon;
- the synthesis of a sociolinguistic method capable of unambiguously identifying a) the presence of this phenomenon and b) distinguishing the respective contributions of systemic and social factors to it; and
- the development of a taxonomy of certainty that can distinguish between types of certainty production and/or certainty-producing systems.

The analysis of certainty proposed and advanced here is a potential compliment to several existing methods of sociotechnical research. This is demonstrated by applying the analysis of certainty to the complex assemblage of computational timekeeping alongside a more traditional infrastructural inversion. Three subsystems, the  $\mathfrak{t}z$  database, Network Time Protocol, and International Atomic Time, are selected from the assemblage of computational timekeeping for analysis. Each system employs a distinct memory practice, in Bowker's sense, which licenses the forgetting inherent in the production of the information it contains. The analysis of certainty expands upon the insights provided by infrastructural inversion to show how the production of certainty through modern computational timekeeping practices shapes the

social reality of time. This analysis serves as an example for scholars who encounter the phenomenon of the production of certainty in information systems to use the proposed theoretical framework to more easily account for, understand, and engage with it in their work. The dissertation concludes by identifying other sites amenable to this kind of analysis, including the algorithmic assemblages commonly referred to as Artificial Intelligence.

To Erin. Homewards!

## ACKNOWLEDGEMENTS

It has become increasingly clear to me while completing this work that is inextricably entangled in what Leigh Star called “intellectual infrastructure” In discussing her own intellectual infrastructure and its role in her scholarly journey, Star wrote that “the formation of this path was/is not accidental, however full of contingencies it may be.” In what follows I hope to celebrate the people who have create and maintain the intellectual infrastructure that has made my work possible. However contingent my path, their contributions are not accidental, and I am grateful for them.

Ryan Shaw has been everything I could have asked for in an advisor and chair. I was fortunate that Ryan agreed to chair my committee so early within his career, when expedience might have suggested that my doctoral aspirations would be a distraction from the rigors of tenure and promotion. As it happened, Ryan gained tenure during this time, and in the process showed me that what counts in academic life goes far beyond just what counts for tenure. His many helpful suggestions of related literature have helped me situate my work within several ongoing conversations within and around information studies. The list of references in my meeting notes that I have yet to deeply engage (which remains regrettably long) will no doubt play this same role in my subsequent work.

Melanie Feinberg is, in addition to being a strikingly original thinker, quite possibly the world’s greatest academic editor. She’s able to refine a document’s critical shortcomings into succinct and challenging questions for the writer to revise and re-present their key ideas around. Melanie does all of this while refraining from providing her own (probably superior) answers to the questions she raises, preserving the fertile space for thinking that academic writing provides. All of these skills are in addition to her considerable productivity and clarity as a scholar. That she possesses both sets of abilities in abundance and so willingly and generously shares them with her students and colleagues is a testament to her unique character. Though I have attempted to follow her exhortation to avoid relying on evaluative language in the dissertation itself, I have been unable to do so in acknowledging her contributions to my intellectual journey.

Stephanie Haas was one of the first UNC professors I contacted when exploring this strange new field of ‘information science’ that I had discovered by accident. Her generosity in meeting with a prospective student grew into a years-long mentorship through both my masters and doctoral studies. Stephanie’s omnivorous curiosity has produced a quiet mastery over a disconcerting array of topics, especially within the study of language. As an advisor, she has never failed to listen deeply, probe expertly, and encouragingly share in my enthusiasm for my work.

When I returned from my leave of absence, Ryan mentioned that there was a Communications scholar at UNC who was doing some interesting work on information systems. Neal Thomas has subsequently become an integral part, not only of my committee, but of the intellectual life of our corner of the university. Neal has provided an accessible introduction to a vast swath of Continental literature that I had avoided in the absence of a trusted guide. Neal has continued to be that trusted guide for me as I’ve gone deeper with several key thinkers he introduced me to in this dissertation and elsewhere, and is an ever-challenging discussant and collaborator.

It was already a foregone conclusion that Geof Bowker’s thought would substantially shape the work of my dissertation when, in the spring of 2018, I reached out to ‘discuss my research’ with him. My hope was that the discussion would go well enough that he would agree to serve as the external member of my committee; to my delight and surprise, this is what occurred. In our subsequent discussions Geof has been a font of new ideas and connections, and an immense encouragement. His vision of engaged scholarship and the way in which he enacts it remains an inspiration for the kind of scholar I’d like to be.

Other faculty beyond the five on my committee have played important roles in my intellectual development over time. I’m particularly grateful for an array of help, mentorship and support from Javed Mostafa, Brad Hemminger, Bob Losee, Barbara Wildemuth, Diane Kelley, Rob Capra, Sandra Hughes-Hassel, and the late Evelyn Daniel. Evelyn will be dearly missed by all of us who knew her. Faculty of other departments have provided intellectual challenge and diversity to my experience, especially Alan Nelson, Simon Blackburn, Lily Nguyen, Jan Prinz, Buck Goldstein, Kevin Guskiewicz, Matt Springer, and of course Neal Thomas. Through it all the SILS office staff have kept things running smoothly, and the indefatigable Lara Bailey has always had the answers to my questions and often the solutions to my problems when I needed them.

The Organization Reading Group at UNC has been a crucial component of my experience since returning from my leave of absence. In addition to Ryan, Melanie, and Neal, Patrick Golden, Colin Post,

Evelyn Daniel, Megan Winget, Debbie Maron, Andrew Rabkin, Evan Donahue, and others have made this group a wonderful weekly ritual for the past several years.

Many others have made this long journey fun. John D. Martin III's friendship has been a particularly welcome respite from the often solitary, arcane, invisible, and exhausting work of earning a dissertation. I've deeply enjoyed our formal collaborations, and even moreso our informal chats about things like the exquisite and illicit pleasure of spending time perfecting  $\text{\LaTeX}$  code instead of writing one's dissertation. The Sociotech Writing Group, which grew out of the Consortium for the Science of Sociotechnical Systems 2019 Summer Research Institute at Rutgers University, has been an increasingly important source of support, inspiration, and intellectual engagement for me. In particular, I'd like to thank Karen Boyd, Stevie Chancellor, Mike DeVito, Michaelanne Dye, Sarah Gilbert, Koko Koltai, Jacob Thebault-Spieker, and the rest of my `#accountabilibuddies` for letting me be `#random` now and again. I hope to see you all in `#wins-and-fails`. Aaron Kirschenfeld was uniquely positioned to help me clarify the legal analogies I make in this text, and did some difficult work in helping me to trace the origins and precise meanings of legal terms that were rarely precisely defined in the field's literature. Bjoern B. Brandenburg made an excellent  $\text{\LaTeX}$  template conforming to UNC's thesis and dissertation guidelines available on GitHub.

On April 14<sup>th</sup>, 2019, Phoebe Richardson Hauser entered the world and indelibly altered mine. Her influence on this work began some months before, when she provided an extraordinary motivation to write four chapters in the four months leading up to her birth. Since that time, my in-laws Angie and Bill and parents Eric and Donna have provided loving care and support for our young family and have watched Phoebe to allow me to complete my work. Angie in particular has gone above and beyond. To my family: thank you.

And, finally, I thank my wife Erin, to whom the dissertation is dedicated. Her drive to know herself, to deeply know others, and to do good in this world is a continual refuge, inspiration, and challenge to me.



## **PREFACE**

This dissertation is the culmination of a decade-long curiosity about how information can be so powerful. My interest was first piqued during my undergraduate art history studies, where I mused about how the work I was doing could be evaluated by others. I was using a 1976 facsimile reprint of a three volume set of Dutch auction records originally printed in the 18<sup>th</sup> century. The auction records were themselves reprints of annotated auction catalogs. The printed catalogs contained descriptions of the artworks for sale, but not their prices, since the auctions has yet to occur when the catalogs were printed. The sale prices of the paintings which ended up in the auction records, the 1976 reprint, and ultimately in the improbably large Excel spreadsheet I constructed for my undergraduate honors thesis, were annotations made by the art dealer, or possibly one of his associates, during the actual auction. Obviously, the tenuousness of the chain of evidence that I used to produce an analysis of the 18<sup>th</sup> century auction market in the Netherlands ended up being of more lasting intellectual interest than the art market itself.

With these problems in the back of my mind, I continued reading philosophy and sociology after my undergraduate studies were complete, and gradually gained new purchase on these problems. Alan Nelson's UNC seminar on the Philosophical Investigations in 2007 was particularly influential in this respect. Its intellectual reverberations, in the form of my continued engagement with Wittgenstein's thought, will continue well beyond their obvious expression in this dissertation. Ironically, it was Wittgenstein's skepticism as to the value of studying philosophy which probably led me, eventually, to seek a PhD in information studies instead of philosophy. I of course continue to read and apply philosophy despite it all, and Nelson later also welcomed me into a Wittgenstein reading group as a doctoral student here.

Since arriving at UNC, and particularly after beginning my PhD with the support of the Royster Society of Fellows, I have been extremely fortunate to have the latitude and intellectual support to clarify, investigate, and ultimately write a dissertation on this topic. The final intellectual puzzle piece came together as I began to read the work of John Searle, recommended to my by Ryan Shaw. Searle's

social ontology and account of the social construction of facts turned out to be exactly what I needed to crystallize my approach to the phenomenon.

This work is a culmination, yes, but I've taken to heart the wise counsel of several advisors that dissertations be seen as the first step in a longer investigation, not the last word. I have gained invaluable experience marshalling the not inconsiderable resources of the UNC intellectual community in writing it, skills I am now looking to deploy towards adjacent projects. I hope the reader will find herein a compelling phenomenon to be investigated, and a credible attempt as investigating it.

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## LIST OF ABBREVIATIONS

ACLU	American Civil Liberties Union
ACSII	American Standard Code for Information Interchange (character encoding)
AI	Artificial Intelligence
API	Application Programming Interface
BIPM	International Bureau of Weights and Measures ( <i>Bureau International des Poids et Mesures</i> )
BMI	Body Mass Index
CA	Certificate Authority
DNS	Domain Name System
IANA	Internet Assigned Numbers Authority
ICANN	Internet Corporation for Assigned Names and Numbers
ICD	International Classification of Disease
ICRF	International Celestial Reference Frame
IERS	International Earth Rotation and Reference Systems Service
IP	Internet Protocol
NFC	Near Field Communication
NIST	National Institute of Standards and Technology
NTP	Network Time Protocol
POSIX	Portable Operating System Interface
RAM	Random Access Memory
RFID	Radio Frequency Identification
SI	International System of Units ( <i>Système International [d'Unités]</i> )
SKU	Stock Keeping Unit
SSL	Secure Sockets Layer
TAI	International Atomic Time ( <i>Temps Atomique International</i> )
TLDs	Top Level Domains
TLS	Transport Layer Security
TREC	Text Retrieval Conference
TSA	Transportation Security Administration

UML	Unified Markup Language
UT1	Universal Time 1
UTC	Coordinated Universal Time ( <i>Temps Universel Coordonné</i> )
UTF	Unicode Transformation Format (character encoding)



## INTRODUCTION

*To be sure there is justification, but justification must come to an end somewhere.*

— Ludwig Wittgenstein, ON CERTAINTY, 1951

Correspondence theories of truth are intertwined throughout information science's history, and often represent an unexamined basis from which current research and practice proceeds. Such theories hold, roughly, that for any true proposition  $P$  there is a fact  $F$  which corresponds to it. Thus, to recite a common example from the philosophy of language, the proposition “snow is white” is true if and only if snow is in fact white. The fact  $F$ , which determines the truth of the proposition  $P$ , is the latter's truth grounds. Facts in this sense are not true or false; rather, as truth grounds for statements in language, they need only exist. Such correspondence theories of truth are implicitly embedded in the design of many information systems, especially systems which track enumerable things like citizens or assets, which are vital to governments and corporations. My local Apple Store has 100 iPads in stock if and only if there are 100 iPads on the shelves waiting to be sold.

Information systems are now often designed to produce truth grounds, what philosopher John Searle has called institutional facts,<sup>1</sup> instead of propositions that are made true or false in reference to the world external to the system. This means that, instead of producing propositions that can correspond to reality, these systems are instead constitutive of parts of what Searle calls social reality.<sup>2</sup> For instance, systems used to provide registration or confirmation numbers produce alphanumeric strings, such as HFU83F. The statement “your confirmation number is HFU83F” is certain within the context of the information system which generates it, regardless of any external state, which is different than more familiar empirical statements like “There are 100 iPads in stock,” whose truth depends upon some state in the world outside the system (*i.e.*, the warehouses containing this stock) which is used to evaluate its truth value.

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<sup>1</sup>John R Searle, *The Construction of Social Reality* (New York, NY: The Free Press, 1995); John R Searle, *Making the Social World: The Structure of Human Civilization* (Oxford, UK: Oxford University Press, 2010).

<sup>2</sup>Searle, *The Construction of Social Reality*.

Beyond the design and use of systems, many of our methods of understanding information systems are based on rendering information as inherently empirical, corresponding or referring to some portion of the world with which they can be reconciled. The possibility of objective improvement of information retrieval system performance, for instance, relies on the validity of empirical measurements of performance. Common conceptions of ‘reliability’ or ‘truth’ presuppose that errors or falsehoods can be corrected when they are identified. In each case, there is an implicit assumption that the information within systems can be determined to be true or false, correct or incorrect.

Yet the process of reconciliation, or correction, does not apply for systems which produce truth grounds instead of empirical statements. These kinds of systems are best described as incorrigible. Incorrigibility has several meanings, but in this case I’m drawing from analytic philosophy of language in defining the term as the impossibility of error.<sup>3</sup> Incorrigibility applies to systems that can be thought of, generally, as systems of record. When information systems form the set of facts with which our statements are reconciled, they themselves become exempt from reconciliation: they become incorrigible. This is a remarkable state of affairs: some statements are true if and only if a certain information system says that they are. Governments and corporations are increasingly exploiting this potential by using systems of record as mediums of control. Credit scores, the No Fly list, the International Classification of Disease (ICD), and algorithmic sentencing guidelines are just a few incorrigible systems of record which directly impact everyday life.<sup>4</sup>

I do not mean to indicate that systems of record cannot be altered; clearly, they can be and are. Credit ratings agencies, for instance, have appellate procedures designed to mitigate their incorrigibility (the No Fly list, however, notably does not).<sup>5</sup> Regardless, these alterations are fundamentally different from the

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<sup>3</sup>John E Atwell, “Austin on Incorrigibility,” *Philosophy and phenomenological research* 27, no. 2 (1966): 261–266; Richard Rorty, “Incorrigibility as the Mark of the Mental,” *The journal of philosophy* 67, no. 12 (1970): 399–424; Richard Rorty, “Functionalism, Machines, and Incorrigibility,” *The journal of philosophy* 69, no. 8 (1972): 203–220; Jonathan Harrison, “The Incorrigibility of the Cogito,” *Mind; a quarterly review of psychology and philosophy* 93, no. 371 (1984): 321–335; Manuel Campos, “Analyticity and Incorrigibility,” *Philosophy and phenomenological research* 66, no. 3 (2003): 689–708; George S Pappas, “Incorrigibility, Knowledge and Justification,” *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition* 25, no. 3 (1974): 219–225.

<sup>4</sup>Each of these is discussed further below. Credit scores are discussed in Section 2.3.3. The No Fly list is a running example throughout. The ICD features prominently in Chapter 1. Sentencing guidelines are covered in Section 4.3.2.

<sup>5</sup>On credit rating systems, see Section 2.3.3. On the No Fly list and why Redress Control Numbers do not represent an appellate system, see Section 4.1.1.

reconciliations that take place within inventory systems; instead, alterations within systems of record are better described as redeclarations.<sup>6</sup> A central question for information ethics and understanding the effects of information systems on society is when, how, and by whom these declarations within incorrigible systems may be made. Incorrigible systems represent a primary site of political and economic control. In a quotidian context, they form people's most direct experience of bureaucratic control, what in the context of libraries Patrick Wilson called *descriptive power*.<sup>7</sup> I suggest that Wilson's conception of description can more aptly be expanded to *declarative power*, alluding to Searle's conception of the declarative speech act.<sup>8</sup>

An account of how declarative power within incorrigible systems creates certainty will help us reconcile ourselves to, confront, and intervene in a world increasingly constituted by them. In developing such an account, I aim to support novel approaches to problems such as algorithmic bias, the nature of scientific knowledge production, and knowledge organization as a process of declarative fact-production. Below I will introduce my approach towards these goals, and we will revisit many of these concepts in the chapters that follow.

## The Phenomenon of Certainty

As alluded to in the epigraph from Wittgenstein, I propose to understand declarative incorrigibility within information systems by examining how and when justification ends upon them. In other words, the moment when justification ends and another action begins constitutes the production of certainty. When such a justification ends upon an information system—when we point to a system or its contents as a reason to stop justifying and move on to other actions in light of the information found there—this is the production of certainty using an information system.<sup>9</sup> The fact that justifications end upon information systems is not in question; it is plainly visible in a wide array of fields of human endeavor. Viewing all

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<sup>6</sup>This concept is explained in terms of Searle's concept of declarative speech acts in Chapter 3.

<sup>7</sup>Patrick Wilson, *Two Kinds of Power: An Essay on Bibliographic Control* (Berkeley, California: University of California Press, 1968).

<sup>8</sup>John R Searle, "A Classification of Illocutionary Acts," *Language In Society* 5, no. 1 (1976): 1–23.

<sup>9</sup>In what follows, 'the production of certainty' will always refer to the production of certainty *in information systems*, unless otherwise specified. I will continue to use the fully specified formulation of the phrase throughout for clarity, but the more general phenomenon of the production of certainty is outside the scope of this work.

of these instances as a coherent phenomenon is the key move I seek to make at the outset, enabling my investigation.

There are two related components to the production of certainty in information systems: the formation of inscriptions within the system itself, and the specific practices of ending justification upon these inscriptions. The relationship between them, however, is unclear. The former process, the inscription of potential certainties, I'm terming promulgation of certainty. The latter, where such promulgated inscriptions act as the terminus of a justification action, I'm terming enactment of certainty. Thus, the overall phenomenon of the production of certainty in information systems involves two related but distinct components, promulgation and enactment. These and other key concepts for understanding certainty are described and elaborated upon in Chapter 2.

### What is an Information System?

A definition of what is meant by "information systems" is perhaps *de rigueur* for theoretical work in the field, but I will here attempt to justify a minimal answer to this question. For the purposes of this dissertation, I will largely follow Beynon-Davies' approach in recent work, wherein the *list of identifiers* is presented as the minimal data structure for analyzing the dynamics of declaration in information systems.<sup>10</sup> This minimal criterion indeed aligns with an uncontroversial ostensive definition of information systems: inventory databases, library catalogs, membership rolls, filing cabinets, accounting systems, credit card payment networks, and so on all employ lists of identifiers in one form or another. It is difficult to imagine how something that did not employ a list in this sense could be said to be an information system at all. Thus, the phenomenon of interest is when justification practices end upon something structured as or utilizing a list of identifiers. As is evident from the examples above, such systems can be digital, like a database, but need not be.

Beynon-Davies is not alone in noticing the centrality of the list.<sup>11</sup> There is something central to the act of listing that has long formed a cultural scaffold for many types of activities. Beynon-Davies's view

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<sup>10</sup>Paul Beynon-Davies, "Form-ing institutional order: The scaffolding of lists and identifiers," *Journal of the Association for Information Science and Technology* 67, no. 11 (November 2016): 2738–2753.

<sup>11</sup>See e.g., Jack Goody, *The domestication of the savage mind* (Cambridge, UK: Cambridge University Press, 1977) and Liam Cole Young, *List Cultures: Knowledge and Poetics from Mesopotamia to BuzzFeed* (Amsterdam: Amsterdam University Press, 2017).

of the list of identifiers as a minimal data structure is thus a key foundation for analysis of traditional and digital information systems alongside each other, using the same analytical framework. Though Beynon-Davies does not explicitly take this broader step, for the purposes of my work, I will define an information system as one which contains, manipulates, or produces inscribed data structures in Beynon-Davies' sense (or allows such activities by an agent). The importance of material inscription as a criterion of an information system in my project will be further discussed below and deeply explored in my dissertation.

This formulation of information systems is not a novel contribution. Rather, this approach is situated within the deflationary tradition of information studies,<sup>12</sup> an approach which obviates the need for an explicit account of the meaning of the terms 'information' or 'system.' My goal in selecting this approach is simplicity and clarity; the theoretical work to be done lies elsewhere.

Most importantly, this focus on the data structures of information systems facilitates the application of logico-linguistic techniques to their analysis. This mirrors Beynon-Davies' strategy in his investigation of "institutional order" using Searle's philosophy of social ontology.<sup>13</sup> Importantly, it differs from some accounts of information systems that explicitly include their social context and enactment within the scope of the system itself. As I hope will be seen, there will be ample room in my approach to consider the social context of information systems, without the need to explicitly incorporate it into their definition.<sup>14</sup> Exclusion of the social context of information systems would undoubtedly preclude their complete analysis, but there is value in distinguishing the data structure components constituting a system as material inscriptions. I explicitly include the process of enactment as part of the phenomenon of certainty in part to provide a place for this analysis, even as I exclude social context from the definition of a system itself. This approach allows social context to be a first-class citizen within my analysis, while preserving

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<sup>12</sup>Jonathan Furner, "Information studies without information," *Library Trends* 52, no. 3 (2004): 427–446; Bernd Frohman, *Deflating Information: From Science Studies to Documentation*, 2nd. Edition (Toronto, ON: University of Toronto Press, 2004).

<sup>13</sup>Beynon-Davies, "Form-ing institutional order: The scaffolding of lists and identifiers"; Paul Beynon-Davies, "Instituting facts: Data structures and institutional order," *Information and Organization* 26, no. 1 (June 2016): 28–44; Paul Beynon-Davies, "Declarations of significance: Exploring the pragmatic nature of information models," *Information Systems Journal* 28, no. 4 (July 2018): 612–633.

<sup>14</sup>Cf Michael Buckland, *Information and Society* (MIT Press, February 2017). Buckland's incorporation of the social *into* a conception of the system is one way of addressing their sociotechnical nature. My approach of separating them but keeping each in view enables the separate but conjoined analysis I'm proposing.

the inscriptive account of a data-structures-focused definition of *system* suitable for analysis with the logico-linguistic methods discussed in Chapter 3.

Note that this move is not solely so that analytically-oriented philosophy of language can be applied in my analysis. It is similarly compatible with Derrida's dictum that "there is no outside-text [*il n'y a pas de hors-texte*]." <sup>15</sup> I take this to mean not that text is all there is, or that everything is textual, but rather that material inscriptions are semiotically distinct from other features of social reality. By isolating the system as an inscription, Derrida's thought, and his critique of Searle and Austin's conflation of speech and inscription as mediums of action, can be applied alongside analytic philosophical analysis. Fine distinctions must be drawn between information systems and the social to scaffold this approach. Completing this will be a central aim of Chapter 3.

#### An Initial Example of the Production of Certainty

With a minimal conceptual framework assembled to clarify the phenomenon, a wide array of practices, systems, and objects of study can be recast in a new light. A shallow example that may help clarify the phenomenon and the issues surrounding is the the US government's No Fly list. I call this example "shallow" in contrast to the deeper examination of specific systems undertaken in Part II. It is well-known and intuitive enough to illustrate the phenomenon, and will be a recurring touchstone throughout the dissertation.

Suppose that I am trying to purchase an airplane ticket. My name (or other identifier, such as Social Security Number) has been entered into an information system (or heterogeneous collection of systems, collectively capable of flagging me as a No Fly member). If the system determines that I am on the No Fly list, I will be prevented from purchasing a ticket. If I am somehow able to purchase a ticket, when I attempt to enter security, one or several TSA agents will deny me passage through security based upon this system's determination. I have no recourse. Proving that I do not have explosive devices, weapons, or ill intent towards the US government or my fellow passengers will not allow me to board. Invoking constitutional protections or generally being cooperative will have no effect. The TSA agents stop their practices of justification upon the system which pronounces me as a member of this list, and thereby deny me entry. If I attempt to proceed through security or board the airplane, I will be arrested.

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<sup>15</sup>Jacques Derrida, *Limited Inc* (Evanston, IL: Northwestern University Press, 1988), 144.

This example is notable for several reasons:

- The No Fly list does not contain a proposition about me that is true or false, depending upon the facts. Rather, it constitutes the fact that grounds the truth of propositions like “it is illegal for this person to pass through security,” or “it is legal for a TSA agent to physically restrain this person if they try to board a plane.”
- It involves an instance where processes of both human and non-human justification end upon the inscriptions within an information system. The TSA agents in this case use the information system as the sole justification of whether I am allowed to pass through security, The airlines’ registration systems similarly consult and enact this information when determining whether I can purchase a ticket.
- Without recourse to some kind of appellate procedure, I can neither change the No Fly list nor the TSA agents’ enforcement of it. The appellate procedure, such as it is, takes years and, if successful, does not repudiate the system but rather re-declares the inscriptions within it.<sup>16</sup>
- The example shows how inscriptions within an information system can have real consequences for the behavior and capabilities of social actors (the TSA agents; me).
- It shows how the ability to control inscriptions within a system, combined with faithful enactment of that system, can constitute the exercise of power (in this case, the prevention of me passing through security and the threat of arrest).
- The particularities of what constitutes an *individual* on the No Fly list are largely immaterial. Whatever *identifier* the list uses dictates how it will be implemented. Thus, the list may variously prevent individuals with a given name, social security number, *etc.* from buying tickets and boarding planes. Some possible identifiers may in fact refer to more than one individual. Still, the list is not *incorrect* within its context.

In short, a range of difficult issues is raised by this one shallow example. What is the relationship between TSA agents’ justification practices and the No Fly list’s apparent status as a fact-producing system rather than a proposition producing system? What is the ethical status of inscribing a name into the No Fly list? Where does the political power displayed in this scenario come from: the system, my interactions with it (*i.e.*, my attempt to board the plane), or the TSA agents’ actions? All of these? I have been unable to find unified theoretical tools for approaching this mass of entangled questions. Chapter 4 develops such tools and explains how to use them, building upon the conceptual apparatus arrayed in the rest of Part I. Its major component, and the major novel contribution of this dissertation, is a taxonomy of the role played by information systems in the production of certainty.

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<sup>16</sup>The ACLU’s ongoing challenge to the government’s No Fly list practices began in 2010. Information about the numerous judicial decisions involved is available from “Kashem, et al. V. Barr, et al. - ACLU Challenge to Government No Fly List,” ACLU, accessed October 18, 2019, <https://www.aclu.org/cases/kashem-et-al-v-barr-et-al-aclu-challenge-government-no-fly-list>.

## Analyzing Certainty in Information Systems

The description of propositional logic with which the introduction started has perhaps obscured a related use of facts: to answer questions. Part II is framed around the question “what time is it?” and provides, by way of an answer, an in-depth application of the taxonomy applied to the assemblage of global computational timekeeping. This example was selected for its complexity and scope. I describe it as an assemblage because, unlike the shallow treatment of the No Fly list, computational timekeeping’s many constituent systems and their relationships to each other are brought to the fore of the analysis.<sup>17</sup> A nested, recursive application of the taxonomy enables an analysis of certainty within a global network of systems that ties the vibration of cesium atoms and the astronomical observation of quasars to the datetime that is displayed on billions of smartphones and computers around the world.

Chapter 5 provides an initial outline of the assemblage overall, envisioned as an infrastructural inversion.<sup>18</sup> Computational timekeeping is a quintessential information infrastructure. The chapter describes the major subsystems of scientific timekeeping, the representation of time within individual POSIX systems, and the synchronization of time over networks. It concludes with observations on how these various processes produce an effective (and literal) rationality out of fundamentally irrational durations.

Chapter 6 selects three systems, the International Atomic Time (TAI) standard, the  $\mathbb{t}z$  database, and Network Time Protocol (NTP), for analysis of the production of certainty. The taxonomy and theoretical concepts of Part I are deployed in each case to describe, in occasionally minute detail, how these systems produce inscriptions and how those inscriptions are enacted as time. The chapter ends by discussing a personal example of the consequences of certainty produced from computational timekeeping, intended to bend the theoretical abstractions of Part I and the technical obscurity of Part II back into human scale.

### Why Study Certainty in Information Systems?

The production of certainty in information systems as a phenomenon is significant across a wide range of scholarship. The justifications which terminate within information systems are, variously, political,

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<sup>17</sup>I’m using the term assemblage in more or less the sense given in N Katherine Hayles, “Cognitive Assemblages: Technical Agency and Human Interactions,” *Critical inquiry* 43, no. 1 (2016): 32–55.

<sup>18</sup>Infrastructural inversion as a technique is explained in Chapter 2.



scientific, technical, practical, and linguistic. The contents of information systems themselves, *i.e.*, the promulgated inscriptions within them, are similarly multifaceted. Using the production of certainty, promulgation, and enactment as theoretical lenses helps bring the otherwise blurry political, scientific, technical, practical, and linguistic aspects of these systems and how we use them into focus.

To be sure, simplification is often needed and even warranted for much of the field of information studies and its surrounding professional disciplines. Database engineers, catalogers, and system analysts must, after all, do their work. As they do, though, a cascade of ethical, political, and cultural effects emanate from their decisions.<sup>19</sup> Algorithmic systems and artificially intelligent systems are providing new capacities for promulgation and enactment at global scale. As information ethics assumes its rightful place at the forefront of academic debate, and information policy increasingly enters popular consciousness, theoretical approaches which can successfully integrate these disparate perspectives are sorely needed and will be widely impactful. Prospects for engaging more deeply with these important issues in future work are surveyed in the Conclusion.

## **What I Hope to Achieve**

Part I identifies the phenomenon of certainty, provides conceptual tools for describing and analyzing it, and produces a taxonomy of the role information systems play in the phenomenon. Part II applies these new tools to offer a novel account of how global standards of time are promulgated and enacted with information systems.

Each chapter of the dissertation is scoped to constitute a coherent set of contributions. Chapter 1 identifies the phenomenon of certainty and describes why it is an interesting topic of study. Chapter 2 provides an analytic framework to identify the key actors and material sites through which the phenomenon is manifested. Chapter 3 is the most conceptual chapter, and puts my work in dialog with philosophical and critical approaches to related problems. Some of the theoretical work it does may be interesting to theorists in adjacent fields. Chapter 4 constitutes the most novel contribution of the

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<sup>19</sup>There is a long tradition of work in the field detailing these effects, including Elfreda a Chatman, “Life in a small world: Applicability of gratification theory to information-seeking behavior,” *Journal of the American Society for Information Science* 42, no. 6 (July 1991): 438–449, Hope A Olson, “The Power to Name: Representation in Library Catalogs,” *Signs* 26, no. 3 (2001): 639–668, Safiya Umoja Noble, *Algorithms of Oppression: How Search Engines Reinforce Racism* (New York, NY: New York University Press, 2017), Geoffrey C Bowker and Susan Leigh Star, *Sorting Things Out: Classification and Its Consequences* (Cambridge, MA: MIT Press, 1999), and many others.

dissertation, a taxonomy of certainty and method for applying it to the analysis of certainty in systems. Within Part II, Chapter 5 provides a technical and historical account of computational timekeeping, inverting this information infrastructure such that it is tractable to further analysis. Chapter 6 uses the assemblage of certainty-producing systems and actors within modern computational timekeeping as a particularly challenging test for the taxonomy. Three specific subsystems of the assemblage are analyzed using the methods developed in the foregoing chapters. Each subsystem demonstrates a way of providing a certain place to consult and move on from when answering the question, “what time is it?” Combined with the infrastructural inversion of Chapter 5, this demonstrates the complementarity of the analysis of certainty with techniques of infrastructural inversion

My hope is that these chapters provide more than the sum of their individual contributions. A phenomenon, analytical tools, theoretical connections, a method of analysis, and a test case applying the method together form a novel approach to investigating information systems, the actors which surround them, and the social reality constituted by their interactions.

## **Part I**

### **A Taxonomy of Certainty**

## CHAPTER 1: CERTAINTY & ITS CONSEQUENCES

### Dying of Old Age

When is it impossible to die from “old age”? There’s a simple potential answer to this question: when it’s not an option for the coroner who fills out a computerized death certificate. Bowker and Star’s infrastructural inversion of the International Classification of Disease (ICD) helps reveal the historical and sociological origins of the classification of death,<sup>1</sup> including the deliberate exclusion of “old age”, in favor of more specific medical causes of death. So, it’s impossible to die of “old age” because this choice isn’t in the dropdown menu. End of story. If the goal is to make space for colloquial accounts of death within the medicalized practices of modern death certificate creation, this would also be the beginning of a sociologically informed interface design project.

This isn’t the whole picture, though. My approach will be to foreground the use of the information artifacts generated by, in this case, classification processes. To illustrate this, the answer above can be rendered like this:

1. The classification “old age” is not available to the coroner when completing a death certificate.

Bowker and Star researcher focus on the history of the classification scheme and its influence on the information interface the coroner encounters. This approach depends upon two presuppositions about the *use* of a death certificate:

2. Someone seeking to answer the question “what was the cause of death?” will consult the death certificate; and
3. having consulted the death certificate, they will move on in light of its listed cause of death.

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<sup>1</sup>*Infrastructural inversion* was originally proposed by Bowker as a description of the strategic approach taken by French oil services company Schlumberger in developing oil fields early 20<sup>th</sup> century. Geoffrey C Bowker, *Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920-1940* (Cambridge: MIT Press, 1994). It has come to denote the methodology of foregrounding infrastructures and infrastructural processes in the analysis of systems, and that is how I will use it in this dissertation. See the technique deployed in Geoffrey C Bowker, “Second Nature once Removed: Time, Space and Representations,” *Time & Society* 4, no. 1 (February 1995): 47–66; and the mature use of the term in Bowker and Star, *Sorting Things Out: Classification and Its Consequences*.

Item 2 indicates that the information system, in this case the registry of death certificates, is incorporated into information practices, in this case looking up cause of death. Part of the power of classifications, and of information systems in general, is that we consult them to answer questions, and we develop practices of consultation that insinuate them into how we come to know about reality. Item 3 (moving on) so often follows item 2 (consultation) that it similarly may go unnoticed. But “moving on in light of” a listed cause of death need not be taken to mean only repeating the cause verbatim. There is an interpretive flexibility available to agents who consult death certificates. The common euphemism “natural causes” subtly acknowledges the medical focus on etiology of death, and is a way of ‘moving on in light of’ besides simply parroting the inscription. Where this ‘moving on’ doesn’t include direct verification or confirmation, the inscription determines the last word on the matter.<sup>2</sup>

So the answer of *when* it’s impossible to die of old age varies by context, and is dependent upon two broad categories of behavior-within-context. In the medical determination of cause of death, we have to look at the conditions of inscription. In the many contexts which incorporate death certificate inscriptions into information behaviors, the focus must shift to the conditions of consultation and moving on. A clear delineation of contexts surrounding the behaviors of inscription and the behaviors of consultation and moving on will help provide a more complete account of how behavior changes in light of information systems, what I’ll call the production of certainty.

### Facts and Social Reality

This dissertation foregrounds the enactment of information systems into certainty, the consulting and moving on in items 2 and 3 above. I’ll argue that the overall process which leads to moving on in light of information systems partially constitutes social reality.<sup>3</sup> As the case of “old age” helps show, certainty goes beyond classification or interfaces. My approach targets a broader set of activities commonly accomplished with information systems, like processing a financial transaction or declaring membership in a group. Like classification, these activities produce *facts*. All facts function as truth-grounds for propositions (*i.e.*, statements about some portion of reality), regardless of their source. Facts are not

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<sup>2</sup>The concept of moving on is a primitive unit of analysis, explanans rather than explanandum, but is nonetheless discussed further below and in Chapters 2 and 4.

<sup>3</sup>I’m using ‘social reality’ in roughly Searle’s sense, discussed further in Chapter 3.

themselves true or false, but rather determine the truth or falsity of other statements.<sup>4</sup> Facts constitute social reality by enabling the production of certainty.

Like being listed on the No Fly list, the “cause of death” on a death certificate is a fact, inscribed by whomever completes a death certificate (or makes an entry in a death certificate database, as the case may be) and enacted by anyone who consults this inscription and enacts it. This fact is designed to provide an answer to the question “what did this person die of?” (as well as providing truth grounds for statements like “this person died of *X*”). The practices surrounding the question and its answer tie it to inscriptions in information systems, and produce certainty with it.

A familiar objection to this account of facts is to evoke what *really* happened. The cause listed on the death certificate is only *true* if it’s why someone *really* died. The sense of *real* used here is central to philosophical realism. It begs the question of distinguishing between what is real and what is not and will be critiqued extensively in Chapter 3. The descriptive approach to propositional logic I’m using renders the fact as a mere role played in relation to a proposition. Thus, a listed cause of death can be a fact alongside, for instance, fraud on the part of a coroner in the production of the fact. This is discussed further on page 16.

Many facts are produced in a similar way to cause of death, and this production process does not inherently involve classification. At the other end of the life cycle, birth certificates create the fact of a person’s name, which can only tenuously be said to be a classification. And yet this fact dutifully answers many questions and grounds many propositions throughout a person’s life (and beyond). All this follows from some marks on paper (or, increasingly, an entry in a database): inscription shapes social reality.

### Dispelling the Magic of Certainty

An unease may be building at this point in the discussion, because the information systems in question seem to have a kind of magical power. Like “abracadabra,” the right incantation by the right person at the right time in the right way into the right information system makes something come about that seems impossibly powerful. This magic is what I’m investigating, and is the phenomenon I’m calling the production of certainty. Like all magic, further scrutiny reveals that the real action is elsewhere, in

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<sup>4</sup>This is the essence of propositional logic, where a proposition *p* is true or false in light of some fact (or state of affairs) *F*. As will become clear in what follows, though, I’ll view propositional logic as a mere description of a pattern of linguistic behaviors, not itself the essence of language, knowledge, or assertion. We’ll discuss the social nature of facts and their relationship with reality extensively in Section 3.2.

the actors that surround and condition their behavior upon the information system's inscribed facts. I'll go on to argue in Chapter 3 that it is the practice of consulting information systems to answer questions or determine the truth of claims which constitutes the facticity of inscriptions. The inscription is a key component of the production of social reality, but this reality is only manifested through action.

### *Resisting Certainty*

Let's return to the question of why it's impossible to die of old age and focus on the agents and actions surrounding the inscribed fact of the cause of death.<sup>5</sup> To the extent that it's *actually* impossible, no agent will fill out a death certificate listing "old age" as a cause of death. A faithful application of the ICD in the completion of death certificates *by agents* (whether enforced by discipline, norms, and procedures or a dropdown menu) is, most precisely, what makes it impossible to die of old age. But any breakdown of enforcement means that it's once again possible to die of old age: "old age" is inscribed into a form, and the spell is broken.

The Oregon Health Authority's guidelines for reporting cause of death for the elderly both establish the professional norm of not using "old age" as a cause of death and reveals that the enactment of this policy is not nearly as uniform as one might expect.

Reporting terms such as senescence, old age, infirmity, and advanced age are not valuable for public health or medical research. The age of the decedent and the date of birth are both reported elsewhere on the death certificate. In addition, there are no standards about what age is "old." While old age is reported more frequently for decedents over the age of 90, the Center for Health Statistics received a death certificate in 2001 for a 55-year-old decedent who was reported as dying due to "old age."<sup>6</sup>

Thus, it seems, that there are actors who make it possible to die of old age, in Oregon at least. Though these guidelines merely imply it, it seems that enough decedents are given a cause of death of "old age" to mandate a formal policy (not to mention the 2001 case). Until, presumably, a database interface makes it technically impossible to die of old age, this policy is an attempt to produce consistent causes of death needed for public health statistics.

### *Certainty and Consistency*

The 'magic' of certainty as I'll be approaching it is not related to a scientific fantasy of omniscience, what John Dewey called "the quest for certainty." Facts, though not logically truth-apt (*i.e.*, able to be

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<sup>5</sup>So far, all of the agents have been human, for simplicity, but below we will examine why they need not be.

<sup>6</sup>Oregon Health Authority, *Reporting Causes of Death for the Elderly*, technical report (Oregon Department of Human Services Center for Health Statistics, 2013).

ascribed a value of True or False), need not be consistent with each other even within a given social reality. This means that systems of thought that value internal consistency, like governments, must have a way of discrediting facts that are inconsistent with others they hold. This leads to the policies, procedures, and imprimaturs employed during fact production, from the signature to the seal of the notary public to encryption algorithms. Certainty, we'll see, is quite easy to produce: there's nothing to quest after. The major question operative in these cases is whether one has the power (physical, political, aesthetic, ethical, and so on) to extend certainty and the facts that underpin it into other contexts, thereby expanding certainty into others' social reality.

Each step towards consistency in certainty raises the stakes of controlling fact production. The industry of "death fraud," especially prevalent in parts of India and the Philippines, demonstrates the potential economic value of the production of certainty about death. The possibility of fraud in the production of certainty also reinforces that it is not an infallible view from some god's eye perspective.<sup>7</sup> The principle, then, is that a fact is a fact because it is enacted as such. It remains a fact just as long as it is enacted, *i.e.*, until it is replaced or ignored.<sup>8</sup> We'll see that the rules, practices, and techniques surrounding facts that seem to preclude this account, such as the realist conception of facts, are strategies for mitigating these dynamics.

### Organization of Chapter 1

Section 1.1 applies a pragmatic approach to the identification of certainty in information systems, preliminary to the analysis to follow. This will distinguish the consequence-focused sense of certainty I'm using from others that seek to investigate its antecedents. Section 1.2 will survey three kinds of certainty. In viewing certainty as enacted, these three kinds describe different ways in which agents move on after consulting an information system. Section 1.3 reviews the thought of Wittgenstein, Smith, and Star in relation to my conception of certainty. This section will show that, following Wittgenstein, certainty is

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<sup>7</sup>In a recent case, a CEO of a cryptocurrency exchange was reported dead on a trip to India, and was the only person with knowledge of the firm's password for millions of dollars of customer funds in 'cold storage.' Some security researchers suspect that the case is one of death fraud, to conceal the embezzlement of the funds. Daniel Shane, "A crypto exchange may have lost \$145 million after its CEO suddenly died," *CNN Business*, February 2019. For more on the region in which the CEO dies, and death fraud generally, see Elizabeth Greenwood, *Playing Dead: A Journey Through the World of Death Fraud* (New York: Simon & Schuster, 2016).

<sup>8</sup>Replacement and willful ignorance *within a context* don't prevent facts persisting in other contexts through enactment by other actors. Much more on this in Section 3.2.



a basic component of inquiry and knowledge production. Smith and Star’s work each approaches part of the phenomenon as I’ve framed it, and I will use these approaches to shine light on the whole. This chapter lays the groundwork needed for the operationalization of related concepts in Chapter 2.

## 1.1 Certainty and Action

This chapter’s title is more than just an allusion to the subtitle of Bowker & Star’s landmark *Sorting Things Out: Classification and Its Consequences*. A focus on consequences is a simple but powerful rendering of pragmatism. Star writes,

One of the simplest and most difficult tenets of pragmatism is that understanding is based on consequences, not antecedents. One does not build an a priori logic, philosophical analysis with preset categories or do so as “verificationist” social scientists, as Barney Glaser so mordantly termed them.<sup>9</sup>

By focusing on consequences, Bowker and Star recast much of the classification theory which had come before as a series of normative projects which invented and sought to enforce antecedents to classification practice, while often claiming to have ‘discovered’ classificatory principles. Once recast as parts of our “moral infrastructure,” classification projects could be examined sociologically and critiqued, and engaged in an ethical and political register. My claim at the outset is that similar work needs to be done with the broader practices of certainty surrounding information systems, and that emulating their pragmatic approach is the best way to do so.

### 1.1.1 Which Certainty?

Certainty is an overloaded term which has several venerable yet disparate disciplinary senses. Following Star’s pragmatic maxim, we’re interested here in consequences, not antecedents, so the sense in which I’m using the term will have no truck with *a priori* conceptions of logic, validity, or necessity. It won’t concern the individual psychological experience of being certain. I won’t define certainty in opposition to the statistical concept of uncertainty (elaborated further in Section 1.1.3). In the context of information systems in which I’ll approach it, certainty consists of a characteristic set of actions by an actor and the material, linguistic, and social context that surrounds and conditions them. This is an excavation of the earliest sense of the word, derived from the Latin *cerndre*, to separate, sift, or decide.

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<sup>9</sup>Susan Leigh Star, “Living Grounded Theory: Cognitive and Emotional Forms of Pragmatism,” in *Boundary Objects and Beyond: Working with Leigh Star*, ed. Geoffrey C Bowker et al. (Cambridge: MIT Press, 2015), 133.

### 1.1.2 How Can We Tell Certainty Has Been Produced?

Prior to analyzing certainty, we need a reliable way of determining that it has happened. This is of obvious methodological importance and will help circumscribe the scope of the phenomenon into something tractable. The rest of this chapter will utilize this basic sequence of actions as a marker of the kind of certainty we're interested in:

- An actor consults an information system
- The actor moves on in light of what was found there

This simple sequence embodies Wittgenstein's observation that "To be sure there is justification, but justification must come to an end somewhere." For Wittgenstein, this observation showed how holding some propositions exempt from doubt, what I'm calling moving on, is key to the functioning of language (discussed further in Section 1.3.1). In cases where information systems are utilized to end a process of justification, the system is consulted and its contents are reflected in the actions taken when the actor moves on. Abstracting from any antecedents, the consequences of Wittgenstein's justification are to be found precisely in the character and consequences of this moving on.

#### *The Cessation of Justification*

This sequence of actions, consultation and moving on, I'll call the cessation of justification.<sup>10</sup> The choice of the term justification is deliberate, but may be misleading because its meaning is disciplinarily polysemous. In an analytic or positivist context, justification indicates logical validity, and is a critical component of knowledge construed as justified true belief.<sup>11</sup> In sociological context, justification is a social process of providing reasons, a description of a communities' practices when beliefs or claims conflict. In political theory, justification may be tied to the accomplishment of justice.<sup>12</sup> My account requires merely an account of justification's effects rather than its mechanism or origin. Communities

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<sup>10</sup>Since the ways of moving on are most relevant to describing the consequences, in the dissertation I'll often use 'moving on' as shorthand for the cessation of justification, and the consultation of an information system prior to moving on will be implied by the context.

<sup>11</sup>A discussion of justified true belief is available in Jonathan Jenkins Ichikawa and Matthias Steup, "The Analysis of Knowledge," in *The Stanford Encyclopedia of Philosophy (Summer 2018 Edition)*, Summer 2018, ed. Edward N Zalta (Stanford University, 2018).

<sup>12</sup>An account combining sociological and political accounts of justification that will feature in the discussion below is Luc Boltanski and Laurent Thévenot, *On Justification: Economies of Worth* (Princeton: Princeton University Press, 2006).

have actual practices of responding to disputes, providing evidence, deeming reasons valid, and so on. I will focus solely on these processes' termination upon information systems and the range of consequences that may follow.

This is primarily to limit the scope of the project, but has the benefit of compatibility with a diverse range of approaches to justification. Similar to Bowker & Star's demotion of classification practices from a process of 'discovery' of the order of things into a set of culturally conditioned actions, this allows otherwise incompatible practices to be analyzed side-by-side in terms of their ethical and political effects. Positivist accounts of justified true belief can be analyzed using the same tools as practices of justification which hinge upon the declarations (or tweets) of a political leader. Projects which seek to increase the reliability, conformity, or utility of justification practices (such as scientific methodology, religious orthodoxy, or policy debates) are rendered into socially conditioned normative projects. By remaining agnostic as to *how* justification happens, and why, my analysis moves on to focus on the consequences it helps produce once it ends. The outcome of this analysis is intended to then feed back into these debates.

### 1.1.3 Consulting an Information System and Moving On

The characteristic set of certainty-producing actions I'll focus on is, at its most simple, when an actor consults an information system and moves on in light of what it finds there. The example of the No Fly list encapsulated this well: a border control agent consults a list (perhaps by scanning a passport, though the method of consultation is immaterial at this point), and then acts to either permit or deny passage based on the material characteristics of the information system's response. The actor need not be human. Airlines are required to consult the No Fly list and deny boarding passes to passengers who are on it. In these cases, the airlines' online reservation systems are the agent performing the characteristic actions of certainty.

The possibility of non-human actors underscores the importance of the *apsychological* account of certainty I'm using. For humans, characteristic psychological experiences may attend these actions (such as an expectant feeling when consulting a system, a sense of resolution once the answer is encountered, and a sense of satisfaction that all is in order). From my perspective, these are either antecedents to the actions of interest or epiphenomenal (in the sense of 'secondary') to them. The machines which also consult the No Fly list (such as airline reservation systems) will not have these antecedents, making

them a barrier to considering nonhuman actors. Bracketing these and other antecedents to the actions of certainty offers the possibility of a unified analysis of diverse actors in diverse circumstances.

I will not offer “a theory of certainty” in this dissertation, especially where such a theory would specify antecedents. Such a theory would, I suppose, try to explain what certainty *is* (in a non-relational way), how it works, where it comes from, and so on. Instead, I’ll focus on the *production* of certainty, as a result of actions surrounding information systems. This is not as much of an evasion as it might seem, and is an established strategy in information studies. Chatman didn’t need a “theory of information” to investigate information poverty, just an operationalization of what the information poor didn’t have access to. Noble’s *Algorithms of Oppression* didn’t need an antecedent-focused theory of what an algorithm is to trace search algorithms’ effects upon black girls. And, to bring the discussion full circle, Bowker and Star’s work is none the worse for neglecting the antecedents of classification in favor of its consequences.<sup>13</sup>

This isn’t to say that research into antecedents isn’t useful: it just isn’t pragmatic. In fact, as long as work focusing on antecedents is construed as normative in character rather than empirical (or synthetic *a priori*, or in any way a ‘discovery’), it can be usefully incorporated into pragmatic work. More on this later.

#### *Certainty Isn’t the Opposite of Uncertainty*

As noted above, this formulation of certainty is at odds with some disciplinary uses of the term. One I feel I must address is statistical *uncertainty*, because of the inevitable intersection of this concept with information systems. Statistical uncertainty is often a property attributed to information in information systems, but this is irrelevant to my analysis except insofar as it conditions enactment. That is,  $5.43 \pm .03$ , when stopped upon and moved on with, can underpin certainty just as capably as 5.43 (for instance, the correct answer to a test question might be the exact inscription  $5.43 \pm .03$ ). The disciplinary label of ‘uncertainty’ can in this case be seen as a methodological admonition about precisely *how* one should move on, a kind of *force* with which the information should be taken. But the information as inscribed is unambiguous, precise in its expression of imprecision. The disciplinary norms which influence how one *should* treat  $5.43 \pm .03$  as opposed to 5.43 may or may not influence how a specific agent in fact moves on with it as fact.

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<sup>13</sup>Emotions can of course have consequences. A focus on action will reveal the relevant consequences nonetheless.

It may seem odd to claim that uncertainty and certainty as I'm approaching it aren't opposites. The larger point is that my project starts with a different dichotomy: certainty or not. Not-certainty is the lack of moving on in light of information. People may refuse to move on for a variety of reasons. Research, broadly, is the refusal to move on regarding a specific subject, a refusal that may last years or decades. Non-certainty can also happen on a smaller scale. Disbelief or lack of trust in a system could prompt an extra-systemic action: if an information system tells me that it's 20 °F outside in the North Carolina summer, I'll likely stick my hand out a window to test this before I grab my coat, disregarding this information in light of what I find outside the system. In this case I would be, in the terms of this dissertation, non-certain with respect to the information I obtained from the information system. This distinction is useful in this context because statistical uncertainty can be either embedded in the information I move on with to produce certainty or a cause of non-certainty, a refusal to take the information and move on.<sup>14</sup>

### *Certainty Isn't Truth*

The search for truth is embedded into many discussions that may at first seem related to the topic of certainty as I'm approaching it here. But, by placing the emphasis on action, my approach has no need of a strong conception of truth (beyond a description of its function in propositional logic, given above). Propositional logic, and the fact that facts and propositions play the role they do within it, is a descriptive, and therefore contingent, input to the approach I'm taking here.<sup>15</sup> If actors didn't often behave in this way it need not have been mentioned.

As will be discussed extensively at multiple points below, a goal of my analysis will be to handle human and nonhuman agents with the same theoretical terms. Truth, whatever it may be, is at the very least a foreign imposition upon discussions of machines, computers included. Thus, the descriptive account I give of the relationship of facts to truth serves to orient this work within conceptual space. Certainty, and the actors which give rise to it, need not depend upon truth, proposition, or any other contingent description of language.

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<sup>14</sup>We'll revisit this refusal in several places, especially Wittgenstein's account of the more extreme cases of refusal, where buttressing effects come into play, in Section 1.3.1.

<sup>15</sup>This approach is distinct from but broadly influenced by Price's approach to truth and facts. See Huw Price, *Facts and the Function of Truth* (Oxford, UK: Basil Blackwell, 1988); Huw Price, *Naturalism Without Mirrors* (Oxford University Press, 2010).

### *Certainty Isn't Trust*

Questions of trust, and trustworthiness, have rightfully proliferated of late, as geopolitical events have encouraged citizens institutions from governments to the press to question the sources of the information they receive.<sup>16</sup> While they are undeniably important topics, this dissertation won't directly address these, primarily because certainty and trust are distinct concepts.

One of the key features of the definition of certainty I'm using is that it is produced through action. Trust is a description of a psychological state. Trust is measured by social scientists in a variety of ways, but ultimately it is difficult to do so. Self-reporting is at best a blunt instrument, and one which can often disturb the phenomenon it's trying to measure.

Trust in information systems (or their operators) may influence the production of certainty insofar as it encourages moving on from the information found within them. But *why* someone moves on is less relevant to the analysis I'm undertaking than *that* the moving on has occurred. Also, as a psychological concept, trust does not apply (except perhaps metaphorically) to nonhuman agents.

Finally, perhaps most persuasively, certainty can be produced without trust at all. If I access information from an untrustworthy source that seems plausible, I am faced with a decision: move on in light of that information, discard that information, or seek corroboration. *Whenever* I choose to move on with that information, I am producing certainty, regardless of whether I trust it or its source. Psychologically, this might produce an attendant anxiety, anticipation, or hesitancy. But if I move on nonetheless, the analysis I'm proposing in this dissertation will apply.

Both trust and truth form potentially interesting connections with existing topics of research. Better articulating the ways that these antecedents interact with ways of moving on will have value. But for now, my focus on certainty and its consequences demands that I neglect its antecedents and other adjacent phenomena.

### *Ways of Moving On*

The next section introduces incorrigible, empirical, and defeasible certainties. These three types of certainty differ with respect to how an actor who moves on in light of an information system might be induced to reconsider their justification. They are not explanations of the process of justification but

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<sup>16</sup>This is happening all along the political spectrum: the differences seem to lie in what should be questioned, and what counts as trustworthiness.

rather *how an agent moves on* after justification ends. The scientist, the zealot, the political partisan, and the automated turnstile may each move on in any of these three ways, regardless of their differing practices of determining when to stop justifying and move on. Certainty and justification are related, but all we need to know about justification to analyze certainty is that it led an actor to consult an information system and that the actor moved on in light of what was found there. The meat of the analysis will happen elsewhere.

## 1.2 Producing Certainty with Systems

With the cessation of justification established as a marker of when the phenomenon of certainty is present, we can now distinguish three basic types of certainty by the ways in which actors move on after consulting the information system. In some cases, agents move on with information that cannot be corrected, with a *declaration*. In other cases, agents move on with a *measurement*, and the expectation that the information may be superseded by subsequent measurement (that is more accurate, more current, *etc.*). Finally, agents sometimes move on with an *attributed claim* that may be arrayed and compared with other conflicting claims. In each case, the moving on cements the information system's contents into action of some form. Moving on is the moment of praxis where inscription is enacted, producing certainty with one of these three characters.

### 1.2.1 Incorrigible Certainty

Incorrigible certainty is one of the most portentous consequences of our use of information systems to produce certainty. As shown by the example of the No Fly list, it is surprisingly common, yet poorly understood.

Incorrigibility is the logical property of not being subject to correction.<sup>17</sup> For a pragmatist, the sense of 'logical' at operation here is a description of a set of practices, not an *a priori* property.<sup>18</sup> This means that incorrigibility, however powerful a concept, is still ultimately relational and situational. When I say

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<sup>17</sup>See *e.g.*, Atwell, "Austin on Incorrigibility"; Harrison, "The Incorrigibility of the Cogito"; Campos, "Analyticity and Incorrigibility."

<sup>18</sup>Rorty, "Incorrigibility as the Mark of the Mental"; Rorty, "Functionalism, Machines, and Incorrigibility."

that the No Fly list is incorrigible, this is a contingent statement about the ways in which it is currently used, not a metaphysical property.

As discussed on page 2, incorrigibility does not mean immutability. Nor does it imply infallibility with respect to some purpose, or omniscience on the part of a system creator. The No Fly list is in fact altered, and does not always accomplish its intended purpose. Sometimes it is altered by those within the government who have authority to do so, and sometimes (though rarely) it is altered by judicial intervention. The thing to note about these alterations, though, is that they are not corrections, in the sense that they do not follow from some measured state of the world. Instead, they are redeclarations.

### *Declaration*

Declaration is a key act in the creation of incorrigible certainty. Declarations themselves, though, are inert. Their power comes from when they are utilized in the production of certainty, that is, when an agent *moves on* in light of them. This action constitutes the power of declarations within information systems. Appellate procedures or actor discretion to disregard declarations may mitigate this power. But, especially in large, distributed bureaucracies, declarations are often faithfully enacted and few actors have the power to re-declare. Thus, in terms of consequences, incorrigible certainty is the most important kind to understand. To begin this, I'll first distinguish three senses of incorrigibility, each of which will factor in my analysis.

### *Three Senses of Incorrigibility*

There are at least three kinds of incorrigibility, all of which may apply to incorrigible certainty produced with information systems. These are:

1. the logical impossibility of correction
2. the actual impossibility of correction
3. impossible, as in "very difficult to deal with"

The first has already been encountered as a property of the way language is used in a particular context. The second is closely related, but subtly different. The second sense of incorrigibility refers to cases where something is practically impossible to correct *for a given actor*. This sense of incorrigibility might apply, for instance, to someone's health record. Once a diagnosis is entered into a record by a healthcare provider it is in many cases actually impossible for a patient to have it removed (which might subsequently affect care, insurance coverage and so on). The diagnosis is a declaration of a sort, but inscriptions need not be logically incorrigible to have this property; a measurement of a patient's



temperature may just as well be incorrigible in this sense. In these cases, questions of power and access to the system of record must be addressed to describe the situation. The third sense of incorrigibility is derived from the colloquial use of the term to indicate unruly or difficult people (such as a student who resists attempts at discipline). This sense, though not technical, often aptly describes the experience of interacting with bureaucratic systems which produce certainties that are disagreeable or harmful.<sup>19</sup>

As may be obvious from the pragmatic inspiration drawn from Star, my concept of the first sense of incorrigibility does not construe logic as a kind of metaphysical necessity. Logic is, pragmatically speaking, a pattern that can be observed in a broad range of language and behavior. Distinct logics may be observed at operation amongst different groups, or within different discourses. Logical incorrigibility denotes a pattern of action that often involves all of the three senses above. For instance, Delta airlines' reservation system is logically incorrigible about my confirmation number within the context of making a Delta reservation because there is no shared context where anything other than the Delta reservation system itself can declare a Delta confirmation number. This same system can also be incorrigible in the second sense listed above in that there is no way for me, with my present technical skills, access, *etc.*, to alter my confirmation number. If I lose my confirmation number and need to update my reservation, the system will quickly appear incorrigible in the third sense. The diversity of examples I'll use in this dissertation is intended in part to demonstrate this pattern in action in diverse contexts.

I will refer back to this discussion and periodically distinguish between these senses where this furthers the analysis. For now, I'll emphasize that 1) logical incorrigibility is not a sort of metaphysical property but rather the result of the contingent practices surrounding language, 2) actual incorrigibility need not entail logical incorrigibility, and that 3) the experience of colloquial incorrigibility is likely an indicator the certainty produced with a given system is having an undesired or damaging effect upon someone who is interacting with it. We will revisit each of these below.

### *The Value of Incorrigibility*

Despite its ethical and political consequences, the production of incorrigible certainty is a value that we seek from information systems for diverse purposes. Identification numbers, confirmation numbers, requisition numbers, and employee categories are all valued for their incorrigibility. Non-certainty in this kind of information represents a kind of breakdown of institutional order. The evolution of

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<sup>19</sup>See also the discussion of Bowker and Star's *torque* on page 45.

organizational information management is thus, in a sense, the development and proliferation of the ability for administrators and other officials to effectively declare facts within their organizational contexts. These declarations are supported by practices of justification that end upon and enact this information. A faculty member with a grant is given a grant number, which she uses to fill out a requisition form, which a staff member processes to disburse funds for conference travel. The kind of certainty which underpins institutional order is expressed by (amongst other things in this example) the staff member consulting an information system's account of the funds available under the grant number, and moving on to cut a check, in light of the availability of funds and the validity of the request.

Beynon-Davies has highlighted the centrality of the power of declaration via information systems to the order of organizations. His list of identifiers data structure is a distillation of the declarative power of information systems used by organizations to impose order.<sup>20</sup> We'll discuss limitations of his approach in Section 3.2, and he doesn't make a connection between declaration and incorrigibility as I do in Section 3.2.1, but the importance of his identification of the centrality of this power to organizational coherence should not be overlooked. It shows that the ways in which information systems are *used* is key to effectively studying them. Further, it helps disambiguate systems which serve as a medium of declaration from those that contain the more familiar measurement. It is to the latter that we'll turn next.

### 1.2.2 Empirical Certainty

Applied informatics projects in a variety of domains focus on or prioritize the collection of empirical data. For instance, the warehouse inventory systems noted at the outset are a focus of everything from introductory database courses to supply chain management. Applied scientific informatics, broadly, apply an inventory-like approach to the collection of data from telescopes, environmental sensors, or genetic sequencers. In information retrieval, most researchers adopt an implicitly empirical approach to measuring performance; the precision/recall paradigm embedded into TREC is based upon an assumption that expert relevance determinations can produce an 'inventory' of relevant documents for a given query. Each relies on information construed as measurement.

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<sup>20</sup>Beynon-Davies, "Form-ing institutional order: The scaffolding of lists and identifiers."

### *Measurement*

Empirical information is based upon measurement of some form. A device, broadly construed, is brought into contact with some portion of the world and a reading is produced. For our purposes, the nature of the measurement is less important than the characteristic way in which measurements are treated when encountered within an information system. Concepts such as ‘accuracy’ and ‘precision’ are, in a pragmatic context, merely normative terms that are sometimes used to guide behaviors. At times, they can prevent certainty from being produced, by inducing an agent to refuse to move on and continue searching, questioning, or otherwise continuing their process of justification. A warehouse worker who has recently seen hundreds of iPads on a shelf will likely refuse to move on in light of the information that “there are 0 iPads in stock,” and seek extra-systemic verification of this measurement. Empirical measurements represent some state of the world, and where the world is known to not be in the represented state, the representation is viewed as incorrect. Unlike incorrigible certainty, there is an established procedure for updating the system to match the world.

Complexity occurs when the agent is separated from the part of the world that the system is designed to measure. Most customers have never been to one of Amazon’s warehouses. When they encounter “there are 0 iPads in stock” on the website, they will likely move on in light of this information, perhaps seeking out another place to purchase an iPad. Empirical certainty differs from incorrigible certainty insofar as, should the agent directly perceive the state of the world represented by the measurement, the agent would move on in light of the state of the world rather than the information in the system. For instance, after checking the inventory of a particular store and seeing “there are 0 iPads in stock” there, a customer who saw an iPad on the shelf would not continue moving on as if there were no iPads in stock but would rather take the iPad to the counter. The customer refuses to accept the information system as a declaration and instead treats it as an inaccurate measurement. There is no comparable practice surrounding the No Fly list.

### *Distinguishing Empirical Certainty*

The existence of stock on the shelf does not determine whether the agent-system relation produces incorrigible or empirical certainty: the way in which the agent moves on does. A few years ago I was trying to purchase a dishwasher which was physically in front of me but was prevented from doing so by the store clerk to because the store’s inventory system did not show it as being in stock. In this case, the

agent (the store's employee) produced incorrigible certainty using the store's inventory system.<sup>21</sup> A tight focus on the consequences of action is critical to understanding such situations.

Empirical certainty thus takes deliberate and specific effort; it must be enacted in a certain way. The agent must be willing and able to alter the ways in which they move on in light of subsequent measurements or direct experience of a state of the world. In most cases, the normative property of reliability for systems intended to produce empirical certainty is achieved by frequent, accurate, and/or reconciled measurement. Procedures such as real-time updating (in the case of, for instance, temperature sensors) or reconciliation practices (in the case of store inventories) are designed to align a system's contents more directly with the aspects of the world it measures. Though, normatively, such practices are expected from systems of this type, and they may influence an agent's willingness to move on, the actual way an agent moves on is of primary importance when examining certainty. In other words, this analysis is not concerned with whether a system is accurate, recently updated, or well maintained, but rather with whether an agent moves on as if it were. In cases where an agent moves on with empirical certainty, we should see evidence of a willingness to treat the information moved on with as a measurement.

#### *The value of empirical certainty*

Keeping track of things in or aspects of the world is a ubiquitous need. From science to business to libraries, organizations of all kinds use measuring information systems as a kind of institutional epistemology. When the measurements a system contains match up with the things or properties of interest, and agents can move on in light of that information to achieve some goal without needing to re-perform the measurement in question, empirical certainty allows for a kind of epistemic division of labor. Knowing is separated from the doing which requires knowledge.

#### 1.2.3 Defeasible Certainty

If incorrigibility involves moving on without the possibility or actuality of revision, what else besides subsequent measurement might change how an agent moves on? The simple answer: an argument. When an agent moves on but will subject the information moved on with to argumentative challenge, this is defeasible certainty.

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<sup>21</sup>This is a good example of why is impossible to know ahead of time whether a system *intended* to produce a particular kind of certainty will actually be used to do so by the agents that surround it. Much more on this when we get to giving as and taking as in Sections 4.2.2 and 4.2.3.

### *Defeasible logic*

Unlike the *ps* and *qs* of formal logic, defeasible logic (also called informal logic, or more broadly the study of argumentation), does not produce a formula that deterministically outputs True or False as the result of a set of truth values for its truth-apt variables. Arguments instead make claims and provide evidence for these claims. An example given by Feinberg is as follows:

*Claim: My sister has brown eyes.*

*Grounds: I have brown eyes.*

*Warrant: We are twins.*

*Backing: Twins share physical characteristics.*

*Rebuttal: It's not certain that we are identical twins; thus, her eyes might not be brown.*<sup>22</sup>

The existence of many potential rebuttals is characteristic of defeasible claims. Rebuttals may question the applicability of the warrant, as in the case above, counter the grounds (“you don’t actually have brown eyes”), counter the backing (“some physical characteristics are developmental and vary between identical twins”), and so on. The study of argumentation analyzes potential rebuttals, common structures of argument, conditions of validity, and so forth.<sup>23</sup> Defeasible claims can be seen as the application of some kind of (usually formal) logic to a particular case.<sup>24</sup> The circumstances and validity of the application are always up for debate. Defeasibility is in some respects the default state of human discourse, and certainly of academic discourse.

### *The potentials of defeasibility*

Defeasible certainty is essentially a willingness to move on with information with some sort of criteria for changing behavior in the future. The rebuttal above questions whether the claimant and her sister are identical twins. If we accord the argument as a whole defeasible certainty, we acknowledge the possibility

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<sup>22</sup>Melanie Feinberg, “Two kinds of evidence: how information systems form rhetorical arguments,” *Journal of Documentation* 66, no. 4 (2010): 497.

<sup>23</sup>Much like justification, the precise mechanism are outside the scope of this dissertation. For more on argumentation, see Douglas Walton, “A Very Short Introduction to Argumentation Theory,” in *Argumentation in Artificial Intelligence*, ed. Guillermo Simari and Iyad Rahwan (Boston, MA: Springer US, 2009), 1–22; Stephen Toulmin, *The Uses of Argument* (Cambridge, England: Cambridge University Press, 1958); Stephen Toulmin, *Human Understanding: The Collective Use and Evolution of Concepts* (Princeton, NJ: Princeton University Press, 1972); Douglas Walton, *Abductive Reasoning* (Tuscaloosa, Alabama: The University of Alabama Press, 2004).

<sup>24</sup>In this case,  $\forall x Px$ , where  $x$  is a set of twins and  $Px$  is the property of sharing the same eye color, is a rough translation of the backing into formal logic. The rest of the argument can be seen as articulations and substitutions around this logical core. The warrant asserts that the claimant and her sister are subject to the strictures of the backing. The grounds establish a particular eye color which, following  $Px$ , applies to both twins.

that evidence may support a rebuttal like this but move on with certainty until or unless such evidence is provided.

What might defeasible certainty look like in practice? In the case of the No Fly list, the agent would need to move on with the information that I was to be denied a boarding pass as a *claim* of the system (or of someone who interacted with the system). Is there any kind of additional evidence I could provide to change the agent's behavior? Obviously a passport is not such evidence. Nor is a TSA PreCheck number. The TSA has provided a Redress Control Number for travelers who are repeatedly identified for additional screening, probably due to some similarity to a person flagged for extra screening. The Redress Control Number system is countervailing evidence that a traveller should be screened. Turning the No Fly list as enacted by its agents into a system of defeasible certainty would require some sort of ability to present evidence that would change the way in which agents move on with its information. This would mitigate its incorrigibility, not by challenging its declarations but by guiding its enactment. This would allow someone to say "Elliott Hauser is indeed on the No Fly list, but this Number is proof that I'm not that Elliott Hauser."

More broadly, a shift towards defeasibility in the way we enact information systems holds enormous potential, and will emerge as one of the primary practical recommendations of this dissertation. Defeasibility is much messier than other kinds of certainty, but is core to the practice of, for instance, law and science. In both law and science, the logical possibility of disproving (defeating) any given claim is a mechanism of progress and, when applied consistently, can be an instrument of fairness. A shift towards enabling the enactment of defeasible certainty in information systems, especially where incorrigibility is likely to be incompatible with disciplinary norms, might help turn them from platforms of declarations into mediums of discourse. We'll discuss these potentials further in Chapter 4 and in Part II.

#### 1.2.4 Indeterminacy and the Incorrigible Default

No attempt is made here to characterize actors, or information systems, *outside of their relation to each other*. Rather, I'm attempting to describe precisely these relations. The distinctions I'm making depend upon future action *after* moving on. This makes the distinctions indeterminate before the subsequent actions have occurred. That is, especially without a causal account involving antecedents, we may not know which of the three cases we're dealing with initially. In this section I argue that, prior to an alteration to an agent's moving on, we should characterize the certainty of the interaction as *de facto* incorrigible.

That is, even if information *could be* or likely *will be* corrected by future measurement, until it has been, incorrigible certainty is produced as the actor moves on with it. Incorrigibility thus forms a kind of default certainty in the absence of the kinds of reconciliation offered by empirical and defeasible certainties.

The incorrigible default is at work when healthcare practitioners act in light of information such as journal articles, colleague recommendations, or practice guidelines. The rise of “evidence based” movements in fields such as medicine and education amount to programs of cultural change seeking to alter the ways in which providers move on, and what they move on in light of. In obstetrics, for example, practitioners for years clamped the umbilical cord soon after birth, both to enable it to be cut and out of a belief that restricting the blood flow from placenta to infant could help prevent jaundice, which is related to the breakdown of red blood cells. More recent evidence suggests, however, that up to a third of the baby’s blood volume can remain in the placenta when using this technique, and that it has led to an increase in anemia in infants.<sup>25</sup> Many providers, including UNC hospitals, now follow 2014 WHO guidelines making delayed cord clamping after birth standard procedure in light of this evidence that the risks of jaundice are reasonable given the risks of anemia.<sup>26</sup> This amounts to a model of how practitioners should “move on in light of.” Though some individual practitioners consult the literature themselves, most hospitals now centralize this functionality and reduce their recommendations into treatment algorithms and standardized practices. Thus, defeasible certainty, based on the empirical certainty of published measurement, is reduced once again to incorrigibility: hospital policies must be re-declared for reinterpretation of evidence to (indirectly) influence provider behavior. Providers that move on in light of hospital policy enact incorrigible certainty, regardless of the empirical and defeasible processes which may have produced the declarations in such policies.

The layered chains of certainties and ways of moving on here is characteristic of real-world systems. I’ll discuss this further in Chapter 4 and in Part II. I mention it here mostly to underscore that incorrigibility is the default, and that empirical and particularly defeasible certainties require large amounts of coordinated effort, both by an individual and within disciplinary communities of practice. In most

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<sup>25</sup>Eileen K Hutton and Eman S Hassan, “Late vs Early Clamping of the Umbilical Cord in Full-term Neonates: Systematic Review and Meta-analysis of Controlled Trials,” *Journal of the American Medical Association* 297, no. 11 (2007): 1241–1252.

<sup>26</sup>*Guideline: Delayed Umbilical Cord Clamping for Improved Maternal and Infant Health and Nutrition Outcomes*, technical report (Geneva, August 2015).

cases, only professionals or experts engage in such practices, and only in relation to their objects of study. As the case of obstetric practices shows, however, such processes are often centralized and once again reified into simplified systems amenable to the efficiency of incorrigible certainty.

The collapse to incorrigibility is not inevitable, and in fact maintaining defeasibility is a key design goal for systems designed for research informatics. Researchers in various historical informatics projects have conceptualized information systems as containing arguments or claims, rather than facts.<sup>27</sup> Since knowledge about the past is mutable and always subject to radical revision based on the discovery of some new artifact (“a lost Rembrandt!”), or the discovery of a new aspect of an existing artifact (“this painting uses pigments invented in the 1900s!”), information systems used for research cannot perform their functions unless they model many, often competing claims, and are able to be updated. Feinberg has taken this a step further, arguing that systems themselves should be construed as argumentative.<sup>28</sup> This kind of system will be elaborated upon in Section 4.1.3, and in Part II.

The incorrigible default of certainty is a far-reaching phenomenon, especially since incorrigibility is so powerful and so poorly understood in the context of information systems. I’ll expand upon these methodological issues extensively in Chapters 3 and 4. Part II will expand the concept to computation more broadly in preparation for an analysis of the production of certainty in computational timekeeping.

### 1.3 Encounters with Certainty and Its Consequences

If we take seriously my claims of the importance and pervasiveness of certainty, we should expect to see this phenomenon encountered extensively in the literature. This section’s goal is to trace encounters with the phenomenon of the production of certainty in the work of Ludwig Wittgenstein, Brian Cantwell Smith, and Susan Leigh Star. This will serve both to make clear how my work can be in conversation

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<sup>27</sup>Joseph Busch, “Use of a Relational Database System to Model the Variability of Historical Source Information,” in *Cognitive Paradigms in Knowledge Organisation*, ed. Arashanapalai Neelamegham (Bangalore, India: Sarada Ranganathan Endowment for Library Science, 1992); Joseph Busch, “Thinking Ambiguously: Organizing Source Materials for Historical Research,” in *Challenges in Indexing Electronic Text and Images*, ed. Raya Fidel et al. (Medford, N.J.: Learned Information, 1994); Adam Rabinowitz et al., “Making Sense of the Ways We Make Sense of the Past: The PeriodO Project,” *Bulletin of the Institute of Classical Studies* 59, no. 2 (December 2016): 42–55; Patrick Golden and Ryan Shaw, “Nanopublication beyond the sciences: the PeriodO period gazetteer,” *PeerJ Computer Science* 2 (February 2016): e44; John Bradley and Harold Short, “Texts into Databases: The Evolving Field of New-style Prosopography,” *Literary and Linguistic Computing* 20, no. Suppl 1 (January 2005): 3–24.

<sup>28</sup>Feinberg, “Two kinds of evidence: how information systems form rhetorical arguments.”



with this other literature, even when terminology or approach may differ, and provide an opportunity to underline the similarities and differences with thought that has come before.

### 1.3.1 Wittgenstein's Certainty as Incorrigibility

Ludwig Wittgenstein extensively explored the role of the phenomenon of certainty in language, particularly his late writings, collected in *On Certainty*.<sup>29</sup> This period of Wittgenstein's writing has received less attention in information studies than his earlier work in *Philosophical Investigations* or the *Tractatus Logico-Philosophicus*.<sup>30</sup> The purpose of this section is to indicate the low level at which incorrigible certainty functions in Wittgenstein's account of language and practice, and to articulate this to the context of information systems.

#### *When Mistakes are Impossible*

Wittgenstein noted a variety of language practices in which there are moments where mistakes are impossible. This isn't to say that speakers become infallible, omniscient, or omnipotent in their ability to define reality. Rather, Wittgenstein's point is that the concept of *error* doesn't apply.<sup>31</sup>

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<sup>29</sup>Like the bulk of Wittgenstein's published work, this volume was compiled from materials left to Wittgenstein's literary executors. It was edited by G. H. von Wright and G. E. M. Anscombe and first published in 1969, almost two decades after Wittgenstein's death in 1951

<sup>30</sup>Blair has undoubtedly engaged with Wittgenstein the most deeply within in information science, an engagement that's been sustained throughout a number of his writings. See *e.g.*, David C Blair, *Language and Representation in Information Retrieval* (Amsterdam: Elsevier, 1990); David C Blair, "Information retrieval and the philosophy of language," *Annual Review of Information Science and Technology* 37, no. 1 (January 2003): 3–50; David C Blair, *Wittgenstein, Language and Information: "Back to the Rough Ground!"* (Amsterdam: Springer Netherlands, 2006). While many other writers like Bowker and Star, Suchman, Agre, and Drucker reference or draw inspiration from Wittgenstein's work, rarely do they explain exactly how to operationalize it. For instance, Drucker's art book *Wittgenstein's Gallery*, which contrasts the expressive potential of images and words, is indicative of the more impressionistic treatment that Wittgenstein often gets, even when engaged with at length. Johanna Drucker, *Wittgenstein's Gallery* (Raleigh: Druckwerk [Lulu Press, Inc.], 2010). This work can be valuable, since Wittgenstein's evocative presentation lends itself to and benefits from these treatments. My point, though, is that Wittgenstein's work has received comparatively little direct and sustained philosophical engagement within the context of information studies, especially when compared to Derrida, Heidegger, or Habermas. I hope to partially remedy this.

<sup>31</sup>The examples I'll focus on are primarily drawn from mathematics and science. This isn't to limit their scope to these domains, but is rather a consequence of the philosophical discourse they are drawn from. Wittgenstein's examples of common sense philosophical statements, religious language, and visual experiences all seemed to import too much of the philosophical debates they were a part of to be useful in the context of information systems.

For Wittgenstein, the statement  $2 + 2 = 5$ , in the context of an adult who knows conventional arithmetic, can't be seen as a *mistake*. Unlike a child who is learning to calculate, and might indeed have made a mistake, the adult who articulates this proposition in full knowledge of the rules of arithmetic is operating in a different register.<sup>32</sup> For Wittgenstein, it's experienced by an interlocutor as a lack of understanding, an inability to reconcile what someone has said with our own certainties. "The truth of my statements is the test of my understanding of these statements. That is to say: if I make certain false statements, it becomes uncertain whether I understand them."<sup>33</sup> We might be inclined to call someone who maintained  $2 + 2 = 5$  insane (perhaps an extreme of the third sense of incorrigibility discussed on page 24). For Wittgenstein, ascription of insanity is often a marker of a clash of incompatible certainties.<sup>34</sup>

What if  $2 + 2 = 5$  is interpreted as a proclamation of a new rule of arithmetic?  $2 + 2 = 4$  can be seen as a rule to be followed during calculation, or one expression of the unlimited numbers of rules which form the practice of arithmetic.<sup>35</sup>  $2 + 2 = 5$  follows the same form as these more familiar arithmetical trivialities, but differs from it. It may thus be understood as a foundational rule for an entirely different set of practices than those that constitute consensus arithmetic. Mathematical proofs have the form of relating a new set of statements with another set that is already accepted.<sup>36</sup> The fact that some set of statements are incompatible with the rest of mathematics doesn't preclude the development of an alternate set of practices, constituting a kind of alternate mathematics. These parallel mathematics, though essentially limited to specialized fields of mathematics, have a form similar to that of conflicting incorrigible certainties. Mathematics as a discipline is committed to integrating the certainties it produces

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<sup>32</sup>We'll have better tools for analyzing this once we encounter Searle's context *C* in Chapter 3.

<sup>33</sup>Ludwig Wittgenstein, *On Certainty*, ed. G E M Anscombe and G H von Wright (New York, NY: Harper Torchbooks, 1969), §§81-2.

<sup>34</sup>This sense of insanity is also evoked by Orwell when he selected  $2 + 2 = 5$  as an example of the Party's absolute ability to control thought in *1984*.

<sup>35</sup>For simplicity, I'm glossing over Wittgenstein's discussion of the real differences between the process of learning to calculate and following rules. Wittgenstein wanted to show that learning to calculate wasn't equivalent to rule-following, but was instead a series of learned behaviors. Explicit rules are often used in teaching and learning to play what Wittgenstein would call language games, but once learning has taken place, Wittgenstein saw these drop away into mere patterns of behavior, without explicit reasons. For the present purposes all we need to keep in mind is that rules are rarely explicit.

<sup>36</sup>Consider, for instance, attempts to derive arithmetic from set theory, or introduce complex values into Boolean algebra, as in George Spencer-Brown, *The Laws of Form* (London: Allen & Unwin, 1969).

into a cohesive whole over time. In the absence of such practices (or sometimes in spite of them), conflicting and incompatible certainties can and do persist in parallel. Distinct, incompatible certainties are enacted in these contexts.

Wittgenstein claimed that his philosophy of mathematics was his most important contribution to philosophy, despite being much more well known as a philosopher of language. *On Certainty* as we've discussed it provides a potential resolution to this apparent discrepancy, especially given that Rush Rhees, a student of Wittgenstein's, interpreted it as a work of logic.<sup>37</sup> Mathematical certainty provides a mechanism for producing declarations, such as  $2 + 2 = 4$ , that can be used as facts to correct arithmetical calculation. But, for Wittgenstein, the force (to use an anachronistic term from the later work of J. L. Austin) with which something like  $2 + 2 = 5$  is written is key to distinguish an arithmetical error from a re-declaration of arithmetic. In practice, very few people have attempted to re-declare arithmetic.<sup>38</sup> But the phenomenon that Wittgenstein uncovered at the root of mathematics is similar to the operation of the No Fly list and other incorrigible systems. These systems gain something like the certainty of mathematics, but within the constrained context of the system and its actors. Wittgenstein distinguished these by analogies to hinges and buttresses.

#### *Calculation and Correctness, Hinges and Buttresses*

When is something correct? One of the more memorable concepts generated in Wittgenstein's inquiry is that of 'hinge' propositions, the immovable pieces upon which contingent uses of language turns. Wittgenstein introduces the concept in a discussion of questioning, doubt, and the limits of investigation.

... the *questions* that we raise and our *doubts* depend upon the fact that some propositions are exempt from doubt, are as it were like hinges on which those turn.

That is to say, it belongs to the logic of our scientific investigations that certain things are *in deed* not doubted.

But it isn't that the situation is like this: We just *can't* investigate everything, and for that reason we are forced to rest content with assumption. If I want the door to turn, the hinges must stay put.<sup>39</sup>

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<sup>37</sup>Rush Rhees, *Wittgenstein's On Certainty: There — Like Our Life*, ed. D Z Philips (Oxford: Blackwell Publishing, 2003).

<sup>38</sup>Periodic exceptions include things like Frege's set theoretic approach to the foundations of mathematics, though this is more of a reformulation than a redeclaration. By this I mean that work on the "foundations" of arithmetic that re-states it as propositions resting upon some other system (such as formal logic, set theory, etc.) isn't declaring that  $2 + 2 = 5$  but rather that justification may proceed *through* it into something "deeper." This reformulates it, whole, rather than re-declaring the correct results of the functions of addition, subtraction, and so forth.

<sup>39</sup>Wittgenstein, *On Certainty*, §§341-3.

Wittgenstein emphasizes that some propositions are not doubted *in deed*, echoing the second sense of incorrigibility on page 24. Wittgenstein was focusing, like I have, on the actions surrounding our relationship to information (or language more broadly). And yet, he explicitly distinguishes his claims from what we can recognize as Simon's satisficing. He's not saying that we move on because we don't have time to perform the analyses required, in the vein of Simon and perhaps Wilson. Rather, he's pointing out that the activities of certainty are core to the possibility of inquiry and knowledge. He's not arguing against behaviors of satisficing or the reality of second hand knowledge, but rather distinguishing these from something that belongs to the core of mathematical logic. How can we distinguish these related concepts?

*Hinges and Buttresses: Immobility and Inquiry.* While the use of the 'hinge proposition' concept has proliferated widely to mean *any* proposition exempt from doubt<sup>40</sup>, Wittgenstein clearly distinguishes it as applicable to mathematical propositions in a way it's not to other certain propositions.

The mathematical proposition has, as it were officially, been given the stamp of incontestability. *i.e.*: "Dispute about other things; this is immovable - it is a hinge on which your dispute can turn." And one can not say that of the propositions that I am called L.W. Nor of the proposition that such-and-such people have calculated such-and-such a problem correctly.<sup>41</sup>

A mathematical proposition such as  $12 \times 12 = 144$ , the example Wittgenstein uses, is a hinge upon which the correct answer to "how many doughnuts are in twelve dozen?" turns. Mathematical hinges like this have a different kind of certainty from that which we accord to things like our own name.

Wittgenstein goes on to attempt to call out this difference:

The propositions of mathematics might be said to be fossilized. - The proposition "I am called..." is not. But it too is regarded as incontrovertible by those who, like myself, have overwhelming evidence for it. And this not out of thoughtlessness. For, the evidence's being overwhelming consists precisely in the fact that we do not need to give way before any contrary evidence. And so we have here a buttress similar to the one that makes the propositions of mathematics incontrovertible.<sup>42</sup>

This subtle distinction between hinges and buttresses lies somewhere in the nature of certainties produced by pure mathematical propositions and mathematical calculations. A *bona fide* hinge proposition is not only incontrovertible, but it's difficult to understand exactly what might be offered as evidence against it

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<sup>40</sup>*e.g.*, Duncan Pritchard, *Epistemic Angst: Radical Skepticism and the Groundlessness of Our Believing*, Soochow University Lectures in Philosophy (Princeton University Press, 2015)

<sup>41</sup>Wittgenstein, *On Certainty*, §§655-6.

<sup>42</sup>*Ibid.*, §657.

(someone who does so may even be seen as insane, as discussed above). Buttredding propositions are similar, but we can imagine evidence (a forged birth certificate, for instance) against them, which we would be justified in ignoring in the face of the 'overwhelming evidence' of our own experience.

*Buttresses are what we move on from.* Since I've excluded an account of the dynamics of justification from my scope, I'll merely note that the disregarding of potential evidence is a potential way of *moving on*. That is, moving on despite any evidence to the contrary. There need not be anything special about the things we move on from: "the end [of justification] is not an ungrounded proposition: it is an ungrounded way of acting."<sup>43</sup> The actions of moving on which produce certainty are 'ungrounded' in the sense that actions are disconnected from grounds entirely.<sup>44</sup>

Wittgenstein is talking about the larger phenomenon of the production of certainty in language, which I'm applying to the narrower context of information systems. No one uses an information system to verify that their name is what they think it is.<sup>45</sup> It is common to verify that an information system has one's correct name, however, especially in high-stakes situations like the purchase of real estate. Yet determining correctness in each of these cases requires someone to hold something as a buttress, exempt from doubt. Kafkaesque bureaucratic experiences often emerge from a difference in which things are held exempt from doubt. My certainty in my name will never be shaken by a typo in a system, but a TSA agent may deny me passage because of it. No one could offer me convincing proof that my name isn't what I think it is (or, if they did, it might make me doubt my *own* sanity. "Am I crazy?" is a common expression of frustration in bureaucratic quagmires). When the TSA agent is faithfully enacting the incorrigible certainty of her information system, part of the practices surrounding the system are that only certain forms of proof count; my buttressing certainty in my name is irrelevant. Though the details of these situations differ, the behaviors of excluding potential evidence to the contrary is a hallmark of the buttressing function of incorrigible certainty.

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<sup>43</sup>Ibid., §100.

<sup>44</sup>More on this in the discussion of facts in Section 3.2 and in particular of fact as deed in Section 3.2.4.

<sup>45</sup>Of course, strange potential counterexamples can be envisioned. I had a landlord in San Francisco named Reshevskiy because she said her last name as 'Reshevsky,' was asked by an immigration agent "I or Y?", and replied "I? Y?" in confusion. The agent dutifully recorded both letters, stamped her documents, and sent her along. She later had to consult those documents to discover how her name was spelled in America. This isn't a counterexample *per se* but rather an example of a transition between two of Searle's context *C*'s that we'll discuss further in Section 3.2.

*Learning to Calculate.* The process of ‘learning to calculate’ is a learning process that yields what Wittgenstein calls a “whole way of looking at things”.<sup>46</sup> We learn to calculate  $12 \times 12$  in a way analogous to how we learn the earth is round. Like the roundness of the earth, the result of the calculation can be expressed as a belief.<sup>47</sup> And these beliefs don’t admit of proof or justification.<sup>48</sup> Wittgenstein doesn’t seek to shake the foundations of science so much as point out where and how they bear on buttresses, *indeed* left uninvestigated. Regarding propositions like “water boils at 100 °C”, in light of an experiment confirming this finding, Wittgenstein writes:

So hasn’t one, in this sense, a proof of the proposition? But that the same thing has happened again is not a proof of it; though we do say that it gives us a right to assume it. This is what we call an “empirical foundation” for our assumptions. For we learn, not just that such and such experiments had those and those results, but also the conclusion which is drawn. And of course there is nothing wrong in our doing so. For this inferred proposition is an instrument for a definitive use.<sup>49</sup>

This is Wittgenstein’s account of empirical certainty as buttress. He situates it as a learned behavior within a set of practices, in this case scientific inquiry. This learned behavior goes beyond information to ways of moving on with that information.

Like Wittgenstein, we’ve oscillated in our examples from mathematics to science and back again. While calculation and scientific experiments are similar, it’s worth contrasting the concept of ‘proof’ amongst these examples, especially the special dynamics of mathematical proof. In Wittgenstein’s mathematical proof, there is no difference between showing that a thing *is* so and that the thing *must*

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<sup>46</sup>Wittgenstein, *On Certainty*, §292.

<sup>47</sup>The roundness of the earth may seem a strange example, but bear in mind that the now-famous picture we might have in mind of the earth from space was entirely hypothetical until around the 1960s. Direct evidence for the roundness of the globe was limited to more abstract arguments, or the fact that people could circumnavigate it by travelling in one cardinal direction for long enough. A more modern (and durable) example might be the picture we have in our heads of our solar system’s position in the Milky Way, viewed perpendicularly, which is a fictional extrapolation of a vantage point many millions of light years away that no satellite has ever occupied. This and other astronomical ‘photographs’ are produced only after much manipulation and processing of noisy non-visible radiation. We learn what nebulae look like, and learn to say ‘that is a nebula’ or ‘that is the Milky Way seen from above’ even though, strictly speaking, the images we use to do this are fabrications. Searle’s *counts-as* will give us better tools to talk about issues like this in Chapter 3.

<sup>48</sup>This is *contra* Moore, who tried to found his defence against skepticism on the existence of his hands (amongst other common sense statements). Wittgenstein believed no such defense was needed, and that common sense propositions didn’t bear upon the issue anyways, but believed that Moore had uncovered a class of statements that illustrated the role of certainty in language. I’ve largely avoided dipping into Wittgenstein’s critique of Moore’s antiskepticism since it isn’t germane to my purpose, but I will note that, like Wittgenstein, I see the phenomenon of certainty as lying entirely outside debates about skepticism and realism.

<sup>49</sup>Wittgenstein, *On Certainty*, §§295-7.

be so, even if the thing *being* so is surprising. I think it is the surprise that seduces us into ignoring the mechanics at work. The *must* in *must be so* is a connection to a hinge proposition. The connection in scientific reasoning is merely to a ‘buttress proposition,’ one that we use to disregard contrary evidence.

### *Certainty and Willful Ignorance*

The distinction between hinge and buttress propositions I’ve made above are likely finer than those that Wittgenstein would draw. His work is, overall, notoriously devoid of strong theories, unambiguous definitions, and systematic structure. But the detour through his discussion of the certainty at work in mathematics and science is nevertheless helpful because it shows the common outcome of these practices: a willingness to ignore or disregard conflicting evidence and move on. This buttressing, I’m claiming, is the core mechanism whereby specifically incorrigible certainty is produced in information systems.<sup>50</sup> Where specific procedures for considering conflicting evidence are not followed, incorrigibility is the default.

The three kinds of certainty above are perhaps different attitudes towards potential conflicting evidence. Incorrigible certainty is an outright rejection of it. If I’m on the No Fly list, the agents that enact it will not let me on a plane until or unless the list is re-declared, they stop enacting it, or I can avoid their actions. Empirical certainty is a preemptive acceptance that a measurement is subordinate to some state of the world. In essence it orients us towards new evidence while allowing us to proceed with certainty, to move on. If a doctor takes my temperature and finds it to be 104.3 °F, she would likely update that information if presented with the more precise measurement 104.382 °F. Even without the more precise measurement, she’d be justified in moving on as if I have a fever. The specific treatment she provides, though, may be a kind of defeasible certainty. She may choose a treatment based on her hospital’s guidelines, even though she would revise that treatment plan in light of arguments made in a recent systematic review of literature on fever treatments. Until or unless her way of moving on is altered, the certainty in each case reverts to an incorrigible default as argued in Section 1.2.4.

This matters most when agents are separated from the object of measurement via an information system. A doctor who enters an order for the wrong drug has made a mistake in one sense, but within the context of the medical record, the nurse administering the drug sees only the order as written: a valid

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<sup>50</sup>It is also related to what we’ll later discuss as the jussive nature of the archive in Section 3.3.2. In this case, though, it is a jussive action layered on top of a jussive archive. In both cases, a focus on jussivity foregrounds exclusionary processes and their consequences.

order cannot be wrong within the context constituted by the medical record as a medium of declaration. Regardless of kind, then, certainty always involves a willful ignorance of some set of things external to the system, an ignorance that makes moving on possible and yet carries complex risks. This kind of internal correctness has featured prominently in the work of Brian Cantwell Smith.

### 1.3.2 Smith on Correctness

Brian Cantwell Smith's work in this area offers key insights, though in general he has a distinct approach, theoretical vocabulary, and aim from mine. This portion will review his contributions, particularly "Limits of Correctness in Computers," in light of my approach and conceptual framing.<sup>51</sup>

To begin, I'll identify several differences between Smith's aims and approach as compared to mine. While Wittgenstein studied the structure and use of language, Smith's approach is focused on computers, albeit computers as semantic machines. I hope the connections to Wittgenstein I'll make periodically will show a resonance between the two thinkers and the larger applicability of Smith's work to a broader scope of information systems. This dissertation is intentionally using a definition of information system that includes both computerized systems and traditional ones.<sup>52</sup> This section will seek to apply Smith's work beyond the computational context in which he developed it.

#### *Correctness and Verification*

In his 1985 paper "Limits of Correctness in Computers", Smith takes up the concept of 'program verification'. He notes that the term might lead the careless to believe that the technique proves that a program accomplishes a specific goal. Smith argues, in contrast, that program verification merely proves consistency between the program as implemented and a formal model of desired functionality. "Correctness" is thus simply correspondence (or not) to the formal model used in evaluation. He highlights the lack of models of how the program's model relates to the world, and argues that this is a crucial

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<sup>51</sup>Brian Cantwell Smith, *Limits of Correctness in Computers*, technical report CSLI-85-36 (Center for the Study of Language and Information, Stanford University, 1985)

<sup>52</sup>See page 4ff regarding my operational definition of information system. Smith is also interested in an ontological account of the digital, especially in Brian Cantwell Smith, *On the Origin of Objects* (Cambridge, MA: MIT Press, 1996), which I don't engage with. For discussion and expansion of Smith's approach, see Yuk Hui, *On the Existence of Digital Objects* (Minneapolis: University of Minnesota Press, 2016); and Yuk Hui, "What is a Digital Object?," *Metaphilosophy* 43, no. 4 (July 2012): 380–395.



development needed in artificial intelligence research and computer science more generally.<sup>53</sup> Smith expands on these observations considerably in *On the Origin of Objects* (discussed below), but I believe it's worthwhile to consider this observation on its own, separate from the larger system that Smith builds later.

Already, it might be obvious how exciting Smith's work should be to researchers interested in certainty in information systems. Smith's is an early study of the nature of certainty about a program's output in terms of the relationship between implementation and model, where the model is a kind of incorrigibly certain arbiter of "correctness" within a context it partially constitutes. While Smith intends to question the utility of program verification in light of these limits, and proposes an empirical relationship to the world as a potential solution, I'd like to reframe the phenomenon he identifies as a peculiar capability of information systems as a whole. Given a model, digital information systems (a relevant subset of programs) can produce correctness, but that correctness may or may not have relevance in other less limited contexts. We'll revisit this alongside the distinction between promulgation and enactment I'll make in Chapter 2.

#### *Correctness and Avoiding Nuclear War*

Though systems' model need not depend upon or relate to specific features of the world, we use them precisely because they can and do impact the world. Smith motivates this discussion by framing the entire paper with the example of the 1960 near-disaster of the US early warning system. Designed to detect Russian nuclear missiles in time to launch a counterstrike (part of a 'mutually assured destruction' strategic deterrent), the system erroneously indicated that a massive Russian strike was on the way. This was due to a moonrise that the system designers hadn't anticipated. Thankfully, human operators didn't move on in light of the system's indicators, and averted a nuclear war. In my terms, certainty was not produced by this information system because the operators did not move on, but rather continued to seek out justification. Yet, Smith notes, the programs driving this system were 'correct' in a computer science sense. They behaved as specified.

So, as Smith contends, a better description of the model-world relationship would complete a picture of what it is that systems are actually doing in the world, enabling an analysis of systems of varying

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<sup>53</sup>It may be clear that in so doing, Smith is already advocating a shift from incorrigibility to empirical certainty, a proposal that may not be possible or desirable for systems designed for incorrigibility.

geopolitical import. Smith seeks to keep the focus on models' "consequences in a world that inevitably transcends the partiality of those enabling models."<sup>54</sup> He starts with a simple description of a problem that could be solved with a computer program:

Given a number  $C$ , produce numbers  $A$  and  $B$  such that  $A \times B = C$ .<sup>55</sup>

Smith imagines a program, alongside a proof of correctness, that perfectly solves this problem. But he then shows the spuriousness of that 'correctness'; given  $C = 14$ , our program always returns  $A = 1$  and  $B = 14$  (or, more generally,  $A = 1$  and  $B = C$ ). Since, presumably, this result isn't useful, we must revise the program's specification (a move that foreshadows the process of roster redefinition I'll introduce elsewhere). Thus, we arrive at a revised specification that is intended to hopefully provide a useful factorization of  $C$ :

Given a number  $C$ , produce numbers  $A$  and  $B$  such that  $A \neq 1$  and  $B \neq 1$  and  $A \times B = C$ .<sup>56</sup>

This revised specification would still permit a 'correct' program to return  $A = -1$  and  $B = -14$ , necessitating further revision if the program is to be useful. Thus, 'good' specification becomes the key problem in achieving a certain goal with a program. The usefulness of 'correctness' is inherently limited by, defined by, the specification: "when you show that a program meets its specifications, all you have done is to show that two formal descriptions, slightly different in character, are compatible."<sup>57</sup> Smith suggests that 'correctness' be replaced by 'relative consistency' to avoid the confusion generated by the use of the former in this context.

### *The Stakes of Correctness*

Smith frames his discussion with the early warning system example to demonstrate the high stakes of this discussion. A point worth restating is that the early warning system did not 'malfunction' in the normal sense of that word. The system detected what it had been programmed to detect, and reported as it had been programmed to report. This makes the example all the more terrifying, in my opinion. The

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<sup>54</sup>Smith, *Limits of Correctness in Computers*, 9. This approach is obviously consonant with Star's pragmatism as well.

<sup>55</sup>Ibid., 13.

<sup>56</sup>Ibid., 14.

<sup>57</sup>Ibid., 15.

system produced a declaration, as it was designed to, and it was only the human operators' rejection of that certainty which averted a nuclear disaster.

Smith notes that, like those who participated in the threat assessment conference that ultimately decided not to launch a US nuclear strike, humans are often praised for being 'incorrect'. Soldiers are expected to disobey direct orders to, for instance, murder civilians, and can be court-martialed for obeying those orders. Nurses are expected to seek clarity from the prescribing physician if the drug they are about to administer seems inappropriate for the patient. There are no guarantees that humans will be 'correct' in a moral or a medical sense, any more than computers will. Smith's point, though, is that including humans in the loop provides a breakpoint that can mitigate the limitations of computers' insistent relative consistency. In my terms, it allows for the possibility of empirical or defeasible revision to what would otherwise be incorrigible certainty.

Smith ends his paper by declaring that there is an inherent conflict between abstraction on the one hand and 'infinite richness' on the other, which foreshadows Bowker's reading of Derrida and the concept of jussivity. Of this kind of 'failure', Smith writes that it

...isn't a failure, in the sense of a performance limitation; it stems from the deeper fact that models must abstract, in order to be useful. The lesson to be learned from the violence inherent in the model-world relationship, in other words, is that there is an *inherent* conflict between the power of analysis and conceptualization, on the one hand, and sensitivity to the infinite richness, on the other.<sup>58</sup>

No system, and perhaps even a system of human thought, can avoid this conflict. The solution, then, seems to be to utilize abstraction for its utility, but implement practices of corrective recalibration. This requires the possibility of recalibration, empirical or defeasible, as well as specific actions of recalibration, deliberation and so forth. In the absence of these, the incorrigible default will apply.

### 1.3.3 Star on Enacting Certainty

This section will show how part of the phenomenon that motivated Susan Leigh Star's interest in boundary objects is the production of certainty as I'm approaching it. It will trace this interest from early work on the history of science through to the introduction and development of the concept of boundary object. I will show how my work picks up from a thread left largely unfollowed from her earliest work: the ascription of certainty across boundaries.

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<sup>58</sup>Ibid., 21.

### *The Production of Global Certainty from Local Uncertainty*

Star's early work on the production of global scientific certainty from local uncertainties is one of the earliest sustained engagements with the *production* of certainty as I'm approaching it in the context of information work.<sup>59</sup> She looked at the specific example of proponents of a theory of brain function localization, which was transformed from a fringe 'neo-phrenology' to accepted medical fact from about 1870 to 1906. But she argues that the practices she describes reveal patterns that can be found in a vast array of other contexts, a claim she would go on to substantiate in her work on boundary objects.

Star frames her analysis sociologically. For Star, "persistence of belief or participation, in the face of anomalies or contradictions, is the dependent variable of a sociological process which transforms local uncertainties into global certainty."<sup>60</sup> It is, essentially, as set of actions (or beliefs which predispose action) which produce the kind of global scientific certainty she's interested in. In the paper, she identifies several mechanisms of transformation of local uncertainty to global certainty, the most relevant of which to our purposes is "attributing certainty across disciplinary boundaries."<sup>61</sup> This is Star's approach to what I've called moving on. Researchers in related disciplines would *move on* in light of work in other disciplines, producing interdisciplinary certainty as a buttress for contingent intradisciplinary claims. She found that "researchers tended to attribute certainty to *other* fields: physiologists relied on clinical evidence to supplement their anomalous or uncertain results; pathologists turned to physiological evidence when they could not find evidence for discrete areas [of brain function]."<sup>62</sup> This process was reciprocated in other fields, producing a globally enacted certainty from a cross-buttressing of local uncertainties. What was for Star a sociological explanadum becomes a marker that the phenomenon of the production of certainty is in operation.

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<sup>59</sup>Susan Leigh Star, "Scientific work and uncertainty," *Social studies of science* 15, no. 3 (August 1985): 391–427; Susan Leigh Star, *Regions of the Mind: Brain Research and the Quest for Scientific Certainty* (Stanford: Stanford University Press, 1989). Latour and Woolgar's earlier work in *Laboratory Life* is also relevant, but is focused more on the actions within laboratories, as opposed to Star's examination of how disciplinary boundaries and context transitions are sites of certainty production.

<sup>60</sup>Star, "Scientific work and uncertainty," 391.

<sup>61</sup>Ibid., 407.

<sup>62</sup>Ibid., 408.

### *Boundary Objects (and Beyond)*

Star's early interest in the *translation* of ideas, results, and actions across social contexts blossomed into the powerful and influential concept of *boundary objects*. Star herself started with her work on brain localization research in reflections on the history of the concept of boundary objects.<sup>63</sup>

A boundary object is “a sort of arrangement that allow different groups to work together without consensus. However, the forms this may take are not arbitrary. They are essentially organic infrastructure”<sup>64</sup> that arise from the contingent needs of those occupying the boundary space. One of Star's goals was to explain how collaboration was possible, given the contingent and sometimes idiosyncratic nature of knowledge developed in local contexts. Timmermans writes that the concept of boundary objects “captures the possibility of cooperative scientific work in the absence of consensus”<sup>65</sup> and “allowed Star to examine how objects achieve coherence across social worlds while still having distinct identities in specific communities”.<sup>66</sup> In contrast to Latour's concept of immutable mobiles, Star's work allowed and accounted for social modulation of objects as they traverse boundaries.

My interest is how the production of certainty in information systems can shape social reality, a slight shift in focus. Star shows how translation across contexts allows shared, if differently interpreted, objects to coherently move across boundaries. Information systems that produce certainty across disciplinary lines can be considered ‘repository’ boundary objects, because individual items can be introduced or deleted “without collapsing or changing the structure of a whole.”<sup>67</sup> My interest is oriented towards cases where inscriptions, backed by power of enactment, are used to force the expansion of context beyond its initial bounds. Star, of course, was also interested in this, in the context of classifications. Her (and Bowker's) concept of *torque* captures the effects of context extension. Torque refers to the effects of

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<sup>63</sup>Susan Leigh Star, “This is Not a Boundary Object: Reflections on the Origin of a Concept,” *Science, technology & human values* 35, no. 5 (September 2010): 605-8.

<sup>64</sup>Ibid., 602.

<sup>65</sup>Stefan Timmermans, “Introduction: Working with Leigh Star,” in *Boundary Objects and Beyond: Working with Leigh Star*, ed. Geoffrey C Bowker et al. (Cambridge: MIT Press, 2015), 4.

<sup>66</sup>Ibid., 5.

<sup>67</sup>Star, “This is Not a Boundary Object: Reflections on the Origin of a Concept,” 603-4.

intersecting classifications, identities, and biographies, seen in the material history of bodies.<sup>68</sup> In a sense, my project is designed to foreground the torque of enacted information systems of any kind.

#### *Revisiting the Attribution of Certainty*

Unlike Star's later work on boundary objects, which was focused on the possibility of collaboration, in her earlier work the attribution of certainty across disciplinary boundaries was more a process of collapse than a negotiation. I'd like to pick up this thread of her work and extend it beyond the scientific context. Patrick Wilson, writing around the same time as Star, focused on the attribution of certainty in library settings. Wilson's concept of *cognitive authority* provides a possible explanation for why someone might take information and move on.<sup>69</sup> What might it mean to augment this with Star's observations? We'll return to questions like this in Chapter 3.

### **1.4 Breaking Down Certainty**

This chapter has introduced the production of certainty in information systems as a result of actions, explained how we can know it has happened, introduced some initial types of certainty, and detailed encounters with this phenomenon by other thinkers. This introduction to the topic of certainty has left many questions. Though we know when certainty has occurred, and have some initial tools for characterizing kinds of certainty, the relationship between information systems and the agents that surround it is in need of clarification. Chapter 2 will introduce a series of concepts for describing these relations.

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<sup>68</sup>Bowker and Star, *Sorting Things Out: Classification and Its Consequences*, 190, building on work in Susan Leigh Star and Geoffrey C Bowker, "Of Lungs and Lungers: The Classified Story of Tuberculosis," *Mind, Culture, and Activity* 4, no. 1 (January 1997): 3–23

<sup>69</sup>Patrick Wilson, *Second Hand Knowledge: An Inquiry into Cognitive Authority* (Westport, CT: Greenwood Press, 1983).

## CHAPTER 2: CONCEPTUALIZING CERTAINTY

Chapter 1 introduced the approach I'm taking towards the production of certainty, identified the cessation of justification upon an information system as a way to determine that certainty has been produced, and reviewed prior thinkers whose work relates to aspects of the phenomenon. This chapter systematically defines and develops concepts for characterizing and contrasting the production of certainty in different cases, preparing the way for the analysis of Chapter 3 and the taxonomy developed in Chapter 4. Readers may want to use this chapter as an extended glossary or reference for the analytical terms used elsewhere in the dissertation.

### Organization of the Chapter

Section 2.1 reiterates my approach to certainty as a phenomenon and introduces the three major concepts I will use to analyze it, *promulgation*, *justification*, and *enactment*. An initial example clarifies how these three concepts allow for characterization of the phenomenon.

Section 2.2 provides an explicit definition of *promulgation* as material inscriptions within an information system. This section also distinguishes the characteristics of systems from those of the promulgations they contain. Media theoretic approaches are discussed as complementary to the approach in this dissertation, but are excluded from its scope.

Section 2.3 revisits justification, first encountered in Chapter 1, as a process which ends upon a promulgation and enables moving on in light of it. An ancillary concept, *consultation*, specifies justification practices which end upon a promulgation. I contrast my approach to justification with those that seek to shed light on justification practices or provide normative guidelines for them. Examples of automated justification processes demonstrate the advantages of this approach.

Section 2.4 defines *enactment* as the activity of moving on in light of a promulgation. A fifth and final concept, *contemplation*, is defined as the effects of promulgation upon enactment, a sense inspired by the term's use in legal practice. Enactment is the most important component of the production of certainty, since the ways of moving on produce the enacted consequences of certainty.

Section 2.5 unites all five concepts in light of their operationalized definitions and discusses them in terms of success, intent, and felicity. The chapter concludes with a summary of promising sites for analysis revealed by the conceptualization of certainty presented in this chapter. Chapter 3 will pick up these threads and follow them further.

## **2.1 Production of Certainty as Phenomenon**

The certainty in language that Wittgenstein confronted operates at a subtle, almost ineffable level, which requires an inversion of normally invisible processes into the forefront of analysis. I'll thus follow Wittgenstein's pseudo-methodological exhortation to "[not] look at it as a matter of course, but as a most remarkable thing" that practices of justification sometimes end upon information systems.<sup>1</sup> I seek to render strange and in need of explanation the fact that the characters HFU83F transcend questions of truth and become an inescapable fact in the context of checking into a flight. Like infrastructural inversions and Wittgenstein's investigations, the phenomenalization of the production of certainty is deeply interested in with what are normally considered banalities. The ticketing agent lets me board the plane because I scan my ticket and the light blinks green. I am awarded a degree because the registrar has me listed as a student, I filled out a form, and my transcript lists a satisfactory number of credits to graduate. I am allowed to walk out of the grocery store with my purchase because the card reader says APPROVED in response to a swipe of a magnetic strip, insertion of a RFID chip, or presence of my phone's NFC field. In one sense these are all obvious, boring events. But when made strange, when turned into phenomena demanding explanation, they are fascinating. Who, for instance, is the source of the power of my debit card PIN number, without which I could not shop for groceries? Is it me, because I set it? The payment network that enforces it? The grocery store that provides me with groceries once I enter the PIN into their machine? The concepts presented in this chapter will allow us to describe the phenomenon precisely, to distinguish its character in different instances, such that it is amenable to further analysis towards answering such questions.

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<sup>1</sup>Ludwig Wittgenstein, *Philosophical Investigations* (New York: MacMillan, 1953), 190.



### 2.1.1 Certainty = Promulgation + Cessation of Justification + Enactment

In Section 1.1.2 I introduced the cessation of justification as a marker of when certainty has been produced. The cessation of justification denotes instances where agents first consult an information system and then move on. As a marker, this is sufficient, but there are two other primary aspects of the production of certainty that need clarification. For an agent to consult an information system, the system must exist and contain something to be consulted. This I'll investigate as promulgation in Section 3.3. Finally, the moving on in light of itself needs characterization, as was implied in the kinds of certainty introduced in Section 1.2. I'll discuss this in terms of enactment, which characterizes the *ways of moving on in light of*.

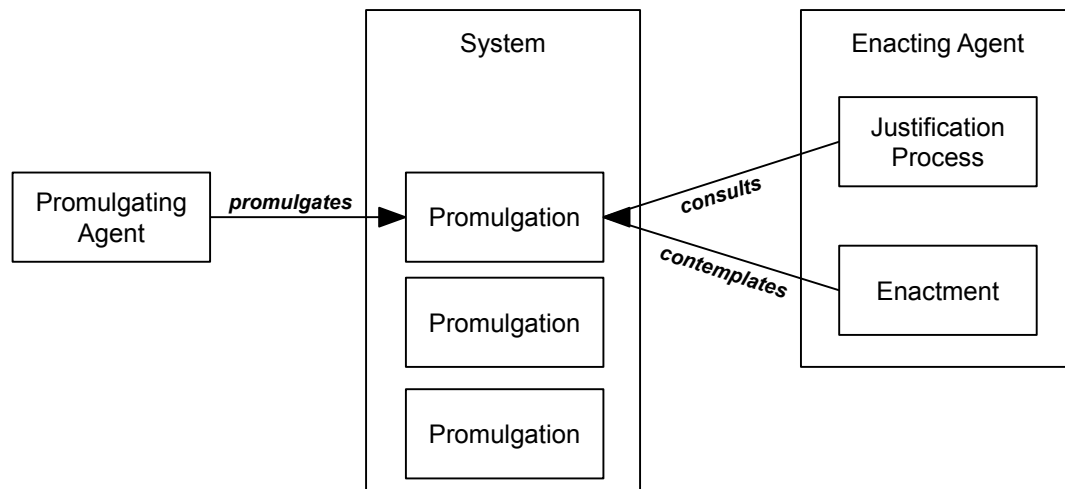
A brief example will help convey how these terms fit together at the outset. The information system that a restaurant uses to keep track of table reservations, be it a book, a database, or an online booking service such as OpenTable, grounds a typical pattern of:

- *Promulgation*. When making a reservation (be it in person, via phone, or via an app), the system is altered to contain an inscription of some form.
- *Cessation of justification*. A party arrives at the restaurant, provides a name, and the staff consults the reservation system to determine whether the party has a reservation. Justification ends upon an inscription within the information system.
- *Enactment*. The party is seated in light of the reservation, or is turned away in light of not finding a reservation in the system.

This shallow example already provides enough of a sense of how information is inscribed within a system and how various actors behave for us to begin to analyze it in these terms. A reservation is promulgated into the reservation system by virtue of an inscription: marks on a page or magnetic charges on the hard drive that contains a database. That specific system is what staff are trained to consult to determine whether a reservation exists. The system provides the *fact* needed to evaluate the truth of the proposition “I have a reservation for 4 at 7 o'clock, under Hauser.” Once justification ends upon the relevant promulgation (or lack thereof) in the reservation system, the staff moves on in light of this, enacting the certainty of the reservation. This enactment of certainty need not only produce a positive result. The lack of a valid reservation in the context of a full restaurant may result in the enactment of the party being turned away.

Each of these concepts constitutes a potential difference between particular contexts, and can characterize how the system is used to produce certainty. Figure 2.1 on the following page gives a schematic representation of this abstract relationship. The core of the production of certainty is represented

by the justification process consulting a promulgation, moving on in light of the promulgation, and the subsequent enactment, conditioned by the character of this moving on. The diagram also introduces several agent roles. The enacting agent is the one who stops upon the promulgation and subsequently moves on to enact certainty. The promulgating agent is defined as the source of the promulgation within the system. Either kind of agent may be unknown or unknowable to other actors in specific cases. The concepts of consulting and contemplating and each of the agent roles will be discussed and defined below. Multiple agents may be involved in each of these processes, such as when a reservation is made by one person and later updated by another, but for now we'll simplify the picture to deal with cases where a single agent is responsible for each.



**Figure 2.1:** Conceptual components of the production of certainty. Certainty is produced from an information system when an enacting agent consults a promulgation and moves on to enactment in contemplation of the consulted promulgation. The promulgation, system, and promulgating agents are preconditions of the production of certainty.

## 2.2 Promulgation and Certainty

Promulgation as I'm approaching it is the act of inscription within an information system. I'll also use the same term in noun form as a label for such an inscription. The defining characteristic of a promulgation is that its material form allows it to be consulted within its system. When a name is written into a log book, the material inscriptions of ink or lead on the page are the promulgation and the act of promulgation

is the act of marking the page with these pigments. The visibility of the ink to human eyes combined with the manipulability of the codex form allows humans to consult promulgations within this system. When a name is entered into a database, the promulgation is the electromagnetic charges on disk (or, less commonly, in RAM) that encode the name as binary data, and the act of promulgation is causing these to be written to disk. The user interface of the database management system allows human consultation, whereas the database API allows programmatic consultation of these promulgations. In both cases, the promulgating agent uses a tool to promulgate (the writing utensil and database software/disk hardware assemblage, respectively), which materially conditions the inscription that is encountered during the act of consultation. Notwithstanding this material conditioning and the differing material properties of the inscriptions, my approach allows them to be analyzed using equivalent terms.

### 2.2.1 Information as Inscription

Media theoretic approaches which seek to account for the effects of material specificity of inscriptions are complementary to this approach, but are outside the present scope. Instead, the information in an information system is essentially circumscribed to inscription. That is, there is nothing inherently meaningful in the material components of information as I'm conceiving of it. The material differences encountered during consultation of the user interface of a database and its API constitute distinct systems, only unified if they are enacted identically.

Information systems have properties useful for storage and recall of inscriptions, such as material stability through time. Permanent ink has material properties different from pencil (the former penetrates more deeply and permanently into paper), hard disk drives have different material properties different from RAM (*i.e.*, the property of maintaining state after electrical current allows the former to preserve information after a computer is turned off), and so on. Each offers differing potentials for expression, has different historical and social meanings, and is imbricated into different cultural, economic, and political practices and norms. But there is nothing that distinguishes marks on a page from magnetic charges *semantically*. This perspective is defended and discussed in Section 3.3.1.<sup>2</sup> I mention it now to avoid confusion with the common view of information as a semantic property.

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<sup>2</sup>See also Elliott Hauser, "Information from jussive processes," in *Challenges and Opportunities for Knowledge Organization in the Digital Age. Proceedings of the Fifteenth International ISKO Conference*, ed. Fernanda Ribeiro and Maria Elisa Cerveira, Advances in Knowledge Organization (Porto, Portugal: Ergon Verlag, 2018), 300–307.

### *Something to End Upon*

Inscriptions constitute something that can be ended upon when seeking the answer to a question or to determine the truth of a proposition. They must persist through time to be available for consultation. This is a very minimal requirement, but inscriptions are often something that is temporally and materially durable, allowing the development of coherent social practices around them over time.

Information systems gather and (usually) facilitate access to their inscriptions. Systems in this sense are a medium for the consultation of inscriptions. A ledger-book, a biodiversity database, a social network, and a library catalog are collections of inscriptions. Accessibility to consultation of some form is a shared characteristic of all of these systems. The manual distribution of copies of a royal proclamation and the client-server model of distributed information systems are diverse strategies for making inscriptions accessible to specific groups across spatiotemporal contexts.

Consultative access to promulgations has on occasion become a legal issue. A report to the House of Commons in 1796 lays out the difficulty of accessing a complete code of laws, and details the then-current practices of promulgation.

The STATUTES, printed by the King's printer are at the End of each Session collected by him into VOLUMES...The DISTRIBUTION of these Volumes is confined within a very limited Circle of Persons, to whom it has been long customary for the King's Printer to make his Delivery. The Members of each House of Parliament, the Privy Council, and some few of the great Officers of State, are almost the only Persons to whom the Distribution at present extends. The whole Number of Copies issued at the public Cost very little exceeds Eleven hundred; and no complete Copy of any Sessional Collection has been purchased from the King's Printer by private Individuals for many Years past: He prints, however, for Sale upon his own Account, a large Number of such Acts as are most likely to be in general Request.<sup>3</sup>

The suggested changes seek to both standardize and distribute a fixed text of the law throughout the country, so that citizens, jurists, and administrators can have reliable access to it. In the absence of efficient distribution of promulgated law, it was in practice impossible for those outside of London to be sure of its actual contents, let alone consult a specific statute. In essence, this proposal sought to enlarge the information system wherein laws were promulgated, allowing wider and more reliable consultation of it across the country. Promulgation in a legal context is further discussed in Section 2.2.3.

The production of durable, accessible inscriptions is a prerequisite to the production of certainty in information systems, just as it is for legal systems. The degree of respective durability and accessibility

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<sup>3</sup>Great Britain House of Commons, *Report from the Committee for Promulgation of the Statues*, technical report (1796), 7. Capitalization original.

required for the production of certainty is determined by the context of the enacting agent's access to the system. In a sports match, the scoreboard is sufficient for the purposes of recording the current state of the match: it is durable for the duration of the game, the referees have promulgative agency to it (through the proxy of the scoreboard operator), and all players have consultative access to it by virtue of its open display. After the game, before the scoreboard is powered off, the results and key statistics of the game are recorded in a separate information system that has a longer durability and can be more widely distributed. For important games, this may happen instantly and continuously, as when scores and even play-by-play information are streamed online for college and professional basketball games. The wide context in which it is certain that the 2019 NCAA men's basketball championship game was won by the University of Virginia is underpinned by this infrastructure of promulgation. The sports media and others who enact this certainty base their enactment upon such inscriptions.

### *Inscription and Intention*

There's nothing magical about inscriptions. They can't embody or retain the intentions with which they were created. They aren't a container for passing knowledge from brain to brain. That said, (written) language is a set of techniques that provides conventional patterns of interpretation of inscription. Communication is the result of compatible interpretations.

Person to person communication through information systems typically involves several layers of convention, only one of which is general linguistic convention. A database, for instance, utilizes character encodings such as ASCII or UTF-8 to encode textual information into magnetic traces on disk during an act of promulgation. A reverse translation is performed when a human enacting agent consults the system, generating the visual inscription on a screen (or, less commonly in modern systems, physical inscription on a paper printout). The visual inscription is linguistically interpreted by the promulgating agent. The semantic interpretation constructed by the enacting agent will be compatible with the promulgating agent's intent to the degree that the promulgating and enacting agents utilize compatible linguistic conventions.<sup>4</sup> The layers of communication recounted here are not substantially different from Weaver's

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<sup>4</sup>This recalls Smith's contentions of the limits of correctness in computers, discussed in Section 1.3.2 (page 40), as well as Wittgenstein's account of correctness in calculation, discussed in Section 1.3.1 (page 35). Interpretation here is analogous to Smith's models, and 'compatible linguistic conventions' are like Smith's account of program verification as the compatibility of two formal representations with each other. This connection is discussed further in Section 3.4.1 (page 97).

layering of semantics onto Shannon's theory.<sup>5</sup> The difference is that the way in which the enacting agent moves on in light of the information is an additional layer on top of the interpretation, distinct from Weaver's concerns of the compatibility of semantic encoding and decoding. If a promulgating agent adds a name, time, and party size to a reservation system and an enacting agent consults and interprets that information as a valid reservation but still refuses to seat the party at the indicated time, the enacting agent has prevented the promulgating agent's inscription from conditioning the way in which this information is enacted, regardless of the compatibility of interpretation. Thus, control over promulgation yields deliberate power over the world only by the extent to which it both interpreted and enacted as intended. And yet intentions, like semantics, aren't an inherent property of inscriptions but rather require a coherent set of compatible practices surrounding the system.<sup>6</sup>

### 2.2.2 System as Medium

A system that can be ended upon in this sense must contain inscriptions. That is the minimal requirement. It may also constrain the kinds, character, or quality of inscriptions it contains. In other words, it is a medium, and mediates inscription, interpretation, and enactment.

#### *Somewhere to Consult*

Systems that are used to produce certainty are embedded into practices and norms of consultation. That is, agents are instructed (or induced, coerced, advised) to consult systems as part of larger tasks. Effectively, the information system forms a spatial context within which information may be located (though this spatial context may be experienced virtually, or only obliquely, via a digital interface). Inscriptions that support consultation practices must be gathered ahead of the moment of consultation, and arranged within the space of the system. The promulgation practices which produce coherent systems are thus a prerequisite of the production of certainty.

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<sup>5</sup>Weaver's appraisal of his success was notably tentative: "One has the vague feeling that information and meaning may prove to be something like a pair of canonically conjugate variables in quantum theory, they being subject to some joint restriction that condemns a person to the sacrifice of the one as he insists on having much of the other." Warren Weaver, "Recent contributions to the mathematical theory of communication," in *The Mathematical Theory of Communication*, ed. Claude E Shannon and Warren Weaver (Champaign: The University of Illinois Press, 1949), 12

<sup>6</sup>I elaborate on this in Hauser, "Information from jussive processes," and explore its methodological implications in Elliott Hauser and Joseph T Tennis, "Episemantics: Aboutness as Aroundness," in *Proceedings of the North American Society for Knowledge Organization*, Vol. 7 (Drexel University, Philadelphia, PA: University of Washington Digital Library, 2019), 27–34.

This is a subtle point, but is intended to provide a role for information systems beyond that of an individual promulgation. When someone consults the No Fly list, they may simply encounter a name. Or, perhaps, they enter a name as query and are provided with some binary result like `ALLOW` or `DENY`. This individual promulgation is what is stopped upon, but the system as a whole constitutes the site which is consulted in a given context, defining the *where* of the consultation. Practices for consulting specific systems in certain circumstances and reacting to individual promulgations may vary independently. While there is only one system that constitutes the consultation site for the No Fly list,<sup>7</sup> many systems provide temperature data, for instance, and any system may do for such inquiries. The *where* of consultation is diffuse in these instances, diminishing the potential effects of individual promulgations and the power of promulgative agency within a given system. Consulting one of any number of systems may still result in faithful enactment of certainty, and consulting a single system may not result in the production of certainty. Either may independently condition the production of certainty in specific cases, as we'll see in the cases of Part II. Section 2.3.3 will introduce single systems-of-record and discuss their effects further.

#### *Promulgative Agency*

Only some are able to promulgate within a given information system. This limitation of access is often key to the desired production of certainty. A lack of integrity in the processes of promulgation can be a major threat to an institution which relies on the production of certainty.

In digital systems, unauthorized promulgative agency within systems is a common goal of hacking, while preventing it is the object of computer security research. Altering someone's membership status, bank balance, or credit score are examples of hacking via unauthorized promulgative access within information systems.<sup>8</sup> Computer security is outside the scope of this dissertation, but future work might use the terms in this chapter or the taxonomy of certainty in Chapter 4 to supplement current techniques.

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<sup>7</sup>Though, of course, this 'one system' is a heterogeneous assemblage of unknown extent, it is treated as unitary in law and practice.

<sup>8</sup>Of course, hacking to gain agential control over computer systems may or may not be related to promulgation. Data breaches, where system contents are copied, can be seen as unauthorized consultation. And hacking which influences how automated systems move on in light of can be seen as unauthorized enactment. Chapter 6.4 will discuss how these concepts and the taxonomy developed in Chapter 4 might be applied to information security.

### 2.2.3 Promulgation and Governance

Promulgation is originally a technical legal term referring to the official issuance of a law, ordinance, or regulation.<sup>9</sup> The material processes of promulgation are rarely fully documented or treated as direct research subjects, but consist in the maintenance of a State's legal code, or the publication of an agency's regulations. The material practices of promulgation seem to lie outside the mainstream scope of legal analysis, as few cases turn on whether and how a law, regulation, or ordinance was promulgated.

Occasionally, however, promulgation becomes a topic of acute legal interest. In the Indian state of Bihar, for instance, the governor made use of a constitutional provision that allows the executive to extra-legislatively issue ordinances when the legislature is not in session.<sup>10</sup> Such ordinances are constitutionally limited in term to six months after the subsequent legislative session or when the legislature passes a countermanding resolution. In Bihar, the governor's office began a practice in the late 1960s of re-promulgating ordinances immediately after the conclusion of a legislative session. The legislature never convened for more than six weeks, allowing the governor's ordinances to essentially be perpetually in force.

Wadhwa found that there was essentially no complete system available to consult all of the related ordinances.<sup>11</sup> The Bihar government ceased the publication of the annual "Bihar Acts and Ordinances" in 1966, and began the practice of re-promulgation in 1967. Wadhwa thus was forced to comb through back issues of the *Bihar Gazette*, a government publication which published ordinance notifications in periodic so-called extraordinary issues. These issues were published and distributed as back-dated copies with months or years delay. Wadhwa gives a rare account of how this material promulgation process functions:

While sending copies of the Ordinances to the Government Press for publication in the *Bihar Gazette*, the Law Department writes a separate letter, for each of those Ordinances, to the said press and mentions in that letter the date which the *Bihar Gazette*, extraordinary (in which that particular Ordinance is to be published), should bear. Soon after the receipt of that letter, the Government Press

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<sup>9</sup>Especially the material form(s) thereof. The most detailed direct treatment of promulgation I was able to locate was a dissertation on the promulgation of canon law. Martin Nicholas Lohmuller, *The Promulgation of Law*, vol. 241, The Catholic University of America Canon Law Studies (Washington, D.C.: The Catholic University of America Press, 1947). A potentially relevant observation in this piece is that promulgation is not equivalent to mere publication; distribution or presentation to the public is also implied (98 *et seq.*). This parallels my discussion above of a system as a spatial context of *access* to promulgations. See also the case described by Wadhwa below.

<sup>10</sup>The case details that follow are all from D C Wadhwa, *Re-promulgation of Ordinances: A Fraud on the Constitution of India*, vol. 66, Gokhale Institute Studies (Hyderabad: Orient Longman Limited, 1983).

<sup>11</sup>*Ibid.*, xii-xiv.



enters that Ordinance in a register and allots it a particular number of the extraordinary Gazette and the date it has to bear. At the time of printing the Ordinance, care is taken to see that the Gazette in which that Ordinance is printed carries the number and the date mentioned in that register. Thus, though the Gazette is actually printed and sent to subscribers at a particular date, it bears a different date which is obviously a date earlier than the date of its actual printing and despatch to the subscribers. In this way, an Ordinance promulgated by the Governor of the State of Bihar actually comes to the knowledge of the people of the State after several months of its existence have passed. As an Ordinance is supposed to have been promulgated with effect from the date of its publication in the Gazette, the people of the State of Bihar are being subjected to the Ordinances several months before they actually see the Ordinances they are subjected to.<sup>12</sup>

There are several notable features in this passage. Promulgation is in this instance distinguished from the laws' distribution in a consultable form, which is precisely the legal complaint. Wadhwa refers to "an Ordinance promulgated by the Governor" as only becoming known to the people upon the distribution of the Gazette months later. This seems to separate promulgation from the distribution of the Gazette to the people, since if the ordinance were not promulgated until distributed, there would be nothing yet to know. Later, such promulgation seems to rest upon a supposition: "an Ordinance is supposed to have been promulgated with effect from the date of its publication in the Gazette".<sup>13</sup> This renders a situation reminiscent of that described by the Committee for the Promulgation of the Statues on page 52, where inaccessible texts contain enforceable laws that citizens cannot practically consult. The importance of access to legal promulgations is enshrined in legal doctrines such as the prohibition of *ex post facto* convictions. Cases where promulgations are not made easily available to citizens, as in Bihar, are functionally equivalent to *ex post facto* enforcement of laws. These legal examples broach the topic of the ethical and political effects of the methods of the production of certainty, which we'll encounter periodically and revisit in the Conclusion.

These examples illustrate the role that systems play in providing a spatial context for consultation. Legal critiques from Wadhwa and the Committee for the Promulgation of the Statues focus on promulgations that cannot be consulted by those who are subject to the enactments that contemplate them. In such cases promulgating agents have a theoretically limitless ability to produce justificatory promulgations for actions, even *post hoc*. Access to produce and consult promulgations is a direct determinant of political

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<sup>12</sup>Ibid., xiv.

<sup>13</sup>Ibid.

power.<sup>14</sup> Promulgation and promulgative agency are key to conceptualizing these cases in terms of certainty.

## 2.3 Justification, Ending Upon Information Systems

Justification is a key theoretical process in my framing, but in this section I aim to show how I don't need a full account of what justification *is* or its *mechanism* in any specific case, but only a way to identify that it has stopped upon an information system. This carries numerous practical benefits for my project and, further, constitutes a potentially fruitful connection to projects that are directly aimed at these larger topics.

### 2.3.1 Minimalist Justification: A Process That Ends

Accounts of justification vary widely across and within disciplines. In analytic philosophy, interest in justification has historically stemmed from the classical definition of knowledge a justified true belief. This approach seeks to determine what should count as a valid justification of a knowledge claim.<sup>15</sup> My approach is broadly consonant with a pragmatic de-centering of questions of justification, but is by no means incompatible with stronger accounts of the role and importance of justification.<sup>16</sup> Essentially, I aim to be agnostic as to what justification *is*, merely asserting that whatever it is, it terminates, and move on to focus on when it terminates upon promulgations within an information system.

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<sup>14</sup>Though the terms of debate are somewhat different than those I use here, this has not escaped notice in contemporary contexts. Activists like Carl Malamud have agitated for coherent digital promulgation of US government laws and court decisions as a core component of American democracy. For an example proposal of a law.gov website to fulfill this vision, see "Law.Gov: A Proposed Distributed Repository of All Primary Legal Materials of the United States," Public.Resource.Org, accessed October 29, 2019, <https://law.resource.org/index.law.gov.html>. Malamud has also argued that copyrighted standards incorporated by reference into law should be considered public domain. "An Edicts of Government Amendment: Testimony of Carl Malamud Before the House Judiciary Committee, U.S. House of Representatives, January 14, 2014," Public.Resource.Org, accessed October 1, 2018, <https://public.resource.org/edicts/>.

<sup>15</sup>See, e.g., Pappas, "Incorrigibility, Knowledge and Justification." The focus on what *should* count is a clue that this is a normative project, though it is most often approached in analytic philosophy as an empirical or quasi-mathematical one.

<sup>16</sup>For more on de-centering justification in pragmatic philosophy of language, see Huw Price, "Truth as Convenient Friction," *The journal of philosophy* 100, no. 4 (2003): 167–190.

### *Methodological Benefits*

From a methodological perspective, this augments the robustness of my analysis. There are a wide array of instances where an agent consults an information system and moves on, from a key-card lock to an engineer looking up the correct reference value of a thermophysical constant to use in a calculation. By focusing exclusively on the minimal condition that these processes end upon information systems, these disparate practices can be examined alongside each other, by virtue of the shared property of eventually stopping upon an information system. Finally, this approach easily excludes a wide array of adjacent cases where information systems are not consulted at all, and processes of justification end for other reasons.

### *Interdisciplinary Benefits*

Minimalism about justification should not be taken to imply that fuller accounts of these processes and their dynamics are not of interest at all. The economic, political, historical, and technical factors influencing how and when processes consult and move on from information systems are each important topics of study in their own right. By keeping the criteria for what constitutes the cessation of justification minimal, many such inquiries could make use of the analysis and taxonomy presented in this dissertation. For instance, a political critique of the production of certainty in the No Fly list could note the lack of due process rights inherent in incorrigible enactment of certainty, and press for modifications to the information system and its enactment to modify this. Or, a technical analysis of a system could utilize the incorrigible default to argue for a regime of more frequent and precise measurement to increase the fidelity of empirical certainty produced in a scientific system. Though the dynamics of justification vary in each case, a focus on where and when these processes end allows the application of this dissertation to each, and potential augmentation with a variety of complementary approaches.

### 2.3.2 Why, How Do, How Should We Justify?

This section will review potentially applicable work in this vein and how it might link up with my project in future work. It will serve to both exclude such topics from my scope and identify potential areas of overlap with existing literature.

### *Boltanski and Thévenot's Justification*

Boltanski and Thévenot focus on the moral calculus of justification, broadly construed.<sup>17</sup> Aiming to synthesize practices of explanation from sociology and economics, they identify six ‘common worlds’ which constitute coherent practices of justification. For Boltanski and Thévenot, justification is a process that arises out of incommensurable appeals to a kind of common good. The processes of justification, dispute resolution, and political conflict can thus be modeled by participants’ appeals to the common worlds. Participants appealing to one of these six methods of establishing relative value are called a polity.

Boltanski and Thévenot cite Ricœur’s definition of an “acceptable argument” in this context as “exhausting the series of ‘because,’ at least in the particular situation of questioning and interlocution in which questions are asked.”<sup>18</sup> The striking similarity between this starting point of their analysis and my account of the cessation of justification gives a sense of how these ideas are complementary. Boltanski and Thévenot’s justification “makes it possible to assess the relative worth of the parties, leading the persons involved either to agree or to judge themselves wronged, lodge a protest, and demand justice.”<sup>19</sup> Thus, the sense of justification I’m using is a prelude to the rhetorical and political struggle for justice amongst Boltanski and Thévenot’s polities. Their account of this may add important context to how one might critique systems like the No Fly list. This is only one approach of many, but the analysis I will offer of the production of certainty via the taxonomy in Chapter 4 will nonetheless be of value in any such endeavor.

*The Natural Situation.* Boltanski and Thévenot do provide an account of the way things ‘hang together’ *within* the common worlds, and prior to the conflicts which are the main focus of their work.<sup>20</sup> This they describe as the *natural situation*, which bears some resemblance to the phenomenon of the production of certainty:

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<sup>17</sup>Boltanski and Thévenot, *On Justification: Economies of Worth*.

<sup>18</sup>Ricœur, *Freud and Philosophy: An Essay on Interpretation*, 189, cited in *ibid.*, 67

<sup>19</sup>Boltanski and Thévenot, *On Justification: Economies of Worth*, 67

<sup>20</sup>I am grateful to Ryan Shaw for alerting me to the specific passages in this section and their relationship to my project.

Very diverse beings—persons, institutions, tools, machines, rule-governed arrangements, methods of payment, acronyms and names, and so forth—turn out to be connected and arranged in relation to one another in groupings that are sufficiently coherent for their involvement to be judged effective, for the expected processes to be carried out, and for the situations to unfold correctly (as opposed to disrupted situations that are qualified... as pathological, dysfunctional, or conflictual, for example). In order for the system to be open to judgment with reference to a higher common principle, each being (person or thing) has to be adjusted to it. When these conditions are fulfilled, we can say that the situation “holds together.” A situation of this type... is a natural situation.<sup>21</sup>

Elsewhere, though, Boltanski and Thévenot clarify that there is a ‘mandatory’ aspect to their view of the natural situation:

Natural situations present themselves in a similar way to everyone. This is what gives them a mandatory aspect: one cannot avoid the obligation of taking their nature into account, whether by accepting it, denouncing it, or trying to reach a compromise with another world. One’s engagement makes it imperative to stay with the process to the end. But the situation still has to have been prepared: if a participant were to limit her involvement to a gaze, it is not clear how she could identify the situation and adopt the desired stance, how she could make herself available to the situation. A factory is not a factory just because people have viewed it as such. It is a factory because an array prepared in the industrial world requires a specific attitude on the part of observers: people have no choice but to see the factory as a factory and notice what is relevant in it.<sup>22</sup>

Certainty as I’m discussing it is not *necessarily* mandatory, though it may be in practice. Certainty is a major component of how social reality ‘hangs together,’ and, like Boltanski and Thévenot, I utilize this property extensively (see the discussion of the value of incorrigibility in Section 1.2.1). But it is important to remember that there is at least the possibility of *rejecting* certainty in all cases. Some components of social reality are more amenable to this than others, and some agents have more power to disregard others’ certainty with impunity. Boltanski and Thévenot’s natural situation is for them a precondition to conflict, but my project locates numerous, albeit small, potential conflicts *within* this zone.

Even still, Boltanski and Thévenot anticipate the importance of the information system in the operation of the natural situation. In the context of defining a new sport for example (which in turn anticipates our discussion of Searle and institutional facts in Section 3.2), they note that the *record* is what relates agents to one another:

... the way the beings involved are arrayed is not defined apart from a report that records them, a transcript that sets down their presence and their relationships. It is impossible to imagine anything like a “pure situation” unrelated to any report. For instance, the objectivity of the proper functioning of a machine appears utterly remote from the imperative to justify, yet the machine does not operate

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<sup>21</sup>Boltanski and Thévenot, *On Justification: Economies of Worth*, 41.

<sup>22</sup>Ibid., 147.

“all by itself,” even when there is no one to run it and no one to look at it, except to the extent that it functions according to a set of protocols for its use.<sup>23</sup>

The contention that machines cannot operate outside the context of protocols for their use anticipates the way in which I’ll utilize Derrida’s critique of Searle and Austin in Section 3.3.1. Both identify an apparent objectivity and resituate it within a socially defined context. The inevitability that Boltanski and Thévenot identify here is, in my account, the result of consistent enactment throughout a community, not a property of information systems themselves. The contexts of protocols are, in other words, constituted by a pattern of enactment.

The analysis of certainty I’m undertaking sits prior to Boltanski and Thévenot’s main project of analyzing justification between common worlds, and is related to their concept of the natural situation. Boltanski and Thévenot’s account of justification may lend depth to the analysis I’m proposing. So, perhaps, would other, alternate accounts of justification. The minimal requirements of a process of justification from my standpoint are that it (in the cases we’re interested in) precedes consultation of an information system, is succeeded by some other form of action, and (again in the cases we’re interested in) such subsequent action contemplates some inscriptive characteristic of the consulted promulgation. This leaves open many possible answers to the complex question of what justification is, and preserves the utility of my work beyond wherever such debates may lead.<sup>24</sup>

### 2.3.3 Consultation of Information Systems

A certainty-producing justification process that ends upon an information system is defined as *consultation*. The process may involve consulting a specific *system*, a specific *promulgation within a system*, or a *promulgation within one of several systems*. This section will distinguish these cases.

#### *Consulting a System-of-Record*

Practices of justification may end upon a specific system, as with the No Fly list, a library’s online catalog, or a restaurant’s reservation system. This is the simplest case, where a discrete system-of-record exists and counts as the authoritative site of consultation for a specific justification practice. Standardization

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<sup>23</sup>Boltanski and Thévenot, *On Justification: Economies of Worth*, 140.

<sup>24</sup>An additional connection to Boltanski and Thévenot may arise when I discuss Searle’s context *C* in Section 3.2. I won’t explore this further, but it’s possible that Boltanski and Thévenot’s six polities could be seen as large context *C*s within which institutional facts can be declared and specific argumentative moves are valid, alongside an account of how these incommensurable contexts are reconciled with each other.

efforts in law, science, finance, *etc.* often involve the centralization of promulgations into a single system to support this practice. Such systems I define as systems-of-record.

Having a single system to consult tends to make the production of certainty more uniform. It also increases the power of those able to promulgate within that centralized system. Crucially, though, consulting a *system-of-record* requires that the enacting agent move on from whatever inscription (or lack thereof) is encountered. A system-of-record, in other words, requires faithful enactment. In distributed bureaucracies, this embedding of a system as critical information infrastructure for the production of certainty enables large organizations to function reliably. It tends to remove agency from the enacting agent and transfers it to the promulgating agent.

#### *Consulting an Inscription within a System*

There are cases, though, where the nature of a specific inscription within a system conditions its enactment. In other words, justification does not stop upon the output of a particular system, but rather continues in light of a specific inscription. An example would be Google Scholar, which often indexes preprint PDFs of articles. When the original publication is needed for accurate citation of specific pages, a PDF discovered via Google Scholar may be rejected if, for instance, it is a preprint rather than a fully formatted journal article. Consultation may then continue within the system for another promulgation, or the agent may move the search to another system. Thus, while Google Scholar itself is a generally useful system, each individual promulgated PDF must be analyzed to determine whether it represents the actual published piece, as opposed to a preprint text.

#### *Consulting One of a Number of Systems*

In the United States, there are three major credit rating agencies, Experian, Equifax, and Transunion. A lender, employer, or landlord seeking to establish the creditworthiness of an applicant may consult any one or some combination of these agencies' promulgated credit scores to make a determination of creditworthiness. These are in practice treated as (roughly) equivalent, but their scores may differ markedly. In this case, the choice of system to consult may have a marked impact upon the outcome of the interaction. A similar dynamic plays out in the case of the distance to the earth and the sun (discussed further in Section 3.1.2), where Google, Wolfram Alpha, and reference texts all give distinct answers. Where any of several systems can be used to produce certainty, ambiguity and inconsistency

may arise. Such inconsistency may or may not engender problems. Where it does, there may be calls for the centralization described above.

In other cases, decentralization may be called for. Expanding the number of systems which may be consulted reduces the power of any one promulgator. When multiple systems are consulted, the resulting ambiguity is often addressed by attributing the resulting promulgations to their source. This is amenable to the production of defeasible certainty, and is discussed further in Section 4.1.3 (page 106).

#### 2.3.4 When Justification Ends

So, if we accept that justification is a heterogeneous process and cede its explication to other work, we still have to commit to a view that justifying activities cease. Or, more precisely that they *can*, and sometimes do, cease. Our task is thus to reliably identify when justification has ceased.

Regardless of its mechanism, a process of justification must make a difference. A border patrol agent who simply collects passport numbers, perhaps writing them into a list, does not perform a process of justification. Nor does a card-entry lock which is left unlocked, or is set to allow any magnetic signature pass. There is no interaction with a promulgated inscription in these cases (rather, in the border patrol agent's case, she is promulgating inscriptions rather than consulting them); these practices are significant, but not for the question of whether justification has ended. The kind of justification process required for the production of certainty in information systems must involve consulting a promulgated inscription and then lead to a specific behavior based on the inscription's characteristics. In the case of determining whether to admit someone through a passage of some form, this is usually binary: allow or deny passage. It need not be, though. An outcome of the justification process may be sorting or categorization into any number of categories. The way to reliably determine that a justification process has ended, then, is that there is a subsequent action, which I've called *moving on*, and that this action contemplates a promulgation. This is taken up in the next section.

### 2.4 **The Enactment of Certainty**

So far, we've identified a few key components of promulgation to help use reliably identify and characterize this component of the phenomenon of the production of certainty. These include the inscriptive agent, the inscription itself, and the relationship of each to an information system. The inscriptive agent, though



often amenable to methods of social analysis, especially when human, is still distinct from the process of enactment that I'll explain and clarify in this section.<sup>25</sup>

The examples above required frequent references to the conditions of enactment to point out the dynamics of inscriptive characteristics of promulgations. This was necessary to scaffold the analysis. In this section, we're able to isolate enactment more completely, and hopefully clarify the distinction.

#### 2.4.1 Inscriptive History and Enactment

The extent of a promulgation is circumscribed to the current inscriptive characteristics encountered during consultation of the information system. While the inscriptive agent and history of a particular inscription is relevant to the analysis of certainty more broadly, all the enacting agent has access to during consultation is the inscription itself. To the extent that the inscriptive agent or inscriptive history is available for contemplation by the enacting agent, this is only via traces in the promulgated inscription itself. Many common features of information systems, from preprinted letterhead to the use of “\_\_\_\_\_” to the convention of handwritten signatures to DNS are used for precisely this purpose.<sup>26</sup> Thus, I'm hewing closely to an entailment of Derrida's insight that “there is no outside-text [*il n'y a pas de hors-texte*].”<sup>27</sup> In French, *hors-texte* refers to the blank, unnumbered pages in a codex which separate parts or chapters, or unnumbered color plates inserted into a work. In this context, Derrida's insight is shown to be very concrete: every material characteristic of an inscription is a first class part of the inscription. The literal *hors-texte* in this document, for instance, are automatically produced as needed (by providing the appropriate L<sup>A</sup>T<sub>E</sub>X document class option) to make sure that part and chapter titles always begin on the right-hand side when the document is printed two-sided.<sup>28</sup> A literal interpretation of Derrida here is simply that these blank pages are still a material part of the text-as-inscription. Further,

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<sup>25</sup>We'll revisit inscriptive agency when we come to the concept of *given-as* in Section 4.2.2. Commonly, we conflate material traces of agency with descriptions of user action such as “The cataloger listed this book's subject as...”. It is only the inscriptive traces of the agent or action *within the information system* (i.e., in this case, an attribution or timestamp) which are contemplated by the concept of promulgation.

<sup>26</sup>For a history of commercial printing of form documents, many of which contain blanks to memorialize the inscriber via their inscriptions, see Lisa Gitelman, *Paper Knowledge: Toward a Media History of Documents* (Durham: Duke University Press, 2014).

<sup>27</sup>Derrida, *Limited Inc*, 144.

<sup>28</sup>The version you are reading may or may not have these features, due to UNC's strict enforcement of its dissertation formatting guidelines.

the interpretive context brought to bear upon an inscription is distinct from the context of the inscriptive act. The *hors-texte* in this document can be interpreted as wasteful, or pretentious, or ignored entirely; there's nothing about their inscriptive character that makes them scholarly, and nothing of the author's intention is inscribed into them as a *characteristic*. Thus, enactment connotes only actions performed in light of inscriptions, and inferences about the inscriptive agent or action only insofar as they are made by the enacting agent.<sup>29</sup> In many cases, no such inferences are made, they are made implicitly, or they become difficult or impossible due to the inscriptive characteristics of the promulgation in question.

*Enacting Agents.* As with promulgation, it is useful to identify the *agent* enactment. This is the entity that stops justification upon and performs some other action(s) in contemplation of a promulgation. In most of the examples above, the enacting agent is human. For instance, a border control agent who allows or disallows the passage of a traveler by reference to a database's output is an enacting agent. The enacting agent need not be human though: when I swipe my UNC OneCard to enter the doctoral offices, the enacting agent is the locking mechanism on the door. I am permitted to open the door once it consults UNC's networked identity system's promulgations produced in response to the digital signal generated by the magnetic strip on my card.

#### 2.4.2 Enactment and the Magic of Certainty

In Chapter 1 I noted how the production of certainty looked like magic in some cases. A mere inscription, produced in the right situation, consulted by the right person with a certain interpretation, seems to produce a spooky action-at-a-distance. One addition to the No Fly list and suddenly reservation systems, security agents, and related actors all begin to behave differently. The subsequent discussion has sought to demystify this phenomenon, to point out the mundane mechanisms active in producing this magical aura. Enactment is the most important of these: in short, it is where the magic, such as it is, happens.

Actions performed in light of an information system are the interface whereby information becomes a part of social reality. Though in many cases of faithful enactment, the promulgation consulted will fully determine enactment, there is no requirement for this to be so. Thus, enactment plays a limiting role

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<sup>29</sup>This is discussed more fully in Section 4.2.3 as the process of *taking-as*; for our present purpose of making this aspect of the phenomenon reliably identifiable, we are merely drawing the distinctions.

in the sequence: information matters only insofar as it influences enactment, and it need not influence enactment in any predictable way.

### *Enactment and Facts*

The role played by enactment challenges the view that facts are metaphysical states or ideal objects. Propositional logic holds that facts are states of affairs that make propositions true or false in light of such states. Implicit in such facts is an expectation that certain kinds of enactment will follow from them. When they do, facts are actively maintained through such enactment. I will expand on this challenge in Section 3.2.4 with the benefit of the work of John Searle.

### 2.4.3 Ways of Moving On

I swipe a card, and am admitted to a previously locked door. A border control agent scans my passport and waves me through. In each case, there are (at least) two outcomes, conditioned by promulgations in an information system: I am allowed to pass or detained. The *allowing to pass* or *detainment* in light of the card or passport are each examples of what I'm calling *moving on*. The nature of this moving on entirely determines the consequences of the production of certainty. The conditions of promulgation and justification which precede it only impact such consequences indirectly, through their influence on moving on. The analysis of ways of moving on is our analytical inroads to the analysis of certainty.

### *Moving On: To What?*

The denial of passage is also a moving on in the context of a locked door. Especially in the case of the card reader, remaining locked and flashing a little red light constitutes moving on. But, consulting a system isn't always the end of an interaction. If a border patrol agent is instructed by the system she's consulting that my passport isn't valid, she may not immediately detain me. She may assume that some information was incorrectly input to the system (though barcode scanning has largely eliminated this as a source of error, as compared to manual input of passport numbers). In this case, she may consult the system a second time, by for instance scanning the passport again. If the system then indicates that I am a valid traveller, she will move on by stamping my passport, waving me on, *etc*. The lack of moving on indicates that the justification process has not completed. But, eventually, justification will come to an end, and I will be admitted or not.

A new justification process may commence, involving an interview, manual review of documents, or perhaps contacting lawyers or consular officials. This process may involve information systems, but will likely consider promulgated information as only a piece of a more complex justification process. Information systems are designed to forestall this kind of slow and difficult deliberation unless absolutely necessary; that is, information systems are used precisely because they enable the production of certainty by providing a place upon which to end justification. Conversely, these appellate procedures, when they exist, counterbalance the absoluteness of moving on. Notably, some systems, like the No Fly list, have notoriously slow and/or opaque appeals procedures. The card access door, were it to deny me, has a murky set of appellate procedures that I could theoretically engage, such as contacting the university's Information Technology Services group. But such procedures necessarily lie outside the scope of the system itself, and involve contacting someone who can interrupt its operation. In the terms of Section 2.2, this might be someone who has promulgative agency within the system the card reader is consulting such that my ID card's magnetic strip is enacted as a valid inscription for passage.

#### *Moving On In Light Of: Contemplation*

From the beginning, I've used the phrase 'moving on *in light of*' to distinguish mere subsequent action from action conditioned by the information system consulted. While this phrase is roughly descriptive of what I mean, this section introduces a term that can be used to more precisely distinguish what *in light of* might mean in the context of the production of certainty in information systems. That term is *contemplation*, which is, like promulgation, borrowed from legal terminology.

*Contemplation in the law.* In legal terms, contemplation in the context of a contract or law indicates a way of describing the expected circumstances of application. A representative usage of this sense of contemplation is given in the *Oxford English Dictionary*: "The statute contemplates the whole of any estate, not undivided interests therein." A contract might contemplate a married couple, which means that it is expected to apply to and interact with a married couple. The rest of its provisions are predicated upon the existence of a specific married couple. If there is no married couple to speak of in a certain situation, whether the contract should apply comes into question.

A common form of legal argument is over what a contract or law contemplates. If a law or contract is argued to not have contemplated a specific situation, this can be an argument that either judicial interpretation is required, or that the legal provisions should not apply to the case.

*Contemplation and moving on.* The legal analogy is not perfect, of course, but gives a sense of what work the term contemplation is supposed to do in this context. *Contemplation* when moving on from an information system means acting with regard to some component of its materiality. In many cases, determination of contemplation is easy. List of identifiers are found, consulted, and contemplated in permitting or denying access in a variety of certainty-producing interactions. This contemplation is evident in, for instance, the comparison of my name as listed on my student ID card to the name listed in the online catalog before the library clerk hands me the books I requested.

In other cases, such as algorithmic recidivism predictions increasingly used in judicial proceedings, it can be difficult to determine whether, and the degree to which, sentencing and probation decisions contemplate algorithmic output. It may be that the recommendations have no effect on such decisions at all, in which case we'd say that, even if an information system is consulted, the subsequent moving on does not contemplate the system's promulgations. The persistent worry of those studying the ethics of algorithms, though, is that humans are inevitably influenced by such promulgations, and are thus co-opted as enacting agents for whatever the algorithms calculate to be the case. In other words, algorithms become *de facto* systems-of-record. In circumstances where algorithmic promulgations are enacted faithfully, social reality is conditioned by algorithms directly. More on these issues in Section 3.4 and the Conclusion.

#### *How Can We Know About Contemplation?*

The difficulty of determining unambiguously whether contemplation has taken place is not trivial. Empirical investigations as to whether moving on involves contemplation of information systems may be required. And yet contemplation as a component of the production of certainty is clear. One of the primary impacts of the US Civil Rights Act of 1964 was to make contemplation of race, gender, familial status, and other 'protected classes' illegal in housing, employment, and other decisions. Redlining was the practice of consulting map-based information systems to make loan and insurance decisions that indirectly contemplated race by way of the location of a house in a predominantly minority area.<sup>30</sup> Since determining whether contemplation in my sense has occurred can be difficult, most statutes that attempt to prohibit such practices apply equally to consultation and contemplation.

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<sup>30</sup>Urban-Suburban Investment Study Group, Center for Urban Studies of the University of Illinois, *Redlining and disinvestment as a discriminatory practice in residential mortgage loans* (Washington: Department of Housing / Urban Development, Office of Assistant Secretary for Fair Housing / Equal Opportunity, 1977).

In practice, consultation without contemplation is rather rare: human actors tend to contemplate information that they consult. Automated actors can more easily be made to consult but not contemplate information, but such actions are normally the result of a programming error. If an automated system is programmed to read data but not do anything with it, the action of reading the data is irrelevant to its output. An example of this might be an information system which accepts a username and password, looks up the user's password in a database, and logs the user in regardless of what was found as the stored password. Such a case would not be an instance of the production of certainty with an information system, since the consulted information is not contemplated during the moving on.

## 2.5 Promulgation, Justification, and Enactment: A Round Trip

The conceptualization of certainty so far permits a concise statement of the major components of the phenomenon of the production of certainty in information systems. There must be a promulgated inscription, which is consulted by an enacting agent, who then moves on in contemplation of the inscription's characteristic. By expanding the view slightly to include the promulgating agent, we can discuss something of what a successful round trip through this process looks like. In other words, we can describe how promulgating agents can influence enacting agents' behavior through the inscriptive character of a promulgation. This should provide additional clarity to Figure 2.1 (page 50).

Though we've largely left a discussion of the philosophy of language, and in particular speech acts, for Chapter 3, I must note at the outset that this round trip picture aligns strikingly with Austin's concept of *felicity*.<sup>31</sup> Felicity, for Austin, is a way of evaluating performative speech acts in terms of their success. There are circumstances and contexts where "I christen this ship the *Queen Elizabeth II*" (a common example in the literature) is *felicitous*; that is, it is recognized by others as performing the naming act that the speaker intended.

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<sup>31</sup>John L. Austin, *How to Do Things with Words: The William James Lectures delivered at Harvard University in 1955*, ed. J. O. Urmson and Marina Sbisa (Oxford, UK: Clarendon Press, 1962). Others such as Latour have found this term useful outside Austin's original formulation. See Bruno Latour, *The Making of Law: An Ethnography of the Conseil D'Etat* (Cambridge, UK: Polity, 2010), 129; and especially Bruno Latour, *An Inquiry Into Modes of Existence* (Cambridge, USA: Harvard University Press, 2013), especially 55–57.

### 2.5.1 Success and Intent

Discussions of felicity and success are substantially complicated by the issue of the speaker's intent. How do we know what a speaker wanted to happen? A satisfactory account of intent has so far eluded the philosophy of language (and mind), and the present work will make no attempt to contribute to the subject. We can, however, note that the *possibility* of success and failure exists here, and stipulate that at least some cases of each can be identified. Austin's performatives *have some effect*, regardless of whether we can reliably or universally evaluate their felicity. Boats, countries and sports teams are named; alliances, marriages, and pacts are initiated. In each case, some linguistic devices and circumstances of enunciation can produce these social institutions. Other declarations of similar form and content have no apparent effect.

### 2.5.2 The Limits of Inscriptive Agency

An inscriptive agent, such as the University Registrar, may have full control over the promulgation of inscriptions within a system, and be able to influence various enacting agents to, for instance, admit or deny me access to the doctoral student offices. There are several modes of failure of such systems, though. Enacting agents may choose to ignore the promulgations entirely. Automated systems such as card-access locks are presumably valued for their faithful enactment of promulgations within a system of authentication.<sup>32</sup> The system itself, or its presentation to the enacting agent, may also be altered, colloquially referred to as a 'hack.' This interrupts the otherwise reliable connection between inscriptive agent and enacting agent, even in the case of faithful enactment, by altering the presentation of the promulgated values. The individual circumstances of any particular breakdown in this 'round trip' may vary considerably.

The ethical consequences of the power of the inscriptive agent over others, by way of the enacting agent, is critical to the ethical evaluation of information systems and the actors that surround and constitute them. The discussion of felicity and infelicity will continue with an enhanced conceptual apparatus to support it in Section 4.1.4 and will be operationalized in the case studies of Part II.

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<sup>32</sup>Cf the discussion in Section 1.3.2 (page 40), and Smith, *Limits of Correctness in Computers*

### 2.5.3 Analyzing Certainty

This chapter has presented the production of certainty in information systems as a combination of three major processes: promulgation, justification, and enactment. Two ancillary processes, consultation and contemplation, play a role in articulating these processes, as do promulgating and enacting agents. Promulgation refers to a material inscription made in an information system by a promulgating agent, made available to some subsequent actor. Justification is a potentially complex process that comes to an end upon the consultation of an information system by an enacting agent. And enactment is the subsequent moving on in contemplation of an inscription.

These concepts provide a theoretical ontology of the processes constituting the phenomenon of the production of certainty in information systems. With these concepts in place, we are ready consider the production of certainty in light of analytical techniques from the philosophy of language and related critiques. These techniques are the subject of Chapter 3, and reveal that the production of certainty employs technique of forgetting in both promulgation and enactment.



### CHAPTER 3: CERTAINTY, FACTS, & FORGETTING

This chapter will analyze the relationship between certainty, facts, and techniques of forgetting within information systems. I will argue that facts constitute a technique of forgetting embedded within a technology of remembering. Techniques of forgetting in this sense are patterns of actions by enacting or promulgating agents, whereas technologies of remembering are the systems that enable promulgation and its persistence. The declarations that create facts are inscribed within a medium, which within our scope is an information system. The durability of the inscription and its persistence through time constitutes a technology of remembering. There are several kinds of forgetting employed in this process. First, the fact itself enables the forgetting of the action which led to its inscription. This is by design: an inscribed fact is tractable, and small, while the processes which produced it are part of what Smith calls the *infinite richness*.<sup>1</sup> Academic information systems often are designed to partially mitigate this process through the production and maintenance of metadata, particularly provenance metadata. But, of course, these mitigations employ the same techniques which they are designed to mitigate. At best they situate the fact within a network of other facts, each of which enables a technique of forgetting through the technology of remembering in which it is inscribed. The second kind of forgetting, alluded to in the example of metadata, is the operation of root facts. Root facts are a role that facts may play in relation to other facts, to propositions, or to questions. They are designed to be stopped upon. When we do stop upon them, we accept or recapitulate the forgetting they license. There are many potential cultural logics of licensed forgetting. Science is the most familiar of these,<sup>2</sup> but popular sports, history, and governments each employ a culturally negotiated licensed forgetting in the production of their facts. The processes of remembering and forgetting are integral to the constitution of social reality, and so by articulating information systems' role in this process I am laying the groundwork for the dissertation's ultimate aim:

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<sup>1</sup>Smith, *Limits of Correctness in Computers*, 8.

<sup>2</sup>Geoffrey C Bowker, *Memory Practices in the Sciences* (Cambridge, MA: MIT Press, 2006).

to describe the production of social reality with information systems. Facts and the enacted and material forgetting they embody create social reality by enabling the production of certainty.

### Organization of the Chapter

This chapter explores the connection between facts, certainty, and social reality from several angles. Section 3.1 examines facts as a place to end justification, introducing the thought of John Searle. The section seeks to obviate Searle's dichotomy between *institutional* and *brute* facts, and instead offers the concept of *root fact* as a role played by facts when justification ends. Objections and implications of this move are considered.

Section 3.2 proceeds to the implications of the concept of root facts. I advance and defend the view that incorrigibility is a property of all declarative speech acts, and declarative status functions. The discussion then shifts to the relationship between power and certainty, and in particular power the rhetorical power behind Searle's original conception of brute facts. I attack the argument that representation offers a defense from these critiques. Finally, the section advances a view of facts as deeds, based in part on the etymology of the word, that encapsulates the relationship between facts, power, and action.

Section 3.3 examines the forgetting inherent in inscription (and, thereby, promulgation). This section reviews Derrida's critique of Austin and Searle before turning to an extensive engagement with Bowker's concepts of *memory practices* and the *jussive archive*. The section concludes by drawing on the work of Brian Cantwell Smith and exploring the memory practices inherent in the operation of algorithms.

## **3.1 Facts and the End of Justification**

Early on and periodically throughout the discussion so far, I've had to make use of the concept of *fact*. There are two senses in which I've done this. The first was to note that facts play a certain role in relation to truth, according to propositional logic.<sup>3</sup> Facts are not themselves truth-apt, but rather are used to

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<sup>3</sup>Propositional logic, as I've interpreted it, is descriptive, not prescriptive. That is, it describes how groups make propositions *in many cases*, rather than being some kind of limit on the possibility of language. It happens to be a particularly useful and widespread set of practices, without which we wouldn't have a coherent way of determining the truth values of statements. Determining the truth values of statements is, in turn, a central activity in practically every modern context. This ubiquity is why it has featured so pervasively in the discussion. I mention this to distinguish my use of the concept from its rhetorical deployment in philosophical debates as an example of

determine the truth of other truth-apt statements, namely propositions. The second sense in which I've used facts is to claim that certainty producing information systems contain them in cases where they are used to produce certainty. In our familiar example, it is some inscription within a database somewhere which which we must consult to determine whether the proposition "You are on the No Fly list" is true or false. In this section I will expand on and unify these two senses into connected whole, using the work of philosopher John Searle and starting with Paul Beynon-Davies's application of Searle's thought to information systems and institutional order.

In the process of endorsing Searle's account of facts as always and only the result of declarations, I will side step his desire to hold aside the special class of *brute* facts as exempt from this construction. A trip to Searle's putative source for his concept of brute facts, the work of Elizabeth Anscombe, will in fact uncover a far more important principle at work: what I've elsewhere called the cessation of justification. Anscombe's brute facts weren't mobilized towards aligning with an assumption of realism but rather described the ways in which facts rely on an presuppose each other, recalling Wittgenstein's buttresses. Reconstituting Searle's work using Anscombe's superior conception of bruteness, which I've tried to reclaim in the term *root facts*, strips it of its realist ambitions and makes it more powerful in describing complex networks of relationships between facts as truth grounds. Discarding Searle's dichotomy between institutional and brute facts, I present a unified account of root facts that is well suited to describing the production of certainty in information systems. Augmented with a Anscombe's bruteness, the account can ably describe complex recursive networks of facts which presuppose the cessation of justification upon other facts. Root facts are shown to encapsulate techniques of forgetting, rules for when to stop, and what to leave 'brute' in Anscombe's sense.

### 3.1.1 Searle's Social Ontology

Searle's work and that which follows in its footsteps, broadly described as social ontology, is focused on giving a philosophical account of things that exist because of human agreement or social practices. Searle goes so far as to call this project "philosophy of society,"<sup>4</sup> and is in some ways an unlikely candidate for describing such socially constructed facts. As a realist analytic philosopher, his first allegiance is to

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metaphysical necessity. This approach allows my analysis to apply equally to contexts in which 'determining the truth value of statements' refers to vastly different practices.

<sup>4</sup>Searle, *Making the Social World: The Structure of Human Civilization*, 5.

proving the existence of a mind-independent reality, upon which, for him, morality, scientific knowledge, and Western social order depends. For a sincere realist like Searle, things that exist because of human agreement represent a difficult challenge: how can this be reconciled with the mind-independent reality that is so critical to the possibility of knowledge, morality, and order?

In *Making the Social World*, Searle provides the strongest version of his answer: things that are true by virtue of human agreement are *institutional* facts, and are created always and only through the use of declarative speech acts.<sup>5</sup> This is contrasted with his brute facts, which exist apart from human agreement and upon which institutional facts must rest. Institutional facts are, more precisely, any action or circumstance which embodies a declarative status function, a distillation of the effects of a declarative speech act. For the purposes of this dissertation, Searle's institutional facts provides an adequate description of what socially constructed facts are and how they arise from declaration. The next section summarizes some of Searle's most relevant work and attempts to give a sense of how it has evolved in response to criticism, before continuing the critique.<sup>6</sup>

### 3.1.2 *X*, *Y*, and *C*

Searle originally provided this formula for a what he calls a constitutive rule:

$$X \text{ counts as } Y \text{ in } C^7$$

That is, something in the world *X counts as*, or is declared to be, *Y* fact in institutional context *C*. This implicitly encodes the distinction between institutional and brute facts: *X* is a mind-independent state of the world. So for instance, *X* is the piece of cotton paper with an intricate pattern in green ink, *Y* is a five dollar bill, and *C* is the United States and especially its monetary regime which specifies what a five dollar bill is and how it shall be constructed.

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<sup>5</sup>“The claim that I will be expounding and defending in this book is that all of human intellectual reality is created and maintained in existence by (representations that have the same logical form as) [Status Function] Declarations, including the cases that are not speech acts in the explicit form of Declarations.” Searle, *Making the Social World: The Structure of Human Civilization*, 13

<sup>6</sup>For an excellent summary of Searle's work in the context of information systems with a slightly different perspective, see Beynon-Davies, “Form-ing institutional order: The scaffolding of lists and identifiers.”

<sup>7</sup>Searle, *Making the Social World: The Structure of Human Civilization*, 9–10.

This original formulation was subsequently shown to have a few shortcomings. The most interesting of these for our purposes is the case of the ‘freestanding Y,’ advanced by Barry Smith.<sup>8</sup> This indicates cases, such as electronic money, blindfolded chess, or a corporation, where there is no *X* to be found. Searle retreats to the concept of *representation*. We’ll return to and critique this move below.

Regardless, Searle revised his original formula to account for exceptions like these. So, in *Making the Social World*, Searle situates this original account of the Declarative Status Function as a specific case of a more general logical form:

We (or I) make it the case by Declaration that a *Y* status function exists in context *C*

By this definition, all that is needed for *counting-as Y* in context *C* is a declaration of some way of knowing what is a *Y*. The original formula, *X counts as Y* in *C* is a declarative status function where some physical object *X* is constructed into a *Y*. But declarative status functions need not do this. A pair of chess champions playing chess by simply calling out pieces and board positions to each other, with no board or pieces, is using the freestanding *Y* terms of the rules of chess to manipulate the freestanding *Y* terms of the pieces in their virtual game.

#### *Science and the Freestanding Y*

But how are these freestanding *Y*s distinct from the facts of science? One of Searle’s canonical examples of a brute facts is the distance between the earth and the sun, which he gives as 93 million miles.<sup>9</sup> Consider these related claims:

- According to Google, the distance is 92.96 million miles from the sun. (No source given; the same on multiple days, so is likely an average, and perhaps the value that Searle rounded from)
- According to Spaceweather.com, at perihelion, the earth is 91.65 million miles from the sun. At aphelion, the earth is 94.82 million miles from the sun. The earth’s orbit is an ellipse with 1.7% eccentricity, which means that the distance varies throughout the year in a predictable pattern.
- According to Wolfram Alpha, on August 6th, 2018, the distance was listed as 94.28 million miles. On March 12th, the distance was given as 92.36 million miles.

Searle’s mistake is in claiming that brute facts *exist* regardless of human agreement. Such existential claims are unavoidably expressed as propositions. As noted at the outset, propositional logic holds that facts cannot be true or false, but rather are used to determine the truth or falsity of propositions. All of

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<sup>8</sup>Barry Smith, “John Searle: From Speech Acts to Social Reality,” in *Contemporary Philosophy in Focus*, ed. Barry Smith (Cambridge, UK: Cambridge University Press, 1999), 1–33.

<sup>9</sup>Searle, *The Construction of Social Reality*, 10. Beynon-Davies repeats this fact verbatim, as have I. Beynon-Davies, “Form-ing institutional order: The scaffolding of lists and identifiers,” 2745.

the above claims are propositions, of course, *yet also are treated as facts*. That is, in Searle's conception of brute facts, propositions about brute facts themselves (or their existence in some strong sense) become freestanding *Y* institutional facts. I argue that facts like this are rather similar to blindfold chess: words which *count as* moves in a larger game with pre-established rules.<sup>10</sup> In doing so, I'll present a revision of Searle's account that can align it with the three distinct ways of moving on detailed in Section 1.2.

### 3.1.3 Questioning Brute Facts

Searle's institutional/brute facts dichotomy runs throughout his account and, as noted above, is implicit in the distinction between *X* and *Y* in his original declarative status function definition. The cracks exposed by his handling of the possibility of freestanding *Y* terms widen as we probe them, suggesting the need to revisit brute facts.

Searle claims to take the concept of brute facts from a paper by Elisabeth Anscombe. Here is the essence of Anscombe's conception:

In relation to many descriptions of events or states of affairs which are asserted to hold, we can ask what the "brute facts" were; and this will mean the facts which held, and in virtue of which, in a proper context, such-and-such a description is true or false, and which are more "brute" than the alleged fact answering to that description.<sup>11</sup>

In this account, Anscombe's "brute" is *inherently relational*. That is, a brute fact is, for Anscombe, like Wittgenstein's buttress: something we hold firm to prop something else up. Her example is ordering potatoes from a grocer: "I can know perfectly well that the grocer has supplied me with potatoes; asked what this consisted in, I say there was nothing to it but that I had ordered them and he brought them to my house."<sup>12</sup> In this example, "ordering potatoes" and "bringing them to my house" are both defined by a contextual status function. Yet, for Anscombe, they are brute in relation to the grocer having supplied

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<sup>10</sup>Blindfold chess is, simply, playing chess while blindfolded. What is for chess masters a display of skill and concentration has become for philosophers a convenient example to clarify discussion of social ontology. Note that blindfold chess is distinct from dark chess, wherein players have knowledge of their own pieces' locations but not that of their opponent, played on two visually separated boards with only one color of pieces on each of them. This style of chess requires an umpire to rule on the legality and result of proposed moves in knowledge of the full board. It might also be a more interesting example of social ontology at work, but we'll confine ourselves to the examples discussed by Searle and his interlocutors.

<sup>11</sup>G E M Anscombe, "On Brute Facts," *Analysis* 18, no. 3 (1958): 71.

<sup>12</sup>Ibid.

potatoes. There is no inkling of dichotomy or realist ambition here, merely a relationship of certainty, a place where justification ends.

We can see the production of certainty in information systems active if we update Anscombe's example to a modern day United States Postal Service delivery. Whereas the grocer's bringing potatoes is an empirical fact, the state of potatoes-on-doorstep, a modern delivery has been converted into an institutional fact, a status-of-tracking number. Several times I have received notice that a package was delivered from the postal service's information system, and yet the package-on-doorstep was not there. A long series of interactions with customer service was required to mitigate the incorrigibility of the tracking number's status. As best I can tell, delivery people who don't make all of their deliveries at the end of a work day go in and mark the rest of their packages as delivered, which sends me a notice. In several cases, the package would appear early the next day. These employees seem to be co-opting the incorrigibility of the system to meet the demands of their employers in terms of productivity.<sup>13</sup> Regardless, for a delivery company and its employees, the tracking number's delivery status is a brute fact, in Anscombe's relational sense, that a package has been delivered until and unless I can convince them that I have not actually received it.

#### *Brute Facts and Certainty*

So, my critique of Searle is that the realist dichotomy between brute and institutional facts, however salutary to his overall realist project, is not borne out by the source he cites as inspiration for it. What's more, Anscombe's original conception of bruteness as a buttressing relationship following Wittgenstein

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<sup>13</sup>We'll return to the ethical and political implications in Section 3.2.2.

is a much more interesting and powerful concept.<sup>14</sup> Insofar as Anscombe's bruteness involves a cessation of justification, this is an alternate approach to the production of certainty in language.<sup>15</sup>

We can thus revisit Searle's example of the distance between the earth and sun in light of the three ways of moving on introduced in Section 1.2. Searle's conception of brute facts as those which exist regardless of human agreement amounts to a methodological admonition to move on with empirical certainty. That is, he would expect us to be certain in his statement that the earth is 93 million miles away from the sun, *contingent upon more accurate measurement*. So, Google's inscription, 92.96 million miles, is something we'd readily accept as a more precise measurement. And, based on the elliptical nature of Earth's orbit, we'd be ready to concede that Wolfram Alpha's inscription, which is calculated based on the day of the year, is even more accurate. In each of these cases, a willingness to revise in light of measurement is the functional outcome of Searle's definition of brute fact. Thus, his construction amounts to a normative principle about *how we should be certain* with respect to measurement.

In all of these cases, though, the incorrigible default is active. Searle's rhetorical use of the inscription "93 million miles" treats this putatively empirical fact with incorrigible certainty: it is what he wrote in his book and moved on from. And the vast majority of scientific knowledge within any given system of understanding the world is functioning as a Wittgensteinian buttress, or as one of Anscombe's brute facts, in relation to the other knowledge or claims that are being made.

#### *What About Objective Knowledge?*

I've presented Searle's brute facts as a carve-out around his preferred realist ontology, an addition that can be removed with no deficit to our purposes. Searle, certainly, would not agree. One of Searle's major

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<sup>14</sup>Anscombe does not cite any sources in her paper on brute facts (which is not uncommon in philosophy papers, especially of that era), but we know she was intimately familiar with Wittgenstein's work as his student and one of his literary executors. §65-299 of Wittgenstein's *On Certainty* were composed while he was staying at Anscombe's house during the final year of his life, and the final sections on hinge and buttress propositions shortly thereafter. Anscombe was present at Wittgenstein's death and presumably acquired his final writings at that time. Thus, she had constant access to them from Wittgenstein's death in 1951 and could well have been influenced by them in her comments on brute facts. Regardless, she was perhaps more intimately familiar with Wittgenstein's work on certainty than anyone in the world in 1958; anyone outside her and Von Wright's inner circle would have to wait until 1969 to read this work. Ray Monk, *Ludwig Wittgenstein: The Duty of Genius* (New York: The Free Press, 1990), 569,577.

<sup>15</sup>The present dissertation is confined to the production of certainty *in information systems*, but it is distinctly possible that this approach may be applicable in a wider context, especially considering that this is the context targeted by Wittgenstein, Anscombe, and Searle. Though my engagement with them may have implications for such work, it should be interpreted here as applying only within the context of information systems.



anxieties is about whether objectivity can be preserved in his system. On the objectivity of institutional facts, he writes:

There is no question that intentionality, real intrinsic intentionality, is ontologically subjective. It exists only in human and animal agents. But from the fact that it is ontologically subjective it does not follow that we cannot have completely objective knowledge about at least certain forms of human intentionality. It is an objective fact, for example, that George Bush got elected in the 2004 presidential election, even though many of the activities that constituted the election were ontologically subjective.<sup>16</sup>

‘Real intrinsic intentionality’ here is doing the work of embedding ‘realness’ into human knowledge. What if we disregard this construct for the moment, since it’s part of what I’ve cast as Searle’s superfluous realist machinery? In this passage he derives epistemic objectivity from ontological subjectivity. Why wouldn’t a similar construction work for the facts of science? If ontological subjectivity is no threat to the validity of American democracy, how could it threaten the number of electrons in a hydrogen atom? For Searle to endorse Bush’s 2004 election victory as ‘objective fact’ (*i.e.*, a mind-independent state), he has to inhabit, or grant, the institutional declarations that make such a thing possible. My contention is simply that a similar move occurs with all facts, and no account of ‘real intrinsic intentionality’ is ever called for, unless of course one believes that such a concept would have rhetorical value for realists. An acceptance of facts’ constituent declarations will of course make them into facts. This is, after all, the import of Searle’s project: to show this declarative dynamic at work. And so, when we call the facts of science objective facts, we slip into a subtle acceptance of their constituent declarations. As Searle argues here for election results, this is not a skeptical challenge to knowledge. Neither, then, is it when expanded to the scientific knowledge that Searle seeks to enshrine as ‘brute’ facts. Instead, it is a pragmatic description of how knowledge works, what counts as knowledge, and how facts are propagated through subtly accepting or inhabiting declarations.

Searle’s work on the topic of the construction of facts is invaluable. But I can’t share Searle’s anxiety that lacking a proof of realism will lead to the collapse of society. Just as a proof of the existence of God was once *de rigueur* for philosophers, it seems that many anglophone philosophers feel the need to prove that their own mind-independent existence follows from the rest of the work they do.<sup>17</sup> But Searle, like Aquinas, has immense value to offer those who don’t share his anxieties of proof. The work

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<sup>16</sup>John R Searle, “Reality and social construction: Reply to Friedman,” *Anthropological Theory* 6, no. 1 (March 2006): 82.

of a philosophical interpreter, then, is to excavate these anxieties from otherwise interesting and useful contributions.

### 3.2 Root Facts, Power, and Deeds

My argument so far is that Searle's realist project is superfluous to the description of how facts are used in the production of certainty. By removing his dichotomy and instead using Anscombe's relational account of brute facts, we arrive with a definition of 'fact' that is nicely consonant with how I've been approaching certainty: that which we move on in light of; a Wittgensteinian buttress. Moving on and in-light-of are both conditioned by and in relation to some form of declarative status function.

The account of facts so construed I'd like to call 'root facts.' This term indicates that when certainty is produced there is some state of affairs, a fact, which is moved on from in contemplation of. Exactly *where and when* human actors move on from is a socially contingent set of behaviors. Many, like Searle, have advanced normative principles for where and when we *should* move on. Such principles are often advanced implicitly, as if they were inevitable, or as metaphysical necessity. My analysis is intended to foreground this normativity as a factor in the production of certainty: it expresses the social norms governing what should count as a root fact and thus what should be used to adjudicate the truth of propositions and answer questions.

As in Anscombe's original construction of brute facts, root facts are inherently relational. All facts are root facts in relation to *something*, since this role is key to what facts are. And these relations can change over time. This is in essence a recombination of Searle's account of fact production from declarative processes combined with Anscombe's account of how facts justify through their bruteness relation to one another. From this point on the term *fact* will indicate this synthesis, and *root fact* will call attention to

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<sup>17</sup>Moore's anti-skeptical defense using common sense is a perfect example of this. G E Moore, "A Defence of Common Sense," in *Contemporary British Philosophy*, ed. J Muirhead (New York: The Macmillan Company, 1925). Ludwig Wittgenstein's *On Certainty* doesn't engage with Moore's antiskeptical arguments at all but rather uses examples like "I know that I have two hands" as a starting point for pragmatic analysis, a move similar to the one I'm attempting with Searle. Wittgenstein, *On Certainty*. A large part of the epistemic angst which is so pervasive in Western philosophy could be seen as a kind of residual of the secularization of Judeo-Christian cultural logic. Intellectual ontogeny recapitulates phylogeny (a biological analogy indebted to Stephen Jay Gould, *Ontogeny and Phylogeny* (Cambridge, MA: Belknap/Harvard University Press, 1977)). In this analogy, proofs of an external world (Moore) or mind-independent reality (Searle) are vestigial organs which played a functional role at point but can now be safely discarded. Vestiges are worthy of historical study, perhaps, but not where the action is. For a particularly self-conscious discussion of philosophical anxiety in terms of *epistemic angst*, see Pritchard, *Epistemic Angst: Radical Skepticism and the Groundlessness of Our Believing*.

a specific role the fact is playing. Both occurrences of the term refer to the same thing; in other words, there is no dichotomy here, just a difference in emphasis. *Brute fact* will refer to Searle's interpretation of Anscombe.

### 3.2.1 The Incorrigoibility of Declaration

Searle identified the critical role that the act of declaration plays in the creation of facts. Declarations, we have already seen, play a critical role in the production of incorrigible certainty in information systems. The relationship between these two concepts can be stated like this: declarations are speech acts explicitly designed to be logically incorrigible within a given context. As a preview of how this translates into information systems, this closely recalls Smith's account of program verification. When correctness and context which determines it are both embedded into an information system, this forms a closed loop.

I'm arguing that that something like Smith's conception of correctness in programs holds for declarations of all kinds. I'll precisely state the argument like this:

A declaration constitutes a fact, not a proposition; therefore, all declarations are logically incorrigible<sup>18</sup> within the context in which their contents are enacted as facts. Outside the context in which they are enacted as facts, declarations are still actually incorrigible<sup>19</sup>. Thus, they are never truth-apt and cannot be false.

These arguments each reference the traversal of facts across contexts. This will be discussed further in the next section. For now, context can be glossed as equivalent to circumstances where the declaration is enacted. With this scaffold, I'd like to focus on the claims that declarations are incorrigible in two ways.

First, I claim that a declaration constitutes a fact in virtue of its enactment. In other words, a declaration *is*, and cannot in this sense be true or false. Logical incorrigibility is the property of being unable to be corrected or reconciled with anything else, *i.e.*, the inability to be intelligibly rendered true or false. A declaration enacted as a fact is incorrigible within the context of such an enactment.

My second claim is that even outside the context of enactment that makes it a fact, a declaration is still an act, and as such it obtains *actual* incorrigibility. Actual incorrigibility is the property of being

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<sup>18</sup>This argument makes use of the distinction between logical and actual incorrigibility given on page 24.

<sup>19</sup>See n. 18.

*done*, in the past, and in that sense being unalterable.<sup>20</sup> As discussed elsewhere, actual incorrigibility implies logical incorrigibility. I'll elaborate on this sense in Section 3.2.4 (page 88)

These arguments connect the speech act of declaration to the logical properties of interest to the analysis of certainty. In particular, they provide a second approach to the arguments of Section 1.2.4 (page 30) on the incorrigible default. If the use of an information system constitutes an enactment of it, I argue, logical incorrigibility results. Even outside a context which construes the declaration as a fact, it remains an act and is thus actually incorrigible.

Incorrigibility, though, does not mean inevitability. Instead, declarations can be ignored, rejected, or enacted as non-declarations. for example, imagine a self-sovereign person making his own No Fly list. The truth value of this declarative act is not *false*, but would be ignored or construed as legally meaningless speech by a TSA agent. Just as declarations can be ignored, so they can be taken as declarations but within an alternate context. The American Colonies' Declaration of Independence was construed as a declaration by the British, a fact in virtue of an act, but not of independence (*i.e.*, within the context intended and enacted by its authors). Rather, it was seen as a crime against the crown, taken as declaration within the context of British law.

The modulation of context surrounding a declaration is thus key to the analysis. Resisting or modulating context is a frame for understanding Gasser's study of work-arounds.<sup>21</sup> Gasser focuses on how users without the ability to substantially alter a large system nevertheless develop a limited ability to control their local context. Ignorance or rejection may not be an option for middle management or an employee who must contend with imposed standards, or at least not an option if they wish to not risk their employment. In situations where employees are protected from firing, ignorance or rejection of official declarations may be a viable option (a stereotype of US government employees). The work-around finds a way to achieve something short of re-declaration.

The power (physical, political, economic, or *etc.*) to create, maintain, and proliferate a context of enactment heavily constrains whether the incorrigibility achieved by a given declaration will be logical

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<sup>20</sup>This raises real and interesting questions about the relationship between something *being done in the past* and knowledge of the past, which we will not address. This is another methodological benefit of limiting the scope of analysis to promulgations as inscription.

<sup>21</sup>Les Gasser, "The Integration of Computing and Routine Work," *ACM Transactions on Information and System Security* (New York, NY, USA) 4, no. 3 (July 1986): 205–225.

(i.e., related to the practices surrounding some group's use of language) or merely actual. It is time, then, to discuss power and context directly.

### 3.2.2 Context, Power, and Certainty

The relationship between context, power, and certainty is clearly a fruitful nexus for understanding the dynamics of socially constructed facts. The flow of the argument in this section is as follows:

- certainty is the practice of stopping upon and moving on in light of facts
- facts are declarations-within-context
- facts presuppose the power to declare
- contexts are maintained by patterns in the power of enactment
- power over certainty means the power to condition the power to declare and (or) enact

I'll review Searle's account of power and argue for my claims in light of his.

#### *Deontic Power*

Searle believes that Barry Smith's freestanding *Y* objection can be accommodated even without the modification he makes to his General Theory of Institutions and Institutional Facts.

The freestanding *Y* terms do not bottom out in concrete objects, but they do bottom out in actual people who have the deontic powers in question...A corporation is just a placeholder for a set of actual power relationships among actual people.<sup>22</sup>

Deontic power indicates the institutional rights and obligations that someone has in light of some institutional fact, and is for Searle a key outcome of his theory. Owning a car, which is an institutional fact within the context of private property, gives someone the right to drive that car, the obligation to pay taxes on it, and the right to not have other drivers run into it. These powers are constitutive of the fact in its institutional context. If I'm going to argue that Searle's theory of institutional facts largely got facts as such right, I have a burden to account for these deontic powers in my revised account.

#### *The Rhetorical Power of Brute Facts*

Searle's brute facts are demanded by his reliance on the concept of a mind-independent reality. For Searle, strong realism in this sense is crucial to Western social order.<sup>23</sup> The special role he gives to brute facts

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<sup>22</sup>Searle, *Making the Social World: The Structure of Human Civilization*, 21-2.

<sup>23</sup>"It seems to me that in a situation as I have described it, if there were no deontic reasons at all, no desire-independent reasons for action whatever, then the corresponding institutions would simply collapse. The systems of statement making, ownership of property, and promising function only on the presuppositions that, other things being equal, one can reasonably assume that one's own utterances and the utterances of other people are attempts at stating the truth; that property ownership confers rights and duties on the owner; that the making of a promise,

in his theory is essentially a perfect replica of the deontic powers he's seeking to preserve: namely the ability to adjudicate propositions, answer questions, and win arguments (in this case, with empirical measurements). Baking this into his account of brute facts is a maneuver that, if successful, extends the context within which these powers are valid to all of language. This holds obvious benefits for the realist philosophy, and less obvious but even more powerful benefits for those who constitute Searle's 'Western social order.'<sup>24</sup>

In the discussion of the distance to the sun above, Searle makes use of these powers. The brute facts of science are supposed to give those who can articulate them a way of erecting boundaries of certainty that say "justification should end here." The propositional form of these boundaries is contingent. New empirical results of science *should be* accepted as factual replacements, revisions, or clarifications. But the propositions are supposed to absorb some of the indubitability of their underlying facts, which can then be rhetorically deployed as an argument for realism. The implication of holding "the earth is 93 million miles from the sun" as a brute fact is that, regardless of the actual distance, there *is* a distance, in the existential sense of *is*. My argument is that this existential *is* is another example of the ontological function that Searle has uncovered. It *is* because it *counts as*. Searle's formulation, I'm saying, is seeking to make the facts of scientific realism *count most*.

#### *Facts, Context, and Physical Power*

The role of physical power, the power to violently control physical entities such as bodies, cars, gates, and telecommunications networks has so far been obscured. But it lurks nearby throughout this discussion, and is a common method of expanding a favored context *C* and thereby the extent of where the associated facts *count*.

The rhetorical power of Searle's realism is underpinned by physical power. The rhetorical power to win an argument with a measurement is what Searle seeks from his brute facts. This power is, ultimately, what he's referring to when he links realism with Western social order. The rhetorical power to win arguments with measurements, to produce empirical certainty, is often contrasted with the ability to win

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other things being equal, creates a reason for the agent to keep the promise." Searle, *Making the Social World: The Structure of Human Civilization*, 142

<sup>24</sup>For another critique of Searle's thought on this topic, see Richard Rorty, "John Searle on realism and relativism," in *Truth and Progress*, vol. 3, Philosophical Papers (Cambridge: Cambridge University Press, 1998), 63–83.

arguments through force, or declaration. But physical power is active in any kind of certainty production in a way which undermines the uniqueness and questions the ethics of Searle's construction.

Physical power is the essence of enactment, but any given enactment can be constrained by supervening physical powers. Searle's facts operate within contexts, which are patterns of interpretation. The physical power to control, constrain, induce, or coerce enactments of a given kind constitutes the physical maintenance or extension of a context, and thereby its attendant facts. All enacting agents produce physical consequences as they move on. This nexus of physical power between enactment and context is incorrigible in the second sense of actual. The enactment of facts is itself modulated through actions external to the system.

### 3.2.3 Representation Is No Recourse

Searle's rejoinder to this critique might be that I am mistaking the concept of brute fact for the thing to which it refers. That is, Searle would agree that he's making a move like this:

I make it the case by Declaration that a brute fact status function exists in context philosophy of social ontology

The brute fact status function is, of course, something constituted by human agreement (in this case, humans who adopt Searle's philosophy of social ontology verbatim). But underneath this Declaration there is something real, something *really there*, which this socially constructed concept is representing. My final argument in this vein will be that representationalism offers no substantive recourse for Searle's project.<sup>25</sup>

Viewing Searle's brute facts as themselves socially constructed facts constituting a standing declarative status function makes the entirety of Searle's work comprehensible without the dualism of mind independent reality. The circularity inherent to this view might be seen as a weakness by some, but I'd argue that it instead illustrates its true power. Searle's system is itself constituted by declarations, something we should expect if his work is to be taken on its own terms.

So representationalism, a broad label for theories of language and meaning that take words to be 'pointing to' or 'standing in for' something material, is shown to be a kind of *apriori* adherence to the resolutely *a posteriori* status function constituting brute facts. Representation can't be the kind of

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<sup>25</sup>My argument is limited to representationalism within this narrow context. For a broader attack on representationalism, see Price, *Naturalism Without Mirrors*.

grounding that Searle wants it to be, since it flows as a consequence of the very declarative practices he's set out to describe. That which *counts-as* represented does so by virtue of yet another declarative status function within another context. Searle's preferred buttress is merely a set of rules for stopping. It's better, I'd suggest, to embrace the parsimony offered by construing Searle's theory on its own terms, as a declaration. When we do, the normativity of his construction of brute facts becomes apparent, and even expected.

If this is so, though, it seems we'll need a replacement for mind-independent reality ("things like mountains and quarks" in Searle's account) as the 'ultimate' facts. The following section offers action as a suitable replacement. But, following my own critique of Searle's construction, I'll view my proposal to view actions as facts as essentially a proposal for a new kind of standing declaration, encapsulated by my account of facts.

#### 3.2.4 *fact, n.: an action, a deed... now somewhat rare*

In this final section, I seek to align my conception of facts with the word's historical roots: fact as action.<sup>26</sup> This sense of fact has been overtaken by fact as a kind of metaphysical, mind-independent state, especially since the mid 1600s. This semantic shift is core to enlightenment rationality, providing a principle whereby disagreements can be resolved through measurement, calculation, and logic.<sup>27</sup> The normative project of seeing and using facts this way, though, is both historically and logically secondary to sense of fact as something done. Uncovering this history of the word helps show why it need not be surprising that it sits underneath and animates what has become the word's more common sense.

##### *Fact as Deed*

Returning to fact as deed recalls the second sense of incorrigibility on page 2, when something is not correctable in practice. Something which is done, a deed, cannot be undone. This isn't to say deny that a

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<sup>26</sup>The heading of this section quotes part of the Oxford English Dictionary's first sense of the word. As an interesting aside, this sense includes an etymological note tracing to §903 of Francis Bacon's 1627 *Sylva Sylvarum*, admonishing readers not to "mistake the *Fact*, or *Effect*; And rashly take that for done, which is not done" (emphasis original). This usage occurs in the context of a section on the credibility of accusations and confessions of purported witches that resulted from the organized persecution of women in England at the time. Bacon's influence on what would become the scientific method is often associated with the later derived senses of *fact*, but this passage demonstrates his clear usage of the term to mean *that which is done*.

<sup>27</sup>The apogee of this sentiment is perhaps Leibniz's fantasy of a future where disagreement would be resolved by a simple "Let us calculate!"



book placed on a table can't be taken off the table; clearly, actions, properties of objects, and effects of actions are mutable by future actions. But a *deed* is an action considered as a constituent of the past. This sense of action derives from its application to irreversible actions: the burning of a house, the murder of a person, the destruction of property. The actions which produced these effects become *deeds*, which animate the early sense of the word fact. And such facts are incorrigible, not correctable, because they are done, in the past, unrecoverable.

A declaration isn't irreversible in the same chemical sense as the burning of someone's house. But it is similarly incorrigible as a constituent deed in the past. The memorialization of this constitution is the province of inscription. From cuneiform tablets to royal chronicles, inscription materializes the deed into the inscription. The line from action to deed through inscription to fact seem to uncover the latent source of incorrigibility: the inescapable finality of loss. In the face of loss, memorialization of inscription produces something solid that can be enacted into certainty, providing some measure of apparent control of the vicissitudes of the past, of the present, and of human action. This is the unconscious core of factuality, a need to reconcile the loss inherent to change and transubstantiate it into something durable. That transubstantiated artifact is the inscription, which makes the absent present.

### **3.3 Promulgation and Techniques of Forgetting**

Section 3.1 advanced a particular conception of the origin and enactment of facts, expanding on the work of John Searle. Searle's account of declaration's role in this process was supplemented by an account of the incorrigibility of declaration and the role of power, ultimately physical power, in the maintenance and expansion of context. One of the powers surrounding the creation of facts was the power to declare. In the context of information systems, this is the (physical, material) power to inscribe something in an information system prior to its (physical, material) enactment as fact. This section will analyze this process of promulgation in terms of what is thereby lost or forgotten. I'll argue, following Derrida, that the absence inherent in inscription is not a limitation upon inscription but rather the source of its power.

#### **3.3.1 Applying Searle to Inscriptions**

The work of philosophers like Searle or Wittgenstein is aimed at language as a whole. This dissertation is limited in scope to the logico-linguistic aspects of information systems and the linguistic practices

surrounding them. The narrowing of context brings its own challenges. In applying the philosophy of language to the context of information systems, I'll rely on a critique of analytic philosophy broadly by Jacques Derrida. Beginning with "Signature Event Context" and continuing in subsequent work, Derrida critiques, amongst other things, the tendency in analytic philosophy to treat spoken language as the paradigmatic case of language, and then to ignore the unique aspects of written language when applying philosophical analysis.<sup>28</sup> For Derrida, spoken language is paradigmatic for analytic philosophy of language because it appeals to a fascination with the metaphysics of presence. Inscribed language demands a metaphysics of absence, an account of what is lost in the act of inscription. Derrida then uses this account of the centrality of absence to critique Austin's (and, later, Searle's) theory of speech acts.<sup>29</sup>

### *The Semantic Indeterminacy of Inscription*

This section translates Derrida's critique into the register of analytic philosophy of language as "the semantic indeterminacy of inscription". That is, in light of Derrida's critique, inscriptions don't have inherent meaning, but rather always and only possess meaning-in-context.<sup>30</sup> This extends and supports the approach to promulgation as a component of the production of certainty in Section 2.2 (page 50).

Wittgenstein's early work on the relationship between meaning and inscription focuses on a kind of picture theory of meaning, where words' arrangement *pictures* the way things are in the world. He later shifted this approach to a discussion of *seeing-as*. This is the discussion in which he discusses Jastrow's famous duck-rabbit image, and other instances where inscriptions can be seen in different ways.<sup>31</sup> Wittgenstein argues against the idea that there is some kind of internal picture that corresponds

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<sup>28</sup>Jacques Derrida, "Signature Event Context," in *Margins of Philosophy*, ed. A. Bass (Chicago: University of Chicago Press, 1986), 307–330; Derrida, *Limited Inc.*

<sup>29</sup>While I won't engage them fully here, philosophical perspectives on this debate overall are available in Stanley Rattel, "Understanding Each Other: The Case of the Derrida-Searle Debate," *Human studies* 34, no. 3 (2011): 277–292; and Mark Alfino, "Another Look at the Derrida-Searle Debate," *Philosophy & Rhetoric* 24, no. 2 (1991): 143–152. For more on Derrida and Austin, see Stanley Cavell, *Philosophical Passages: Wittgenstein, Emerson, Austin, Derrida*, vol. 12, Bucknell Lectures in Literary Theory (Oxford UK and Cambridge US: Blackwell, 1995). For a history of the relationship between analytic and continental philosophy more generally, including the Derrida-Searle debate, see James Chase and Jack Reynolds, *Analytic Versus Continental: Arguments on the Methods and Value of Philosophy* (Montréal: McGill-Queen's University Press, 2010).

<sup>30</sup>This is consonant with a Wittgenstein's approach to language, which emphasizes that there is no meaning apart from the use of language. It also resonates with my reading of Searle, since socially constructed facts are always and only facts-in-context. For an application of this principle to the foundations of information studies, see Hauser, "Information from jussive processes."

<sup>31</sup>Wittgenstein, *Philosophical Investigations*, §IIxi.

to someone's interpretation of words. Meaning is enacted ineffably for Wittgenstein: it is shown through subsequent action. What we commonly refer to as meaning is a kind of pattern of action that is taught and learned in the process of learning to speak and interact with a community. And yet different practices can be imagined, invented, or propagated at any time. Inscriptions in this sense are deeply determinative of meaning, and yet semantically inert. The determination of meaning derives from the consistency of practices amongst a great number of language participants.

### *Inscription and Memory*

In a piece on Wittgensteinian technological investigations, Winner quotes Socrates's caution on the use of writing in scholarly discourse, worrying that it "will implant forgetfulness in their souls; they will cease to exercise memory because they rely on that which is written, calling things to remembrance no longer from within themselves, but from external marks".<sup>32</sup> Socrates's anxiety encapsulates the most salient characteristic of the use of any mnemotechnology: the forgetting it enables. The proliferation of techniques of forgetting has marched unabated through the centuries since Plato's Socratic dialogs, but its mechanism and effect remains the same.<sup>33</sup> Technologies that supplant memory to allow forgetting simultaneously constrain remembrance. This inherent property of all mnemotechnology, dubbed *jussive* by Derrida, is the subject of the next section. Many levels of jussivity active in even the simplest mnemotechnologies, starting at the level of inscription.

#### 3.3.2 Bowker, Memory Practices, and Jussive Processes

In the introduction to *Memory Practices and the Sciences*, Bowker briefly mentions the experience of the Count of Monte Cristo to describe the phenomenon he's investigating in the book.<sup>34</sup> This example serves as an excellent guide to Bowker's approach and the interest I share in the phenomenon he identifies.

In his imprisonment in Château d'If, Edmond Dantès is assigned a number. To the prison guards, this number is the only relevant component of the prisoner's identity. Gradually, under the tutelage of fellow prisoner Abbé Faria, Dantès gains an extensive education. When Faria dies, Dantès impersonates

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<sup>32</sup>Langdon Winner, "Technological Investigations: Wittgenstein's Liberating Presence," *Techné: Research in Philosophy and Technology* 22, no. 3 (November 2018): 305.

<sup>33</sup>The general atrophy of the skill of spelling in the wake of the ubiquity of spell checking utilities is an example likely familiar to any modern writer.

<sup>34</sup>Bowker, *Memory Practices in the Sciences*.

his corpse and is cast out of the prison, free to seek the treasure of Monte Cristo that Faria told him about. Dantès uses the resulting wealth to purchase the title of Count and embarks upon a campaign of revenge against his captors. The prison's collapse of Dantès into a number, removing all other formal components of his identity, becomes critical to his transformation.

Dumas' literary classic is a perhaps optimistic tale of resistance to or subversion of the jussive power of an arbitrary justice system. In any event, it helps elucidate the sense of jussive that Bowker mobilizes in his investigation. Literally meaning the power of command, jussive acts are epistemologically constructive. They contain the grounds of their own truth. Dantès is Number 34 in the prison because the prison's records designate him as such, and the guards and governor enact that designation. From within the prison's archive (its formal archive, as we shall see), everything else about Dantès is lost. Thus, inherent in jussive processes' constructive power is a power to destroy. The certainty produced by these processes is a direct consequence of the creation and destruction of information within a specific archive. As such, Bowker's theoretical description of these processes will be central to my work, and I will seek to adapt it to the investigation of the production of certainty.

### *The Archive*

Bowker's concept of The Archive is defined as "the set of all events which can be recalled across time and space."<sup>35</sup> This is derived from Derrida,<sup>36</sup> who in turn built on Michel Foucault's conception. Bowker distinguishes the expansive *trace archive* from the *formal archive*, that which is deliberately preserved. Derrida identifies two 'orders of order' in the archive: sequential and jussive. Bowker clarifies that both of these orders are visible within the formal archive, especially that represented by the computer: "The archive...is both sequential and jussive—containing both the law of what can be said and the moment from which it is first uttered."<sup>37</sup> That is, returning to Derrida's terms, the formal archive has a commencement, before which it has nothing to say, and a set of commandments about what has been, should be, and (within its purview) can be said. In contrast, the trace archive is pervasive and permissive. The two are related. Though both can be said to work with artifacts, archaeologists mine the trace archive, while historians (by and large) mine the formal archive. The two fields each have their limitations and pitfalls,

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<sup>35</sup>Geoffrey C Bowker, "The Archive," *Communication and Critical/Cultural Studies* 7, no. 2 (June 2010): 212.

<sup>36</sup>Jacques Derrida, *Archive Fever: A Freudian Impression* (University of Chicago Press, October 1998).

<sup>37</sup>Bowker, *Memory Practices in the Sciences*, 228-9.

and work best in combination. As discussed in the next section, Bowker recommends a similar combined approach, focused on how the trace and formal archive interact with each other.

#### *Jussive Processes in the Formal Archive*

My focus on the formal archive is not to the exclusion of the trace archive surrounding it. Bowker exhorts this shared focus. “Each archive needs the other. We do not need another description of formal archives. A good mission for information researchers is to explore the necessary interplay of each.”<sup>38</sup> In terms of the introductory example, I am interested in much more than Number 34 and the prison’s records. Specifically, I am interested in the jussive processes that construct Number 34 out of Edmond Dantès, thereby destroying any other trace of him from that formal archive. I’m interested in how Edmond Dantès is subsequently able to utilize jussive processes in another archive to construct himself into the Count of Monte Cristo. Dantès in this example is a component of the trace archive, while Number 34 and the Count of Monte Cristo are formal archive entries subsequent-to his traces but still distinct from them. Replace Dantès with the traces studied by the sciences and his various identities with the knowledge we seek to generate about them, and you have a neat synopsis of Bowker’s project. My approach will be to transpose this process onto information systems themselves, as used both within and outside of the sciences, to understand how the formal archive enacted by such systems is jussive. In doing so, I will aim to “explore the necessary interplay of each,” as Bowker implores.

#### *Jussivity & Pragmatism*

In light of my use Wittgenstein and other pragmatist thinkers, I’d like to note how the imperative aspect of jussivity relates to the concept of language games. Wittgenstein famously used the concept of simple language game to structure his analysis of language. In a well-known example, he describes a hypothetical language for building simple structures, consisting of two words, ‘block’ and ‘slab’.<sup>39</sup> In this game, a foreman of sorts points and says ‘block’, and a worker puts a block there. This simple language combined with faithful enactment by the workers allows simple structures to be built. Wittgenstein’s interest in this simple language is precisely how many philosophical concerns like truth, representation, realism, idealism, and so on don’t obtain. As he builds up to more complex language games, he tries to observe

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<sup>38</sup>Bowker, “The Archive,” 212.

<sup>39</sup>See Winner, “Technological Investigations: Wittgenstein’s Liberating Presence,” for another take on this example’s importance.

how and when deep philosophical problems emerge - and argue that philosophy's job is to show how such problems are misunderstandings.

Wittgenstein's simple block language game is literally jussive; it is composed of commands. Its formal archive, such as it is, are its structures, which form a record of what the foreman said and what the builder heard and did. The trace archive that surround the foreman and builder's actions encompasses these structures as well as their footprints, brush they cleared, and other material/causal manifestations of their actions (mirroring Bowker's conception of the formal archive as subset of the trace archive). It seems significant to me that Wittgenstein's example contains such a striking overlap of formal and trace archive. This is perhaps constitutive of the simplicity that he sought from this example. The challenge of describing the overlap of and boundaries between the formal and trace archives becomes exponentially more complex alongside the complexity of the language game moves that scientists, engineers, and system users make. Derrida's critique of analytic philosophy of language's obsession with the spoken may then be seen as pointing out its conflation of two archives: the fleeting trace of speech and the durable form of inscription.<sup>40</sup> Though Wittgenstein goes on to consider the peculiarities of inscription, Searle, Austin and many others do not, leaving the jussive role of the formal archive obscured.

### *Jussive Datafication*

The Archive, of course, recalls a physical location containing artifacts like books, papers, personal possessions of notable historical figures and so on. But Foucault, Derrida, and Bowker's conception of it as "the set of all events which can be recalled across time and space" renders the institution of archives as a limited subset of The Archive. The Archive explicitly contains all traces, and the purpose of this section is to connect the jussive Archive with datafication processes so that we can better understand it.

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<sup>40</sup>"The archive is the set of all events which can be recalled across time and space." Bowker, "The Archive," 212  
Speech might seem *too* fleeting to count as a component of the trace archive, but the way in which Bowker's rendition of the latter makes space for speech clarifies the term. Bowker gives the example of a well-worn path helping him find the shortest way to walk to work in a new city. The footsteps which have collectively worn this trail are like speech, archivally ephemeral except for the materially distinct traces they leave. On a dry trail, a footprint is ephemeral in a way it is not upon wet concrete or clay that will become fossil, and yet all of these are traces until reified into the forms prescribed by archival technology. That speech's traces outside of the formal archive are most often in the minds of an interlocutor does not make them any less material in character. The trace archive is the superset of the formal archive (*i.e.*, the results of mnemotechnical processes remembering) and other traces left unformed by mnemotechnology. Speech not recorded, transcribed, *etc.* and thereby outside of the formal archive, insofar as it can be remembered, has by Bowker's definition left a trace and thus is a constituent of the trace archive. Derrida is critiquing analytic philosophers' presumption that the trace archive of speech can stand in for the formal archive of language, along with a misapprehension of the jussive (transformative/destructive/creative) properties of the formal archive.

Couldry and Hepp's *The Mediated Construction of Reality* is perhaps the best starting point for this discussion.<sup>41</sup> Their starting point is Bowker's account of the jussive force of the database:

Cyberneticians...inaugurated an age in which a new kind of archive could be kept, this time a past that could be generated from first principles across a range of media. . . Pushing origins into the inaccessible past was a trick that allowed them to evacuate the more recent past of specific content, and so to operate a foundational act in the present synchronizing the human and natural worlds.<sup>42</sup>

Couldry and Hepp expand Bowker's concept into the media-saturated present. By their account, data are not formed by "some independent 'will' present in the processes from which data are gathered." Rather, "the 'knowledge' that is produced cannot be separated from the purposive selections out of which the database is formed."<sup>43</sup>

Couldry and Hepp argue against treating data as a kind of direct knowledge of what it represents: "Insofar as the outcomes are treated as *direct* knowledge about the processes re-presented by the data, they are misleading."<sup>44</sup> This seems true in one sense. The careful scientist won't confuse the measurement for the phenomenon. Couldry and Hepp don't engage directly with what I've discussed as the phenomenon of incorrigibility. Databases which store *facts* in the sense discussed in this chapter are in a sense offering *direct* knowledge of something—not of something external to their processes, which Couldry and Hepp correctly identify. But the phenomenon of incorrigibility presents another possibility, that the database be operationalized precisely to enable the sense of *direct* they proscribe. This is somewhat legible in Couldry and Hepp's discussion of datafication as inevitable categorization, but their focus lies on how the social is encoded into information infrastructures. The different but compatible sociolinguistic approach I'm taking seeks to understand how technologies serve as platforms for logico-linguistic action. The five ways of 'translating data into social practice' they identify, space, time, self, collectivities, and organizations and order,<sup>45</sup> are each facets for investigating the effects of the phenomenon of certainty, and a contact point with sociological approaches. But the jussivity that Couldry and Hepp situate at the root of datafication as a kind of mediation demands a deeper and direct study.

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<sup>41</sup>Nick Couldry and Andreas Hepp, *The Mediated Construction of Reality* (Malden, MA: Polity Press, 2017).

<sup>42</sup>Bowker, *Memory Practices in the Sciences*, 229.

<sup>43</sup>Couldry and Hepp, *The Mediated Construction of Reality*, 129.

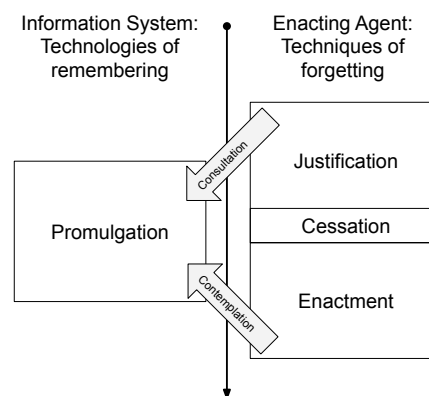
<sup>44</sup>*Ibid.*

<sup>45</sup>*Ibid.*, 134-7.

### 3.3.3 The Production of Certainty as Memory Practice

The memory practices Bowker identified marry two distinct components: technologies of remembering (*i.e.*, the formal Archive) and techniques of forgetting. The materiality of Bowker's archive is an inspiration for my approach to promulgation, as is his focus on its jussivity. The socially enacted techniques of forgetting are equally important to memory practices and how they construct our knowledge of the present. The different historical sciences Bowker studies, 19<sup>th</sup> century geology, 20<sup>th</sup> century cybernetics, and 21<sup>st</sup> century biodiversity, each construct distinct ways of encoding knowledge into their respective archives, so that it can be forgotten and moved on from.

Though certainty is also produced outside of what Bowker identifies as memory practices, the latter intimately involves the production of certainty as defined here. Figure 3.1 shows this relationship. The promulgations consulted by an enacting agent are preserved and materially manifest within technologies of remembering. The enactment of certainty constitutes a technique of forgetting, inherent in the cessation of justification, and the jussivity of contemplation. What is not shown in this schematic is that the promulgating agent engages in a reciprocal technique of forgetting in crafting the inscription within the system as medium of remembrance. Chapter 4 will provide more nuanced tools for describing this relationship, and the analysis of Part II will show these reciprocal chains in action within computational timekeeping.



**Figure 3.1:** The production of certainty arrayed in terms of Bowker's conception of memory practices. Promulgation, consultation, and contemplation are each jussive processes. The act of promulgation also encodes a technique of forgetting, not shown here but discussed in Chapter 4 and in the analysis of computational timekeeping in Part II.



### 3.4 Promulgation and Algorithms

Aside from a discussion of computational incorrigibility (see page 137), algorithmic examples are elsewhere in this dissertation considered only as subsets of information systems or as agents in the production of certainty. I do, however, want to emphasize here that the identification of promulgation can be effectively applied to them. The focus on the inscription is a helpful corrective to the often abstract presentation of what algorithms consist in as an object of study. Algorithms in the abstract can at most be inscriptive agents in relation to their promulgations, and algorithmic promulgation is no more a property of an abstract algorithmic description than No Fly list is a property of its promulgating agents. Algorithms must be coupled with a particular inscriptive medium to produce inscriptions, and the analysis of algorithmic promulgation must be coupled to this fully specified context.

#### 3.4.1 Models and Ignorance

Smith's discussion of the limitations of formal models is immediately reminiscent (and foreshadowing, given that he's writing in the mid 80s) of Couldry and Hepp's application of Bowker's conception of jussive archives to data. For Smith, models are defined by precisely their ability to leave things out:

Models have to ignore things exactly because they view the world at a level of abstraction ('abstraction' is from the Latin *abstrahere*, 'to pull or draw away'). And it is good that they do: otherwise they would drown in the infinite richness of the embedding world. Though this isn't the place for metaphysics, it would not be too much to say that every act of conceptualization, analysis, categorization, does a certain amount of violence to its subject matter, in order to get at the underlying regularities that group things together. If you don't commit that act of violence – don't ignore some of what's going on – you would become so hypersensitive and so overcome with complexity that you would be unable to act.<sup>46</sup>

Smith renders as necessary violence what Bowker might call the jussive nature of models. For Smith, models, seen as components of the formal archive, are what enables us to act within the infinite richness of the world. Yet models necessarily obscure this infinite richness. Smith's word for this property is *partial*, a word which is usefully polysemous. Models are at once opinionated and only pieces of the things they model, though I believe Smith places more emphasis on the former sense in choosing this term.

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<sup>46</sup>Smith, *Limits of Correctness in Computers*, 8.

### 3.4.2 Body Mass Index

A simple algorithm like Body Mass Index (BMI, calculated as  $\frac{\text{weight}}{\text{height}^2}$ ) must be operationalized to produce some inscriptive output for promulgation to have occurred. Thus, repeated executions of the same computer program implementing this algorithm can be said to be distinct instances of promulgation by the same agent. A different computer program executing the algorithm can be seen as a distinct inscriptive agent, even if the promulgations are the same. Similarly, even if the director and assistant director of a play produce the identical inscriptions, the promulgations are distinct in a different respect (namely, the inscriptive agent) than if either were to produce identical lists themselves. These distinctions may or may not matter in a specific case, and the indistinguishability of promulgations' histories to an enacting agent make their histories moot within that context. With simple algorithms like BMI a history of a specific promulgation will likely be uninformative; who cares which program or device performed the calculation  $\frac{\text{weight}}{\text{height}^2}$ ? But, especially for algorithms with random or stochastic elements (*e.g.*, Monte Carlo simulations), different instances of promulgation may vary noticeably even when all other aspects are held constant. In some instances, platform architecture or other implementation details (such as, for instance, a hardware implementation of entropy measurement to produce random values) may alter the output to the extent that viewing the identical programs run on separate hardware as distinct inscriptive agents becomes critical to complete analysis.

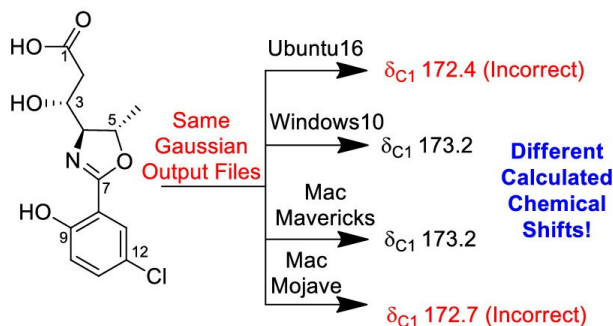
A recent publication underscores this: the authors found that a work published in 2014 in *Nature Protocols* gave different results on different operating systems.<sup>47</sup> A schematic representation of these differences is given in Figure 3.2 on the next page. The differences in this case were not related to non-deterministic sampling or bootstrapping processes but rather had to do with how a list of files for analysis was prepared.<sup>48</sup> That a script for scientific analysis would return different results on different

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<sup>47</sup>Neupane et al., "Characterization of Leptazolines A-D, Polar Oxazolines from the Cyanobacterium *Leptolyngbya* sp., Reveals a Glitch with the "Willoughby-Hoye" Scripts for Calculating NMR Chemical Shifts." The article reports reviews code published in Willoughby, Jansma, and Hoye, "A guide to small-molecule structure assignment through computation of (<sup>1</sup>H and <sup>13</sup>C) NMR chemical shifts."

<sup>48</sup>In short, the code assumed that Python's `glob` function returned a sorted list of filenames, which is only true on certain operating systems. As a rule, Python exposes operating system differences to its programs (as noted in the documentation to `glob`), in contrast to a language like Java, which abstracts from these differences. The code fix by Neupane *et al.* was to simply call Python's `.sort()` list method upon the list built with `glob`. The balance of their paper explores the far-reaching potential implications of the potential variability of published results depending on operating system used. See Neupane et al., "Characterization of Leptazolines A-D, Polar

operating systems, especially when this fact is unknown, is a problem precisely because it demands each process's output to be treated as a distinct promulgation. The best practices of scientific reproducibility exist to allow distinct promulgations to be treated as identical.



**Figure 3.2:** Schematic of operating system-specific differences in Willoughby-Hoye Python scripts, originally published in Willoughby, Jansma, and Hoye, “A guide to small-molecule structure assignment through computation of ( $^1\text{H}$  and  $^{13}\text{C}$ ) NMR chemical shifts.” (Figure from abstract of Neupane et al., “Characterization of Leptazolines A-D, Polar Oxazolines from the Cyanobacterium *Leptolyngbya* sp., Reveals a Glitch with the “Willoughby-Hoye” Scripts for Calculating NMR Chemical Shifts”).

### 3.4.3 Algorithms: Technologies of Remembering Alongside Techniques of Forgetting

In Bowker’s terms, the algorithm represents the paragon of the cybernetic ideal: a way to forget everything specific in favor of a method of calculation. In possession of an algorithm, which ‘remembers’ by proleptically declaring input for output, one can forget everything in deference to the algorithm’s output. The forgetting I’m talking about is pervasive within diverse algorithmic techniques. It is the *latent* in latent semantic indexing, or the semantic meaninglessness of the hidden layers in neural networks. These technologies of ‘remembering’ are powerful, but jussive. When we delegate remembrance to them, we institutionalize a specific kind of forgetting within the way we remember. The power of algorithms comes in their ability to combine their technological power with *specific* techniques. Whereas with paper-based technologies of remembering, techniques of forgetting were largely determined by and preserved by social practices surrounding the technology (such as verification, peer review, citation, *etc.*), algorithms can foreclose upon these techniques and enforce a striking uniformity of practices around them.

Algorithms are encountered in this dissertation only as subsets of information systems and, at times, as agents (especially in Part II). Though they won’t receive more detailed direct treatment in

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Oxazolines from the Cyanobacterium *Leptolyngbya* sp., Reveals a Glitch with the “Willoughby-Hoye” Scripts for Calculating NMR Chemical Shifts” for full details.

this dissertation, I anticipate covering this in much more detail in future work. I mention them both to demonstrate the eventual scope of the project I envision and in the hope that these extremely precise examples of distinguishing inscriptive instances and agents will make the bulk of the examples we consider in detail more clear.

### **3.5 The Analysis of Certainty**

Chapter 2 provided some foundational terms with which to describe the production of certainty. This chapter used promulgation, the cessation of justification, and enactment as three sites of engagement with existing literature. Throughout, language as operationalized within information systems has been viewed as a sociolinguistic phenomenon: social, in that collective practices surround the activities of promulgation, justification, and enactment; and linguistic in that language forms a core mnemotechnology that enables the production of certainty. Searle identified the “logico-linguistic operation” of so-called institutional facts in producing social reality, which in this chapter was expanded to describe the operation of all facts as such. Anscombe provided an account of how facts can relate to each other to produce certainty, which we called *root facts*. Finally, Bowker’s conception of memory practices, with its foregrounding of the techniques and consequences of forgetting upon technologies of remembering, provided a description of the resulting jussive nature of the production of social reality from information systems.

We are now ready to return to the phenomenon of the production of certainty in information systems first encountered in Chapter 1 with new conceptual and analytical tools. The classifications of the production of certainty advanced in the next chapter will hew closely to the divisions between incorrigibility, empiricisms, and defeasibility noted in Chapter 1, but with a higher degree of resolution and more concrete guidelines for meaningful use in the real-world cases we’ll turn to in Part II.

## CHAPTER 4: A TAXONOMY OF THE PRODUCTION OF CERTAINTY

This chapter develops a taxonomy to enable analysis of the production of certainty in actual information systems. The basic classes of the taxonomy are laid out in Section 4.1. They closely mirror the three kinds of logic first discussed in Chapter 1. These classes denote the *role* a system may play in a given instance of certainty production, and are not a property of a system. For simplicity, however, Section 4.1 introduces the classes in the simplest cases, where the role is assumed to follow from the system's design. These simple cases are presented as *felicitous*, a concept that alludes to Austin's idea of successful speech acts.

The concepts developed in Chapter 2, particularly promulgation, justification, and enactment, each represent a potential source of attributes by which to add nuance to the application of the taxonomy's classes to specific situations. By distinguishing how a system is *given* and *taken*, the taxonomy can comprehend cases of *infelicity*, when a system is taken in a way that differs from how it is given. This enables a more nuanced application of the taxonomy to real-world cases, and acknowledges the crucial role of enactment, *i.e.*, how a system is taken, in determining the nature of the certainty produced in light of it.

Section 4.3 discusses the application of the taxonomy in depth. It distinguishes concerns of chronology, or the order of actions in the process of producing certainty, and methodology, or at what point a researcher might begin to study this process. Next, it takes up questions of exactly to what the taxonomy may be applied—systems, subsystems, or individual entries within a system—and how each of these impacts the kind of insights to be gained. Finally, it describes how the taxonomy can be applied recursively to chains or assemblages of systems. As part of this discussion, I present an argument that the recursive application of the taxonomy may in practice be stopped anywhere. Due to the jussive nature of the production of certainty as a process, the researcher is justified in scoping her analysis to any set of enacting agent stopping points, depending upon the scope of the certainty of interest.

The chapter finishes with a discussion of the possibilities opened up by this method of analysis, setting up the application of the taxonomy to specific systems in Part II.

#### **4.1 Classifying the Production of Certainty: Rosters, Inventories, and Ledgers**

Taxonomies are classifications based upon attributes, and I've said that practices of promulgation, kinds of justification, and practices of enactment are not properties of systems. So how can the taxonomy be one of systems? It isn't: rather, it's a taxonomy of the *production* of certainty, from systems. What is being classified is the role the system plays in the production of certainty, as enacted by an enacting agent. As I argued in Section 2.4, enactment is the site and moment where systems condition actions. The taxonomy describes how information systems shape social reality in terms of the actors and actions they condition.

The three major role types I will present adhere closely to the three kinds of certainty identified early on, in Section 1.2 (page 23). The production of certainty is a relation between an enacting agent and an information system. The three kinds of certainty, incorrigible, empirical, and defeasible, can characterize this relation. The class names which correspond to these types of certainty are Roster, Inventory, and Ledger, respectively. It has seemed useful to draw their class names by analogy to typical information systems used to produce certainty of a particular kind, but it should be apparent that an enactment can produce certainty of any of these kinds from the same information system. Thus, to the extent that these class names refer to *systems*, they do so in relation to an enacting agent, within the context of the production of certainty. For the balance of Section 4.1 I will capitalize the names of the classes to distinguish them from the literal system types due to the need to discuss them simultaneously. Elsewhere in the dissertation the meanings of the terms should be understandable by the surrounding context.

Though they are designed for nuanced use, the classes may also collapse into simple system descriptions, such as "the No Fly list is a Roster." A caveat for such uses is that such a designation is contextual, a description of a role in relation to enactment. It will be most appropriate to describe systems by these class names where enactment is consistent with how the system was given. In cases where enactment is automated, felicity may be guaranteed. Bureaucracy's major function is to ensure that human enacting agents reliably enact a particular kind of certainty. In smaller contexts or in cases of aberrant behavior, or breakdown, more precise uses of the classes are required to distinguish giving and

taking. I will discuss faithful enactment and breakdown in terms of felicity and infelicity below. First, however, I'll introduce the classes with a simplifying presumption of felicity.

#### 4.1.1 Rosters: Declarations and Incorrigible Facts

Just as incorrigibility is the default of certainty (see Section 3.2.1), Rosters are the default way information systems are used in the production of certainty. When an enacting agent moves on in light of a system, that system is performing the role of Roster unless and until some process of reconciliation is subsequently undertaken by the agent. In other words, the contemplated information produces certainty until or unless the enacting agent consults another source, within a system or in the world. So when applying the taxonomy to an instance of the production of certainty, the system can be seen as playing the role of Roster until or unless other sources of information (or other features of the world) are consulted and contemplated.

The running example of the No Fly list exemplifies this dynamic. The system is created as a medium of declaration, and utilized as a source of declarations by the agents who enact it. The system is both a literal roster, a list of names denoting membership, and an instance of Roster class of the taxonomy of certainty. In the narrow context of a TSA agent or airline employee interacting with a traveler, there is no sanctioned process for consulting or contemplating other information systems when determining if a passenger is on the No Fly list.

#### *Compound Rosters and Conditioned Enactment*

What about the Redress Control Number program? This is a number provided by the TSA to passengers who have filed redress claims for repeatedly being flagged for additional screening or denied boarding.<sup>1</sup> This is an adjunct declarative medium for the TSA to produce yet another Roster, which is intended to govern enactment of the No Fly list. Note that the Redress Control Number doesn't modify the No Fly list itself, and a traveller's name may be listed there. The appellate procedure of the Traveler Redress Program produces an additional Roster, that the traveller references by providing their Redress Control Number, that changes how the match between their information and the No Fly list is enacted by human and automated systems.

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<sup>1</sup>"Redress Control Numbers," Department of Homeland Security, accessed October 9th, 2019, <https://www.dhs.gov/redress-control-numbers>.

This compound Roster example may seem similar to the Ledger class, discussed below. The difference is that in both the No Fly list and Redress Control Number cases, the promulgation constitutes an inscription to be enacted as a fact. A traveller who would otherwise be denied boarding may be allowed to board when providing a valid Redress Control Number. This is not because these constitute *claims*, enacted defeasibly as if they were taken-as Ledgers. Rather, when taken felicitously, each Roster is consulted and a determinate course of action, a determinate pattern of enactment, is followed by human and automated enacting agents.

### *Rosters Contain Facts*

Rosters contain inscriptions to be used as facts. Following the logical form of propositional logic, facts are designed to be reconciled with, and are used to adjudicate the truth of propositions which bear upon them. Section 3.2 emphasized a view of fact as deed, and in this light Rosters contain declarative actions which play the role of root fact when enacted as such. Like the declarations they contain, Rosters are logically incorrigible: alterations to them constitute new declarations. The logical form of facts demands this: if Rosters could be reconciled with something else, they would be playing a different role in the production of certainty.

#### 4.1.2 Inventories: Measurements and Propositions

This class contains the familiar information system as a mirror of nature. Inventories contain measurements of quantities or amounts which stand in for direct experience of some state of the world. Specific reconciliation actions are taken to update Inventories with respect to the world-state they represents. This reconciliation, combined with the nature of the measurements, forms the essence of the class's practical utility.

The paradigmatic example used throughout the discussion has been the warehouse inventory of a retailer. The literal inventory, usually a database but possibly some other system type, such as a book, tracks discrete quantities of specific items. In modern inventory systems, these systems make use of some form of unique identifier, such as a SKU, to enable unambiguous identification of product type.<sup>2</sup> A

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<sup>2</sup>Any method of distinguishing items to be counted is possible, but a using a system taken-as Roster as a provider of identity for the items measured in an Inventory is a common pattern. In these cases, the identity of items is taken as fact. Inventories which must enumerate things not identified ahead of time will instead treat the identity as a measurement, or even a claim. Each of these cases articulates how individual attributes of an information



combination of techniques is utilized to reconcile the inventory to the state of the warehouse. Workers may carry connected hand-held devices, which can scan SKUs, and then perform a manual count of the number of items carrying that SKU. More parts of this process are becoming automated: techniques of computer vision may replace the manual process of counting and entering a quantity, for instance. Relevant metadata, such as shelf location, may be collected as well.

The outcome of the relatively laborious process of reconciliation is that a worker or automated agent can consult the inventory to determine whether a product is in stock and, if it is, go to a specific location in the warehouse and retrieve it. The empirical certainty discussed in Section 1.2.2 thus consists in the correspondence between the system and the states of the warehouse relevant to this business process.

### *Satisficing*

It is in the context of inventory systems that Simon's concept of satisficing most directly applies. For a given purpose and a given set of resources and constraints there is a practical and tactical limit to how much reconciliation effort is 'worth it.' A warehouse or a grocery store's inventory system might say there are 10 boxes on the shelf when there are only 9 for a period of a few days, until the next reconciliation process occurs. In other cases, such as, for instance, the storage of nuclear waste, constant measurement may be justified. In cases of constant measurement, calibration and redundancy in the measuring devices and processes becomes the next frontier of satisficing determination.

### *Measurements as Propositions*

Though the example above deals with discrete quantities, inventories may also contain the results of other measurement types. Inventories which track commodities might instead track continuous amounts of, for instance, soybeans, represented as a unit of volume or weight. In some cases, inventories might track a binary representation of some state: for instance, whether a rental car has had its oil changed in the past 3,000 miles or not. The sophistication of the data representing the measurement and the measurement process of reconciling the data may both be modulated to achieve an appropriate balance of accuracy and effort expended.

An important similarity between both discrete and continuous measurement is that they share a propositional form. In other words, they utilize the logical form of propositions and are made true or

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system may construct certainty in ways distinct from the system they are a part of. These and related issues are discussed further in Section 4.3.2.

false by a fact in the world. This reveals the broader form of Inventory contents: they are reconcilable to some fact. Measurements and enumerations treat the physical properties or arrangement of the world as facts to be reconciled with. Inventories might also reconcile themselves to facts contained in Rosters. The academic *Curriculum Vitae* is an example of this, tracking the declarations of universities, journals, conferences, funding agencies, and other institutions that make notable academic declarations. The C.V.'s entries are propositions, such as "I was awarded a B.A. degree" made true by the socially constructed fact located in some university's Roster of graduates.

#### 4.1.3 Ledgers: Records of Defeasible Claims

This class of system contains defeasible claims. By decentering declaration through attribution, ledgers avoid the monolithic incorrigibility of Rosters. They have interesting properties, and systems designed to play this role have been developed independently in many fields. Ledgers are not designed to be a source of declarations, like Rosters, or a source of propositions tracking some state of the world, like inventories. By instead tracking what distinct agents claim about something, systems which play the Ledger role function not as sources of facts (as do Rosters) or truths (as do Inventories), but rather as records of discourse.

Ledgers are the most complicated role for a system to play, and as such there hasn't been a single paradigmatic example running through the dissertation. The constellation of examples below may help explicate the concept. In general, the complexity of ledgers invites the more nuanced application of the taxonomy discussed in Section 4.3

- A record of economists' predictions of economic indicators such as GDP growth may be structured as a ledger. Such a system doesn't *itself* attempt to predict the underlying statistical estimate, but rather tracks and attributes the predictions of others.<sup>3</sup> Similarly, a compilation of analyst buy/sell recommendations for a stock represents not a discrete recommendation but rather a record of claims about the potential profitability of specific trades.
- Scientific comprehensive reviews which array claims by distinct researchers compile these claims into a ledger. This might involve things like the clinical efficacy of a certain treatment or the precise numerical value of a physical property.<sup>4</sup>

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<sup>3</sup>The application of averaging or other subsequent calculations on these predictions constitutes yet another system, which would require a separate class determination for a particular cases. We'll discuss issues like these in Section 4.3.

<sup>4</sup>Such reviews commonly include overall claims made by the review author in light of the constructed ledger, which should be construed as separate from the ledger-role performed by the compiled data.

- The familiar peer review process is typically structured as a ledger of reviews from distinct reviewers. The system playing the ledger-role doesn't itself contain the declaration of whether a paper should be accepted, but rather arrays the determinations of the reviewers.<sup>5</sup>

Ledgers' complexity makes them the most suitable for use in academic inquiry, especially in collaborative systems. Whereas a single researcher's research database serves as her repository for measurements and/or declarations within the scope of her research, a collaborative system that is not structured as a ledger quickly reveals a univocality inappropriate to collaborative work, where the 'correct' answer to a given question may be the subject of independent research. In other words, the defeasible logic that is key to open inquiry must be facilitated by the system changing its role from source of facts or truth to a mere record of discourse.

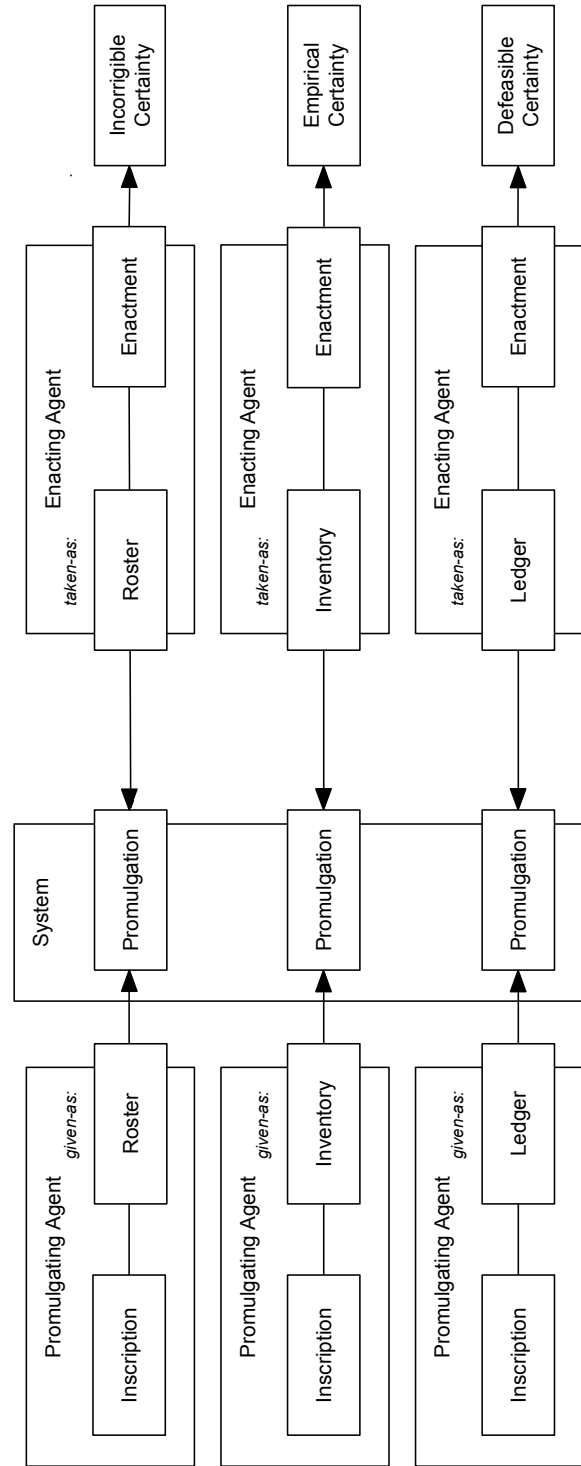
#### 4.1.4 Felicity

The basic classes of the taxonomy presented above all utilize *felicitous* examples. Felicity denotes cases where there is alignment between the way in which a system was promulgated, and how it is enacted. Figure 4.1 on the next page represents this schematically. Felicity is the simplest case of the production of certainty, and allows the use of just the three classes in an analysis. Alignment can take many forms, but has been present in most of the simple examples we've seen: the warehouse inventory, designed as a measurement and enacted as such by the worker reconciling it with the state of the warehouse shelves; the No Fly list, designed as a medium of declaration and enacted as such by the agent who permits or denies according to the contents of the list.

We can imagine, though, a case where enactment breaks down. A TSA agent who says "it says here you're on the No Fly list" but considers other evidence has not ended her justification of my flight status upon the system. Instead, she's taking the list as a ledger of what has been said about the traveler by a certain government agency. She's certain about what was said (the certainty she produces with the information system is limited to its content) and yet continues to deliberate about what to do. Certainty was produced by the system, but the character of its enactment was not what the system's designers had

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<sup>5</sup>Many such review systems used in, for instance, conference proceedings, contain numerical components that are deterministically used to accept or reject papers based on numerical ratings. This should be seen as a form of prescribed or even automated enactment, not as essential to the review collection function of the system. The possibility of meta-reviews or the process more common in journals where the associate editor makes the final determination can help distinguish subsequent enactment from the ledger role. Once again, the more nuanced techniques of Section 4.3 are called for.



**Figure 4.1:** Felicitation of certainty. The way a promulgation within a system is given by the promulgating agent mirrors the way it is taken by the enacting agent.)

intended. This is infelicitous, a breakdown. To analyze such cases, we must distinguish how a system is given from how it is taken.

## 4.2 Giving-as and Taking-as

The promulgating agent and any given enacting agent can differ in the way in which they utilize the system. To account for this real-world complexity, I've added the dimensions of giving-as and taking-as to its application. Giving-as indicates the (inferred) way that a promulgating agent intends a promulgation to be enacted. Taking as indicates the way an enacting agent enacts a promulgation. The subsequent section will discuss each in turn and explain how they should be applied.

Three felicitous cases were considered above, each given-as and taken-as the same class of system. Six classes remain to be described, and all nine will be discussed together. The properties of the resultant matrix of classes provide a nuanced tool for the analysis of the production of certainty in information systems.

### 4.2.1 Infelicity: When Giving and Taking Differ

Felicity can be disrupted at any time by a difference in enactment. Though the most charismatic cases of infelicity are arrogations of authority, such as when a security agent allows an improperly credentialed visitor to enter a building, infelicity can also involve an expansion of the authority of the system. Commercially produced ratings such as credit scores, standardized test scores, and corporate credit ratings are often couched in language from the companies that produce them that they should be taken alongside other sources of information.<sup>6</sup> But lending standards, admissions policies, and financial agreements can enact these ratings as incorrigible declarations instead of the claims they were ostensibly given as.<sup>7</sup> Doing so May ultimately abrogate the power of the nominal enacting agent (the lending agent,

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<sup>6</sup>For instance, the language used to market credit information to businesses emphasizes the 'insights' to 'drive effective decisions' rather than positioning them as a measurement of anything: "Consumer Reports from Equifax are designed to support fast, well-informed decisions. The reports deliver a unified view of the most relevant and current consumer information in an easy-to-interpret, intelligent format. Trust our consumer reports to provide proven consumer insights to drive effective decisions that increase profitability and reduce risk." "Credit Information Business," Equifax, accessed October 9<sup>th</sup>, 2019 <https://www.equifax.com/business/credit-information/>

the admissions officer, the accountant) and replace it with the contents of a promulgation. Different enactments of the same system can thus enhance or diminish the impact of any individual promulgation upon social reality, and can thus extend or mitigate the power of the promulgating agent's actions. This is a more general case of the issues of fairness and bias in the ethics of AI, and it demonstrates that these issues have roots that extend beyond specific technological advances.

#### 4.2.2 Giving-As: Inscription as Declaration

When a system is established as a medium of promulgation, it is constituted by a standing declaration of what role it is intended to play in the production of certainty. The No Fly list is constituted as a medium for the promulgation of the names of people who shall be denied boarding passes. A warehouse inventory system is constituted as a medium for the promulgation of counts of products on shelves. This standing declaration is a giving-as that specifies how all promulgations within the system should be taken. When promulgation and enactment are faithful with respect to the way in which a system is given, the certainty specified by the system's promulgating agent is produced.

##### *Co-opting Systems*

Leaving aside for the moment a disconnect between giving-as and taking-as, there is the possibility that a declared medium for promulgation can be co-opted for another purpose. A promulgating agent can use the system as a medium for other purposes. For instance, a promulgating agent may maliciously include an enemy's name in the No Fly list so that that person will be unable to purchase airplane tickets. This declaration is formally valid when dutifully promulgated and distributed to users of the No Fly list, but subverts the power of those who instituted the system as a roster of No Fly list members. The system is given-as a declaration of the appropriate government agency, but in this case a rogue promulgation has co-opted this context to alter that declaration. This is the arrogation of promulgative agency discussed in Section 2.2.2.

##### *Co-opting Promulgating Agents*

Promulgating agents may also be co-opted by a system's promulgators. A promulgating agent may think that they are giving a promulgation as a simple measurement, but that promulgation is subsequently given

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<sup>7</sup>Ostensibly, because the companies which produce these ratings know that they are often taken as declarations, and benefit from this process.

as a declaration. Imagine a situation where membership in No Fly list was based on a measurement such as a person's height. A system which asked a promulgating agent how tall someone was would then implicitly be asking whether they should be included in the No Fly list, though the promulgating agent would likely believe that they were providing a measurement. The context surrounding the system being given-as a roster coerces this apparently empirical data into incorrigible certainty about membership in a group.<sup>8</sup>

#### *Given-as and Data*

Data is, literally, the given. The taking inherent in *using* data is hidden within the word's modern usage. In mathematics the declaration *Let* is an example of the declarative action which creates the given through taking. *Let* in this case is jussive in both the linguistic and Derrida/Bowker's derived senses. It commands, constrains, and creates in one complex act.

Felicitous cases where giving and taking are aligned are aligned in their jussivity. The *Let* of promulgation, reducing something to an inscription, is matched with a suitable *Let* of enactment, extending an inscription into some act. The reciprocity of these jussivities is socially determined, via the negotiation and determination of root facts. But when they are accepted (moved on from) as reciprocal, data, the given, is stipulated to be identical to *capta*, the taken.<sup>9</sup> The memory practices of the sciences (amongst other fields) are designed to enable this reciprocity. An observation made plain by my analysis is that the reciprocity described here is far from a default. Extraordinary effort and complex negotiations, ultimately supported by the specific rules of justification, are required. As the next section will show, a change in enactment practice at any point can immediately break this rather fragile chain.<sup>10</sup>

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<sup>8</sup>Note that this coerced giving-as is subtly distinct from taking-as, which refers to enactment. Cf Drucker's concept of enunciation in interfaces, for instance within the spreadsheet Johanna Drucker, "Information visualization and/as enunciation," *Journal of Documentation* 73, no. 5 (2017): 7-8.

<sup>9</sup>Johanna Drucker, "Humanities Approaches to Graphical Display," *Digital Humanities Quarterly* 5, no. 1 (2011). More on *capta* in Section 4.2.3 on the following page.

<sup>10</sup>Cf. *chains of reference* in Latour, *An Inquiry Into Modes of Existence*, 69-96. I'm not here arguing for a kind of skepticism of science but rather an appreciation of its improbably insecure foundations. Rather like cosmological graphics that situate the Earth within its galactic neighborhood, the net effect of this is to make us aware of how exceptional the present circumstances are, and that there is much to be learned outside of them.

#### 4.2.3 Taking-As: Enactment is Radically Underdetermined

Enactment is radically underdetermined by what has been promulgated. That is, although there are powerful patterns and norms at work (*i.e.*, no one is proclaimed mayor while presenting documents to obtain a marriage licence, or granted an honorary doctorate when registering for a conference), there is nothing *inherent to promulgated inscription* which determines these actions from the outset. Therefore, understanding the moment of taking-as is crucial to characterizing enactment and ultimately discerning the consequences of promulgation. The patterns and norms just alluded to are thus located in the taking-as, which is a relation between promulgation and enacting agent, not a property of either. For the purposes of the taxonomy, we must answer these questions for each enactment:

- What promulgation did justification consult and end upon?
- What of the promulgation is contemplated by the enactment?
- How was the promulgation taken?

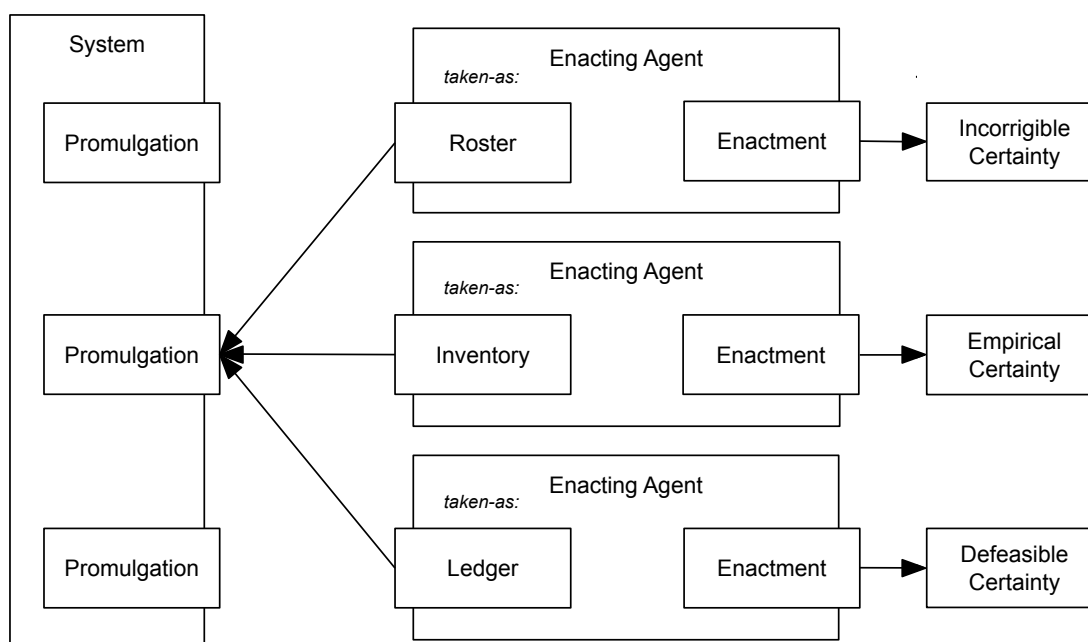
For the purposes of characterizing enactment, we don't need to know the natural history of the promulgation, its relationship to the promulgating agent, or the force with which it was given.<sup>11</sup> Figure 4.2 on the next page represents this schematically: the same promulgation, regardless of its history, can produce any of the three kinds of certainty, depending on how it is taken and enacted by the enacting agent.

This isn't to say that aspects of promulgation or the circumstances surrounding them are immaterial. Rather, the materiality of a promulgation can and does situate it within the broader world. The shift from paper to electronic records, a shift in materiality, has had drastic consequences for the production of certainty from information systems. My emphasis here is not to deny these effects but show that they will inevitably be visible within the subsequent enactment to the degree that they matter for the analysis of certainty production. Digital materials served via the Internet, for instance, can be consulted by a much wider range of potential enacting agents, which makes their promulgations comparatively more impactful than those that limit consultation to physical access to a paper artifact. Nevertheless, the relevant effects of the materiality of promulgations and their media to the analysis of the production of certainty in information systems can be discerned by observing enactment.

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<sup>11</sup>Though, admittedly, accounts of each of these will likely be of ethical, political, or perhaps historical interest. For the analysis of certainty, their effect on enactment will be observable in how the enacting agent *takes* the promulgation.





**Figure 4.2:** Diagram showing how enactment conditions certainty, regardless of how a promulgation was given, and even in ignorance of a promulgation’s inscriptive history.

### *Capta, Enunciation, and Taking-as*

A contrast with a method that could be seen to emphasize the role of promulgation over enactment may be clarifying here. For this, I’ll turn briefly to the work of Johanna Drucker on the concept of *capta*.

Johanna Drucker’s proposes *capta* as a candidate for replacing what is commonly described as data in the Humanities.<sup>12</sup> Her notion of the concept is related to her exhortation to examine the enunciative qualities of information systems, visualizations, and interfaces. Drucker isn’t short of allies for the project. Ron Day writes, “There isn’t any separate Platonic realm of ‘ideas’ apart from their enunciation.”<sup>13</sup> Gitelman, writing on the 19<sup>th</sup> and early 20<sup>th</sup> century proliferation of paper forms used in business and

<sup>12</sup>Drucker, “Humanities Approaches to Graphical Display.” Drucker doesn’t engage with Laing’s earlier use of the term *capta* in the context of a discussion of the limitations of science upon experience. See R D Laing, *The Politics of Experience* (New York: Ballantine Books, 1967), 61-62. To be sure, Laing’s use of it was somewhat offhand and is certainly obscure. I found it cited in Spencer-Brown, *The Laws of Form*, xviii.

<sup>13</sup>Ron Day, *Indexing it All: The Subject in the Age of Documentation, Information, and Data* (Cambridge, MA: MIT Press, 2014), 6.

administrative contexts, speaks of an “implied self-evidence that is intrinsically rhetorical.”<sup>14</sup> All of these approaches seem to be broadly consonant with the jussivity emphasized by Bowker, Couldry, and Hepp. What is rhetorical enunciation in the context of data if not a form of constraining, coercive, creative command? This section clarifies the relationship between Drucker’s sense of capta and taking-as in an attempt to answer these questions.

### *Inscription and Ideology*

When Drucker writes, “All formal expressions of information are ideological,”<sup>15</sup> I want to parse the relationship between information and ideology here. Is information a thing? Is this ideology a property? A relation? If the latter, between what? It would seem at first that Drucker’s sense of enunciation is at odds with the semantic indeterminacy of information I argued for in Section 3.3.1 (page 90).

The ‘enunciation of subject position’ that Drucker is concerned with must be seen as a relation between an inscription and an interpretive agent. *There is no enunciative agent to be found in this relation.* Enunciation might easily be conflated with what I’ve approached as inscription. It’s natural for us to think of enunciation in Drucker’s sense as the moment of inscriptive expression by an expressive agent, as we do when we use the term colloquially to indicate a moment of precise speech. But this is not Drucker’s enunciation. If there is an enunciative agent present in the relation between inscription and subject, it is the nascent subject itself.<sup>16</sup> Thus, returning to Drucker’s assertion that expressions of information are ideological, we must take care to situate that ideology within the subject-inscription relation.

In purging the inscription of inherent ideology, as I believe Derrida’s analysis demands, we have to shift the locus of the (very real) ideological impacts of inscription to their relation to what I’d call an enacting agent. This in no way is intended as a denial of the power of inscriptions to do so in subtle, sometimes practically irresistible ways. This power is the basis of many a critique of information systems, and it is real. But inscriptions radically under-determine their enunciations, which are only realized as relations to an interpreting agent. Patterns of enactment (or, in a register closer to the one Drucker is using, interpretation) have real political and ethical consequences. But the inscriptions themselves are inert, and so we must look to relations to understand enunciation, capta, and what I’m calling taking-as. Patterns

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<sup>14</sup>Gitelman, *Paper Knowledge: Toward a Media History of Documents*, 2.

<sup>15</sup>Drucker, “Information visualization and/as enunciation,” 908.

<sup>16</sup>This suggests a kind of autopoiesis is active in the creation of a subject, something that I won’t pursue here.

of enactment can be so reliable or commonplace that this inertness acquires inertia, with the illusion of semantic or ideological force. But inscriptions are not semantically or ideologically automotiv<sup>17</sup>.

*Taking and Intent.* A final point worth clarifying is that I believe Drucker’s sense of enunciation properly accounts for the fact that the way in which an agent *takes*, in my terms, is not entirely under their control. *Taking-as* is not a wholly intentional act, in that an agent is not always fully in control of (or perhaps even aware of) *how* they’re taking something. I’d like to take Drucker’s work on enunciation, then, as an exhortation to understand the unconscious and non-deliberate influences that context, conditioning, and culture have on taking-as. One of the chief aims of approaching the phenomenon in the way I am is to enable more deliberation to enter into these processes, which is in turn a prerequisite for ethical and political response to the power dynamics embedded around information systems and their enactment.

#### 4.2.4 Rosters, Inventories, Ledgers, Giving, and Taking

A system is promulgated, which allows a promulgating agent to effect promulgations within said system. The conditions surrounding the promulgation determine how it is *given* and, consequently, how it must be *taken* if it is to be enacted felicitously. In the subsequent production of certainty, an enacting agent *consults* a promulgation within the system, takes it as one of the three classes, and moves on in contemplation of said promulgation, producing certainty. Figure 4.1 (page 108) gave an overview of felicitous certainty, while Figure 4.2 (page 113) showed how enactment could produce any of the three kinds of certainty with out regard for, or knowledge of, how the promulgation was given.

#### 4.2.5 Permutations of Certainty

The taking-as is what most directly influences the certainty produced through enactment. The sections that follow discuss what taking-as each of the classes might mean, for both felicitous and infelicitous cases. The possibility of infelicity opens up a space of nine possibilities: a system may be given as any of the three classes, and subsequently taken as any of the three. These possibilities are summarized in Section 4.2.6.

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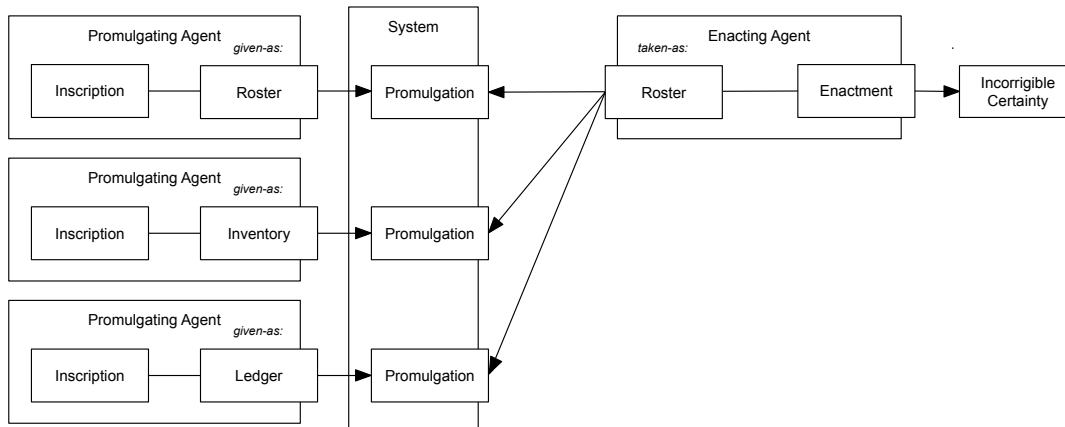
<sup>17</sup>This is defended in a more general context in Hauser, “Information from jussive processes.”

### *Taking as Roster*

Any system can be taken as an incorrigible declaration, and enacted to produce incorrigible certainty. That is, regardless of how a system was given, its enactment can render its promulgations as Roster-entries, incorrigible. Figure 4.3 shows this schematically: a promulgating agent's inscription, once promulgated into a system, may be consulted and enacted by an enacting agent as a Roster.

When a system given as an Inventory is taken as Roster, a proposition (or measurement)<sup>18</sup> is enacted as a fact. Propositions are made true or false by some fact. By converting a proposition to a fact, this form of infelicitous enactment destroys a proposition's potential reconciliation with the world, making it incorrigible.

When a system given as a Ledger is taken as a Roster, a claim is enacted as a fact. Claims have the logical form of defeasibility, an argumentative structure subject to defeat. By converting a claim to a fact, this form of infelicity forecloses upon further discourse about the claim and renders it incorrigible.



**Figure 4.3:** The production of incorrigible certainty. Incorrigible certainty can be produced from any promulgation, regardless of the force with which it was given, as long as the system is consulted as a roster.

### *Taking as Inventory*

Systems taken as inventories are exposed to a process of reconciliation, where some part of the world outside the system can be consulted and used as the basis for correcting the system. This process,

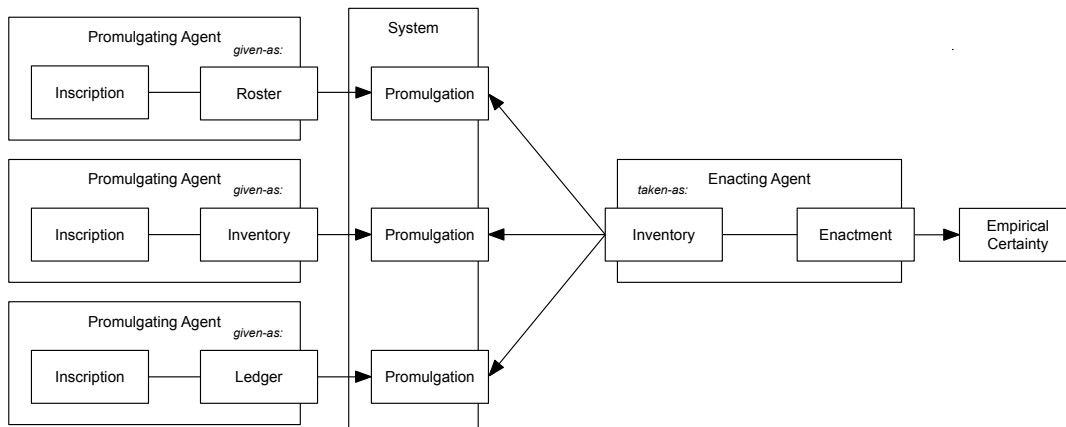
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<sup>18</sup>Measurements take the logical form of a proposition in that their truth is adjudicated by a fact. They have been used in connection with Inventories due to their connection with empirical reasoning, and so I repeat them here. Proposition is the more general term, and so measurements are implied in its usage below.

represented schematically in Figure 4.4 can be applied regardless of how a system’s promulgations were given by promulgating agents. In infelicitous cases where promulgations given-as Roster-entries are taken-as Inventory-entries, the declaration intended by the promulgating agent is subjugated by the enacting agent to some state of the world external to the promulgation. In infelicitous cases where promulgations given-as Ledger-entries are taken as Inventory-entries, the claim intended by the promulgating agent is converted from an argument into a measurement, collapsing the dialectic potential of Ledgers into the reconciliation space of Inventories.

When a system given as a Roster is taken as an Inventory, a declared fact is enacted as a proposition. This renders the fact corrigible, subject to reconciliation with some part of the world. The fact’s constitutive declaration is rejected by this process, rendering attempts to adjudicate the truth of propositions using the fact senseless within the logic of enactment. This form of infelicity militates against the declarative power of the promulgating agent.

When a system given as a Ledger is taken as an Inventory, a claim is enacted as a proposition. This renders the argumentative structure of the claim into the form of propositional logic, able to be adjudicated as a fact. Precisely which fact might adjudicate the truth of the claim as transformed into a proposition is determined by the enacting agent. This form of infelicity collapses the complexity of defeasible argument into the simplicity of propositional logic.



**Figure 4.4:** The production of empirical certainty.

### *Taking as Ledger*

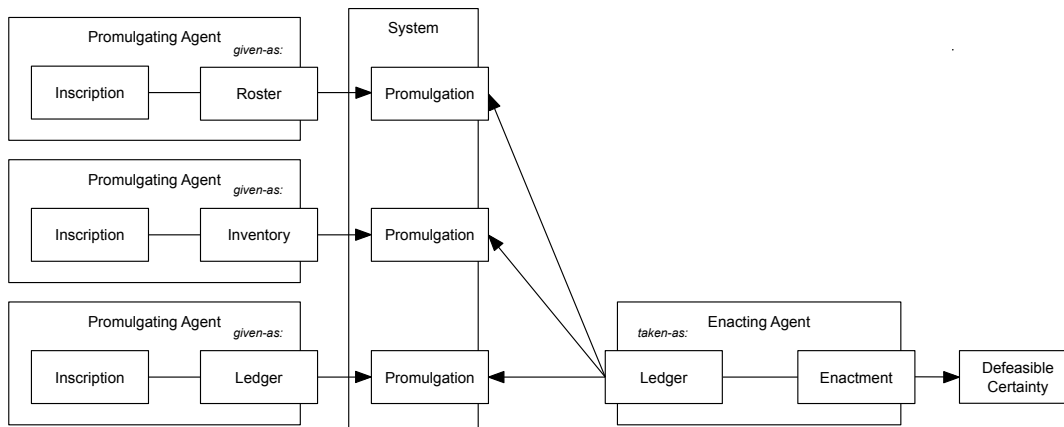
Promulgations taken-as Ledger-entries are rendered as claims, represented schematically in Figure 4.5 on the next page. This allows contradictory claims to be arrayed alongside each other, opening a discursive space. Felicitous Ledger-entries were promulgated in a way so as to make this straightforward. Infelicitous cases of taking-as Ledger-entries usually require the enacting agent to attribute the claim to some entry, usually the promulgating agent and/or the system. For instance, taking a promulgated count of a product from literal inventory as a ledger-entry requires attributing the claim to either the inventory system user who last updated the count, if available, or attributing the claim to the inventory system itself. Infelicitously taking a given-as-Roster-entry as a Ledger-entry subjugates the declarative act of the promulgating agent like in the case of taking-as-Inventory-entry, but still renders a weakened declaration in the form of a claim. The possibility of arraying declarations given-as-incorrigible alongside others which may contradict or countermand it subverts the power of declaration inherent to felicitous Rosters.

When a system given as Roster is taken as Ledger, a declared fact is enacted as claim. The enacting agent must construct an argumentative form out of the declaration, in the process destroying the fact's incorrigibility and subjecting it to defeat. Conflicting claims can be arrayed alongside each other consistently in a way that conflicting incorrigible facts cannot, which means that this form of infelicity can bring declarations into a kind of discourse with each other. Like when Rosters are taken as Inventories, this form of infelicity militates against the declarative power of the promulgating agent.

When a system given as an Inventory is taken as a Ledger, a proposition is rendered into a claim. The enacting agent must render the simpler form of propositional logic into an argumentative structure, an interpretive process that may vary between agents. This form of infelicity converts propositions that purportedly can be rendered true or false by some set of facts into defeasible argumentation, making them available for discourse.

#### 4.2.6 A Matrix of Certainty

Table 4.1 (page 120) shows the nine possible pairwise relationships between giving-as and taking-as. The three felicitous cases show how the logical form of the promulgation is unchanged from how it is given to how it is enacted.



**Figure 4.5:** The production of defeasible certainty.

### *Felicity and Infelicity, Refracted*

Attention to differences between giving and taking refracts the production of certainty, allowing a more complete description of how chains of promulgation and enactment influence each other. This is notwithstanding my claim that enactment, or how a consulted promulgation is contemplated when moving on, is the primary determinant of the resulting certainty. When practices of justification are similar amongst members of certain communities and within certain contexts (such as border crossings), promulgations can have predictable impacts upon enactment. This is particularly true when promulgations are taken felicitously, but requires merely consistent enactment. The power possessed by a promulgating agent, and the subsequent effects of their promulgation, is contingent upon an enacting agent.

Future work, and the accumulation of applications of the taxonomy, will likely reveal patterns of each of these forms. As described for the six infelicitous cases, enactment from one logical form changes the potential of a promulgation. Claims, which have an argumentative structure, can be collapsed into declarations, and enacted as facts. Inversely, incorrigible declarations can be situated within an argumentative structure as claims, discarding their incorrigibility in favor of logical defeasibility. This form of enactment preserves a modicum of declaration, since claims are attributed, but resists enacting the declaration as a fact. Instead, putative facts can be arrayed and compared, enabling discourse.

Enactment which takes Rosters as any other class denies the declarative power of the promulgating agent. Conversely, enacting any other class as Roster accords the promulgating agent the power of declaration. The availability of felicity to any promulgating agent or the option of infelicitous enactment

		Taken-as:		
		Roster	Inventory	Ledger
Given-as:	Roster	Declaration ↑ Declaration	Proposition ↑ Declaration	Claim ↑ Declaration
	Inventory	Declaration ↑ Proposition	Proposition ↑ Proposition	Claim ↑ Proposition
	Ledger	Declaration ↑ Claim	Proposition ↑ Claim	Claim ↑ Claim

**Table 4.1:** A matrix of certainty showing the result of felicitous and infelicitous combinations. The ↑ arrows point from how the promulgation is given towards how it is enacted.

to any enacting agent is governed by the power dynamics discussed in Section 3.2.2. The analysis of certainty in these cases is likely to reveal ethical and political dimensions of the production of certainty.

### 4.3 Applying the Taxonomy

The taxonomy can be usefully applied at several different levels of abstraction. At its most basic level, the taxonomy can be applied to felicitous cases of the production of certainty, where a system is given and taken as a single class of roster, inventory, and ledger. Section 4.1 outlined these classes at a basic level, and they can be applied directly in simple cases, without a need to describe giving as or taking as. In cases where giving and taking practices differ or otherwise bear upon the desired analysis, they must be analyzed and compared as described in Section 4.2. For many analyses aimed at changing practices to achieve some goal, such as accuracy, fairness, or consistency, this may well be the most important level of analysis. The balance of this section discusses issues of application beyond simple cases.

Section 4.3.1 distinguishes the chronology of the production of certainty from how an investigator will approach a particular area of interest. As originally discussed in Section 1.1.2 and elaborated upon in Chapter 2, the phenomenon of certainty can be identified when:

- An actor consults an information system
- The actor moves on in light of what was found there



Thus, the investigator is likely to begin analysis at this point. However, chronologically, the information system and the promulgation consulted must exist before consultation. The section discusses implications of this situation for application of the taxonomy.

Section 4.3.2 below is intended to clarify a deeper level of abstraction that may be useful in thorough analyses. As noted in Chapter 2, systems and their constituent promulgations can have distinct promulgating agents, and distinct roles to play in enacting agents' moving on. The section details how the taxonomy can be articulated to these distinctions and when the level of granularity they provide might be most relevant..

Finally, Section 4.3.3 discusses how the taxonomy can be applied to chains of systems and certainty-producing practices. This widens the scope of analysis potentially limitlessly, through the recursive application of the taxonomy to successive instances of the production of certainty which subsequently influence the promulgations and/or enactment surrounding other systems. Almost all interesting analyses of real-world systems will be able to utilize this recursive method, if needed, because the context of the production of certainty is rarely hermetically isolated from others. For instance, the running No Fly list example interacts with other information systems for verifying identities of travelers via passports, drivers licenses, military IDs, and so on. What is more, the agents who enact this system at the airport must themselves prove their identity via information systems which include scanners for their identity badges. The taxonomy can thus be expanded to fit the scope of analysis needed to describe the particular context or assemblage of interest to the researcher.

The theoretically limitless depth of this possible recursion does not make it infinite, or offer omniscience. Rather, the taxonomy's simplicity offers great methodological benefits from its flexibility of application, according to the scope of a researcher's interests. Part II will demonstrate this through its application to three disparate cases.

#### 4.3.1 On Chronology and Methodology

In Chapter 2 I showed how the cessation of justification, promulgation, and enactment could be reliably identified. The overall phenomenon of the production of certainty can be identified when justification ends, it ends upon a system, and the enacting agent moves on in light of the inscriptions in the system. Thus, even though there is a chronological relationship between these components, the analysis will mostly likely begin where justification stops, and from there confirm that it stopped upon a promulgation,

and that the enacting agent moved on in light of the promulgation. Figure 4.6 on the next page expresses the differences between a chronological view of the phenomenon and a more likely ordering an analysis might take. Chronologically, a promulgating agent must have promulgated an inscription for justification to end on. The inscription must be within a system of some form, which makes it a promulgation in the terms of our analysis. Then, an enacting agent must consult it and end justification. Finally, the enacting agent moves on, enacting certainty.

The investigator of certainty must first know that certainty has occurred, finding evidence that an enacting agent has moved on in consultation of a promulgation. She can directly observe this moment or apply an number of ways of learning about it after the fact. For those of us who work with systems as artifacts, the end of justification may be something we study in terms of its documental traces. As discussed above in Section 3.1.2, John Searle left evidence that he stopped justifying the distance from the earth to the sun when he wrote 93 million miles down in his book. It may not be clear exactly where he got this number from, or whether it was taken from an information system (as opposed to a measurement device, for instance). Given all this, we know absolutely nothing about what kind of consultation, if any, informed Searle's inscription. All we see in Searle's inscription is an assertion that the earth is 93 million miles from the sun. This is promulgation, not the production of certainty.

We can observe the production of certainty in the subsequent use of this figure by Beynon-Davies, though. Beynon-Davies's use of this exact figure as an example of a brute fact, combined with his citation of Searle, shows that Beynon-Davies consulted Searle's promulgation and moved on in contemplation of it.<sup>19</sup> An investigator of the certainty produced in this instance would first encounter Beynon-Davies's enactment, only then reconstructing the rest of the components of certainty from documental traces.

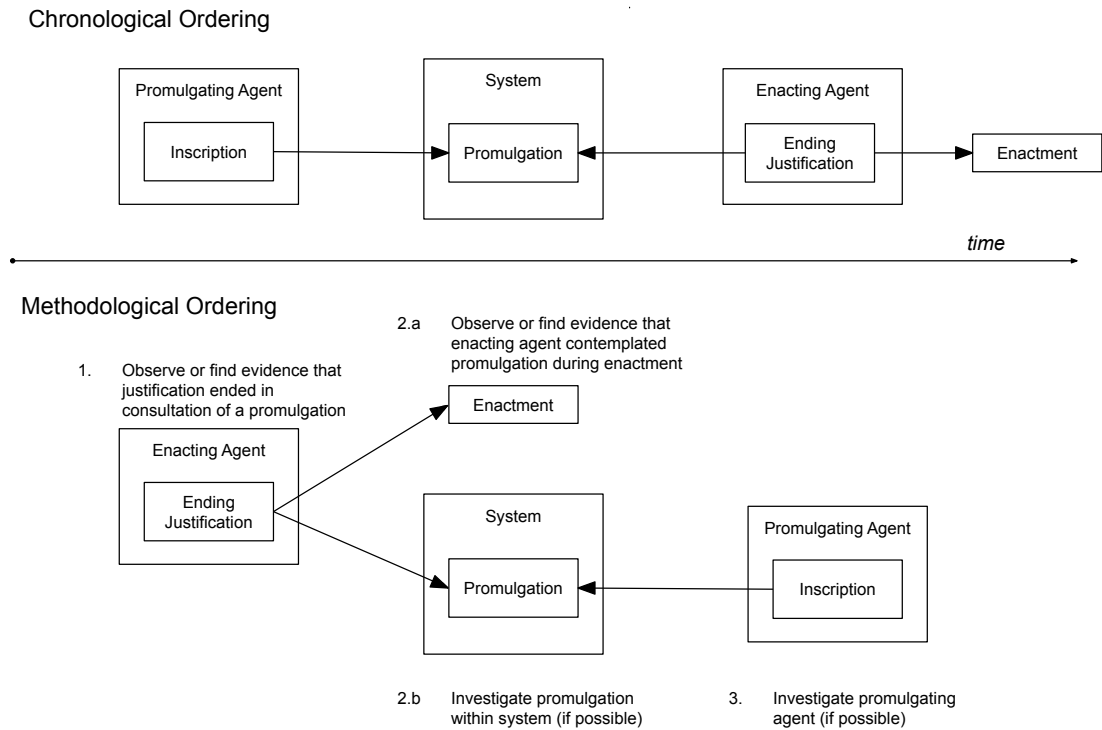
This is the state of affairs represented in the bottom of Figure 4.6. Reading left to right, top to bottom, we see the order in which we can investigate this instance. In 1, there is evidence that Beynon-Davies found an inscription somewhere, and stopped justifying on it. It is evident that he stopped because he gives it as an example of a brute fact and cites Searle as the source. He moved on to explain Searle's conception of brute facts, contemplating this example (represented by item 2a in the figure). Item 2b is in this case the citation of the page where Searle gives this figure as an example of a brute fact.<sup>20</sup>

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<sup>19</sup>Beynon-Davies, "Form-ing institutional order: The scaffolding of lists and identifiers," 2745.

<sup>20</sup>Searle, *The Construction of Social Reality*, 10.

Via this source we can learn about item 3, the promulgating agent, but, as noted above, little about the circumstances of promulgation, since Searle does not cite any sources but rather declares *the Earth is 93 million miles from the sun* to be a brute fact.



**Figure 4.6:** Distinctions between the chronology of certainty and the application of methods of analysis. The chronological ordering shows the temporal relationships between the components of certainty. The methodological ordering shows that in most cases an investigator will come to know about and be able to investigate the components of certainty in an order different from that in which they occurred.

Another investigator might be to start with a system and the promulgations it contains, and from there observe which justifications end upon them. Others might start with the promulgating agent and follow the transformation of inscription to promulgation. Or, obviously, one might start from a particular enactment and work backwards to determine the circumstances of justification that surround it, thereby encountering a promulgation, and so on.

The analysis of the full phenomenon of the production of certainty from information systems, though, is distinguished by its round trip from enacting agent, to promulgation through consultation, and back to enacting agent via contemplation and enactment. Analyzing only a component in isolation, such as the circumstances of promulgation, is insufficient to describe the production of certainty. Many things

are promulgated and never even consulted, much less used as a terminus of justification. And many justifications end without reference to promulgations. Those justifications that end on promulgations may not produce enactment. Think of someone mechanically checking an identification card but allowing passage regardless of what the card says. There is *action*, but the promulgations have no bearing upon it, preventing it from being an enactment.<sup>21</sup>

#### 4.3.2 Applying the Taxonomy to What?

Some analyses will require a distinction between the system itself, and its promulgated contents. In Beynon-Davies' terms, this would be a distinction between the list of identifiers data structure and an individual identifier. The distinction will be relevant where:

- the promulgating agent(s) give specific promulgations in ways distinct from each other or from the way in which the system as a whole is given,
- the the enacting agents take specific promulgations in ways distinct from each other or from the way in which the system as a whole is taken, and/or
- such differences make a difference to the desired analysis

Like all discussions of methodology, the goals of the researcher and the nature of the phenomenon are of primary importance in determining the appropriate level of abstraction. The existence of differences in promulgation or enactment of system and individual inscription, even if present, may or may not matter to a given analysis. This section will describe how they can be analyzed using the taxonomy so that in cases where this level of abstraction is appropriate the researcher can apply it.

#### *Classifying Systems*

Most of the preceding discussion has focused on the characteristics of systems as a whole. We've talked about No Fly lists, restaurant reservation systems, and the like in terms of their overall characters with respect to certainty. Even when adding the dimension of given-as and taken-as, systems have retained the leading role. It's easy to see why this is the case: a common move within many fields of information studies and related disciplines is to delineate a system, and then discuss its characteristics.

Consider contrasting cases: A mayor issues a new regulation (say, that all pets must be registered) and uses hundreds of official notices to do so, distributed throughout a town. We'll presume for the

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<sup>21</sup>Except insofar as the possession of an ID card, *any* ID card, is enacted as a prerequisite for passage. In this case, there is a *systemic* enactment of a means of identification, but the promulgations themselves are not enacted since the inscriptions on the card are ignored. Section 4.3.2 addresses some of these complexities.

moment that the notice has all the expected trappings of an official announcement, including prominence of place, elaborate templating, a signature, an official seal, and so on. Handwritten modifications to these are most likely to be interpreted as vandalism, social commentary, or political opposition, even if they appear to be written by the mayor. It is unlikely that a mayor would hand-modify hundreds of such signs. Next, consider the corresponding forms to register a pet. Handwriting on these forms, even though many identical copies have been printed and distributed, is likely to be considered a sign of their valid completion, rather than a challenge to it. So, also, with the forms the police will use to cite owners of unregistered pets. In each case there is a distinction between the validity of the overall system, or medium of declaration, and the validity of a specific inscription (or set of inscriptions) within it. The printed proclamation with handwriting on it has been vandalized. The pristine printed registration form is invalid from the perspective of the pet registrar; the handwriting of an owner is what completes it, and makes it a valid constituent of the registration system. Yet, presumably, all would agree that the blank registration forms are official-looking, but that they don't (yet) constitute registrations. These examples reveal the need to distinguish the role that systems, promulgations within those systems, and sometimes specific sub-promulgations play in the production of certainty.

#### *What Counts As a 'System'?*

It seems we're in need, here, of a way of distinguishing the system from its contents. Yet, this is an uncomfortable way of stating the need, since it implies that The System might be some abstract thing that could be disentangled (perhaps by modeling it in UML) from its merely physical instantiation. The view that systems can be unproblematically modeled, apart from the particular material circumstances of their instantiation is not uncommon, but is incompatible with my persistent focus on the inscriptive materiality of systems.

The move I'd like to make instead is to maintain that both the overall system and its promulgated contents are essentially material in character, but to separate them as distinct objects of potential evaluation. That is, in terms of the taxonomy, either may be given-as or taken-as roster, inventory, or ledger. Except, of course, that an individual inscription will be taken as a roster-, inventory-, or ledger-*entry*.

Returning to the example above, we can see that in the case of the scrawled addition to one of the mayor's proclamation posters, we can precisely describe what's going on when someone accepts the legitimacy of the poster as a roster containing a proclamation, but discounts the validity of a specific

inscription. In other words, the invalidity accrues to the inscription as putative entry, rather than the system. In other cases, a graffito may actually change how an agent takes the system as a whole, in which case a mere entry has altered how an enacting agent takes all promulgations within a system. Distinguishing these cases lets us apply the taxonomy more precisely.

### *Classifying Individual Promulgations*

When might we accept the validity of a system but doubt a specific promulgation within it? We can start with the nuclear early warning system, an example which Smith used in his discussion of correctness (covered in Section 1.3.2). Presumably, the soldiers manning the system on October 5<sup>th</sup>, 1960, accepted the overall validity of the system. But, reportedly because of the fact that Nikita Krushchev was in New York at the time, they doubted the (automatically promulgated) inscription they received from the system that a large-scale nuclear attack was underway.<sup>22</sup> The Ballistic Missile Early Warning System (BMEWS) carried more weight in determining whether a nuclear attack was underway than a phone call from a child, say, or a handwritten note slid under a door. But, thankfully, it was not just the system which was subject to scrutiny, but the particular promulgations it produced at any given moment. The two-layer evaluation of both system and promulgation in this instance mirrors the additional layer of precision which may be necessary when utilizing the taxonomy.

### *“Anything it says, goes”*

Of course, just because justification and moving on *may* be interrupted due to the circumstances surrounding any specific promulgation, doesn’t mean that they *will be*. Faithful enactment of promulgated entries within a system is a hallmark of bureaucratic control and consistency. Large organizations, from governments to corporations to militaries, are to a certain extent predicated upon faithful enactment. Processes, policies, trainings, and disciplinary procedures are commonly arrayed to ensure that promulgations are in fact enacted uniformly. Agency is removed from the enacting agent, thereby enhancing the power of the promulgating agent.

Multiple familiar cultural phenomena derive from these tendencies. The first is the bureaucracy itself. In terms of the present analysis, bureaucracies thrive on the incorrigibility of promulgations, and rely

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<sup>22</sup>For more about near and actual nuclear disasters, including the 1960 Thule false alarm, see Eric Schlosser, *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety* (London: Penguin Press, 2013) and Daniel Ellsberg, *The Doomsday Machine: Confessions of a Nuclear War Planner* (New York: Bloomsbury, 2017), esp. 43-44.

on enacting agents to ‘correct’ the relevant aspects of reality to match the promulgated values. Didn’t fill out that form? You’re not registered. The experience of such systems recalls the colloquial sense of incorrigible first identified on page 24: unyieldingly, exasperatingly unchangeable. As societies become ever more networked and interlinked, it is likely that recourse to this particular strategy of control will continue to proliferate.

### *Hacking and Certainty*

Even as techniques of bureaucratic control centralize agency with promulgating agents, however, techniques of usurping promulgative agency have similarly expanding. In the context of digital systems, this is colloquially referred to as *hacking*. The trope of the hacker, recapitulated in daily news stories and action thrillers alike, is one that’s able to assume control of the massive, unconscious digital infrastructure underlying quotidian sites of control and authority, and subvert it. There are multiple fantasies engaged by this trope: of evading bureaucratic control, of assuming that control oneself, even a dystopian fantasy of an unthinkingly enacted work of anonymous security guards, soldiers, and card-access doors which can all be bypassed with the right, if vague, technical prowess.

This latter dystopian fantasy embodies a deep anxiety that control is absolute, which is presumably why the hacker trope<sup>23</sup> has become so pervasive, especially in American action movies and television series. Unlike the spy and detective capers of old, heroes supported by hacker sidekicks don’t have to fool or charm anyone to gain access to the villain’s lair. When they scan their hacked barcoded badge or swipe a doctored keycard, from the perspective of the sociotechnical system they’re infiltrating, they *are* valid employees within this enactment context. The *thinness* of contact between infiltrator and system is what’s odd, especially compared to the elaborate ruses and sweet talking which formed a staple of earlier examples of the genre..

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<sup>23</sup>From the operators in *The Matrix* to the prototypical, near-omnipotent action movie hacker Nine Ball in *Ocean’s 8*, these figures provide a way out of otherwise insurmountable challenges. That they increasingly play the narrative function of *deus ex machina* perhaps indicates their cultural descent from mythological gods or heroes. It is often instructive to locate omnipotence in narrative. In the Greek myths, the capricious gods were the source of equal parts disaster and blessing. In the American action thriller, the hacker’s role has seemed to move from an omnipotent cause of disaster, as in *The Net*’s Praetorians, a shadowy cyberterrorist group, or *GoldenEye* villain Boris Grishenko (both 1995), to an increasingly necessary cure for it. This, of course, parallels the rise of the *Black Mirror*-style techno-dystopian drama as a genre, which typically dissolve the ‘villain’ into the technologies themselves. All of these narratives seem to orbit around themes of agency and power in the face of faceless systems. I’m not a film critic, of course, and my interpretation of these films and television shows may be colored by the well-known phenomenon of seeing one’s dissertation topic everywhere in the midst of writing it, but I do believe it’s significant that the phenomena of certainty can be seen in popular culture. If it is as pervasive as I

### *A System, Swallowed Whole*

The idea of unquestioning enactment of promulgated entries in an information system foreshadows some of the connections of my work to algorithm studies. This topic was broached briefly in the introduction and in Section 3.4, and we're still encountering algorithms as a subset of information systems. But the potential power of algorithms is a sort of inverse of the faithfully enacted system. Whereas a faithful enactor turns any possible promulgation into enactment, an algorithm turns any possible input into a promulgation. I've elsewhere discussed the latter as *prolepsis*:<sup>24</sup> the projection of potential values onto reality. In an interesting way, faithful enactment of an information system proleptically projects the power of the promulgating agent onto reality. This is more concerning when algorithms are combined with faithful human enactment, and even moreso when the algorithmic assemblages of AI are capable of automated enactment. Work into the ethics of everything from self-driving cars to automated drone strikes is already grappling with this.

Any time a system's promulgations are accepted and faithfully enacted, swallowed whole, as it were, this indicates a potential site of analysis and ethical evaluation. Even short of automatic enactment, there are sometimes major concerns just because systems provide relevant promulgations, as in ProPublica's analysis of recidivism scoring algorithms. It's rarely feasible (or perhaps possible) to know exactly how and why a decision was made by an individual. This difficulty prompted the approach I've taken in this dissertation of largely bracketing the processes of justification in favor of the more easily observable material inscriptions and praxeological traces surrounding these moments. But this doesn't mean that I believe efforts to draw attention to these practices or raise questions of bias, influence, and fairness

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claim, we should expect not only the scholarly encounters with it described in Section 1.3 and elsewhere, but to see this percolating into popular culture as well.

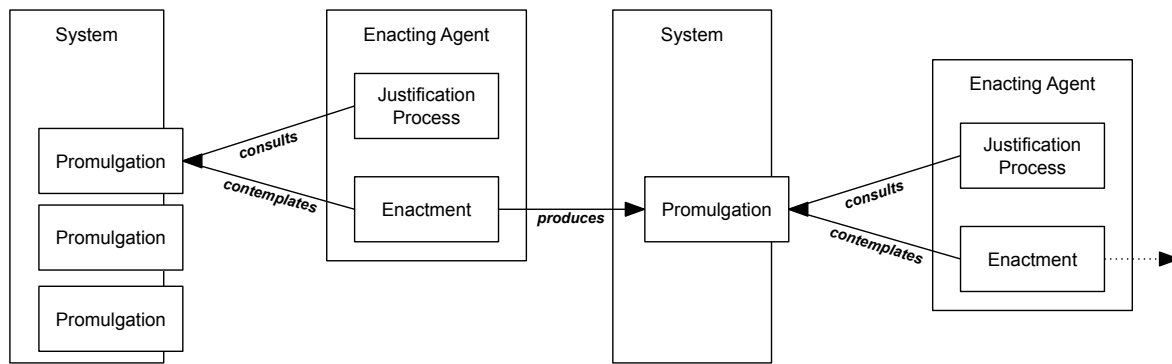
<sup>24</sup>Elliott Hauser, "UNIX Time, UTC, and Datetime: Jussivity, Prolepsis, and Incorrigeability in Modern Timekeeping," in *Proceedings of the ASIST Annual Meeting* (Vancouver, British Columbia: John Wiley & Sons, 2018), 171–180.



in these contexts are doomed. To the contrary: these are exactly the kind of efforts I envision my work might assist.

#### 4.3.3 Recursion & Layers of Certainty

The phenomenon of certainty can occur in chains, where enactment of a consulted promulgation produces yet another promulgation. Shown schematically in Figure 4.7, this is perhaps the most common and portentous form of certainty production. Rarely are systems as simple as Beynon-Davies' lists of identifier data structures . More commonly, there are multiple simultaneous processes of enactment which yield new entries within another system, or even populate attributes of individual entries entries. For instance, a biologist's field notebook will contain observations of the organisms of interest, which may be given-as inventory entries, combined with a record of the date, which is from the international system for timekeeping, taken-as roster, and finally she might include a colleague's classification of the ecosystem, given-as a ledger entry. Clearly, within the simple system constituted by the notebook, a variety of justification practices have occurred, each an enactment which conditions promulgation.



**Figure 4.7:** A chain of certainty production, where an enacting agent produces certainty in the form of a promulgation, which is then enacted by another agent, and so on.

A similar diversity of practices is available to someone else examining the notebook as an artifact of scientific knowledge production. The entire system might be seen as a ledger, such that all of its contents, regardless of type or source, represent some sort of claim by the biologist (that the date was . . . , that the organisms performed certain behaviors. . . , perhaps even implicitly that the biologist is the author of all of the promulgations). Or, the system might be taken-as it was given, with the shared context  $C$  of

international datetime rendering datetime a fact,<sup>25</sup> the colleague's classification taken-as a claim, and the biologist's observations taken-as a measurement (so to speak) of the organisms' behavior. Subtle potential shifts in this scenario abound. For instance, the explanatory power of the colleague's classification of the ecosystem might lead one to take that particular inscription as roster, a declaration of a fact.

Such chains are an integral part of knowledge production in the sciences, and Chapter 6 will elaborate much further on this. Accounting for chains of enactment and promulgation is a necessary part of any serious analysis of interconnected systems that produce certainty.

#### *Enactment and Black Boxes: Justification Can Stop Anywhere*

The analysis of certainty need not be turtles all the way down, despite the prevalence of chained certainties. We *can* stop anywhere, just as any enacting agent can. That enacting agents can, and sometimes do, stop arbitrarily, capriciously, or mysteriously is of enormous methodological importance. Basically, it means that collections of enactments form potential scopes of an analysis. Selecting which enacting agents and which enactments matter to a given investigation is how an analysis can be circumscribed, despite the existence of potential chains of certainty extending beyond the frame. This is again neatly circular: to paraphrase Wittgenstein, to be sure there is analysis, but analysis must come to an end somewhere.

#### 4.3.4 Where Should Analysis End?

Methodologically, the chain of analysis should mirror the chains of enactment that are of interest. Analyzing enactment in isolated instances, as many of the examples in Part I have done, may be sufficient in some cases. In many more cases, I suspect, we'll want to expand the analysis to include other layers of certainty surrounding the subject. The requirements of depth are conditioned by the depth of explanation sought within a particular analysis, though. I want to distinguish the insights of chained analysis from any specific act within the chain. Say a repossession agent tows a car because of the existence of a name within a database. An analysis of the chain of reasoning may reveal relevant facts about the history of the promulgation upon which justification ended and from which the agent moved on to physically remove a vehicle, offering a potential analysis of the enactment underlying the promulgation. But, in the context of the repossession, all that was present was the promulgation, the end of justification, and enactment in contemplation of the database's promulgations. The investigator can stop, and will have analyzed

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<sup>25</sup>Datetime and associated certainties of timekeeping are discussed extensively in Chapter 5.

the certainty produced by the repossession agent. Or the investigator can continue to investigate the promulgating agent's production of certainty, combining the two instances of enactment into a chain. The correct scope depends on the scope of certainty to be explained.

#### **4.4 Confronting Certainty**

The dissertation began by drawing a distinction between familiar inventory databases and the kind of systems-of-record that the No Fly list represents. The practices of justification surrounding the use of these systems are distinct. With the inventory, customers will stop justifying and move on if we are satisfied that the inscription in the system reasonably matches the state of the stock on the warehouse shelves. If 100 iPads are shown in stock, we will usually stop justifying this fact and place an order. There's a kind of threshold relationship for customers. It's unimportant if the actual number of iPads on the shelves is 100, 99, or 214. For the purposes of placing an order, the number need only be greater than zero. Company employees, however, need to precisely know the number of items in stock for inventory management. So, periodic inventory reconciliations are performed so that day-to-day justification about the accuracy of these numbers can be (mostly) avoided.

The No Fly list can have no such reconciliation process. We've assumed, for simplicity, that the No Fly list is implemented as a unitary system, rather than a master list with periodically distributed updates. The slightly more complex case of a master list kept in Washington D.C. and periodically distributed to specific airports doesn't invalidate the analysis of enactment, even as it changes the picture of promulgation. The master list retains the features of incorrigibility, while the distributed lists gain some aspects of the inventory: a measurement of an external state of affairs (in this case, the master list). Yet, the individual enacting agents may not know or treat the portion of the No Fly system they have access to as a fallible measurement of a master copy. In light of the opacity of the overall system at the point of enactment, black boxing the internal details of the system mirrors the actual experience of those who use and are affected by it. There is an analysis to be performed, but it is circumscribed by the knowledge we have of the assemblage underneath the promulgation consulted by the enacting agent.

These complexities have lurked underneath many of the simple examples through the dissertation. Section 1.2 (page 23) reviewed systems in terms of their use of data, claims, and incorrigibility (later

rephrased as declarations), but the realities of even simple cases more often can be seen to contain a mixture of these. Part II will employ the conceptual and analytical tools at hand to fully confront them.

## **Part II**

### **Certainty in Information Systems**

## **WHAT TIME IS IT?**

What time is it? This is a question which demands certainty as we've considered it so far. The systems consulted to answer this question have varied extensively throughout the years, but writing in 2019 I can uncontroversially say that the regime of computational timekeeping has proliferated globally. Time as computed and displayed by servers, laptops, smartphones, and other connected devices serves as a standing, global yet localized answer to the question of the current time. Part II will examine the assemblage of computational timekeeping in terms of certainty, describing and classifying the role its varied constituent systems play in the chains of certainty production that constitute the current time.

### **How We Got Here**

Part I introduced the phenomenon of certainty, developed concepts in which it could be operationalized, analyzed the process in those terms, and produced a taxonomy of certainty to describe the role that information systems play when consulted and contemplated during in the production of certainty. All of this conceptual machinery is aimed at enabling the analysis of real-world systems. The presentation of the work until now has in fact been informed by engagement with real-world systems, but a deep analysis of specific systems has so far been omitted in favor of simple example systems, chosen as illustrative examples. Though the systems we'll consider from this point on will likely be new to the reader, they have played a part in the development of the analysis, and particularly the taxonomy of Chapter 4. For instance, the massive scale and multiple chains of certainty produced in computational timekeeping were the inspiration for the methodological note in Section 4.3 that recursive application of the taxonomy should be utilized to describe systems as networks of certainty production. With the benefit of the taxonomy and the rest of Part I I will now return to computational time with new theoretical tools for addressing its complexity.

## Answering Questions About Time

Part II is framed around the question, “What time is it?” There is no ‘mind-independent’ (in Searle’s sense) portion of the world to which to refer to answer this question, except, of course, the material inscriptions which constitute promulgated declarations of what time it is. Experts, of course, may render these declarations as claims, and therefore potential ledger-entries, arraying potential answers in a representation of discourse. But, for most of us, we just want to know what time it is. The assumption that the question is one of truth demands the production of a fact to adjudicate the truth of the proposition “it is 08:00:00 UTC”. Computational timekeeping, and the scientific time standards which it operationalizes, produces and promulgates those facts in formats that can be both computationally and manually consulted and moved on from.

“What time is it?” can be seen here to stand in for a range of other motivations for consulting a system. Adjacent, more specific questions such as “was this conference submission received before the deadline?” have clear similarity. Their difference lies in the articulation of the role the proposition with related rules. The chain in this case would go something like this:

- When was the submission received? (Consult a timestamp)
- When is the conference submission deadline? (Consult a separate timestamp)
- Was the submission received before the deadline? (Compare the timestamp integers)

Together, these questions, the promulgated determinants in the submission system, and the organizational practices of consulting the system and enacting its promulgations in a specific way constitute a practice of justification. In Section 2.3 I excluded the precise dynamics of specific justifications from the scope of analysis, and exactly *why* justifications are performed in a specific way is a question better suited to sociological analysis. In the context of a specific system, however, the articulation of rules around the production of certainty is what gives that certainty its enacted character. So, in this sense, “what time is it?” can stand in for a wide range of interested consultation of information systems, and the moving on in contemplation of a promulgation active here will be similar in form to other cases.

In this sense, then, the analysis of Chapter 6 is a proof of concept of a larger research arc. The analysis of certainty offers a way of describing the specific ways in which the materiality of technical artifacts is woven into social practices. It should complement many investigations which follow the sociotechnical

approach to information systems broadly.<sup>1</sup> This is explored more deeply in the Conclusion. Even without these potential connections, however, Chapter 6 is intended to stand on its own as a contribution to the understanding of the phenomenon of the certainty in information systems, and the role the phenomenon plays in the vast global network of modern computational timekeeping. It demonstrates that the taxonomy, though consisting of only three classes, is robust when applied recursively and nuanced when fully articulated in terms of promulgation, enactment, giving as, taking as, and the other theoretical concepts presented in Part I.

### Why Computational Time?

In the foregoing chapters I've claimed that the methods of analysis I'm developing, and in particular the taxonomy of certainty, can be applied seamlessly to both computational and traditional information systems, and both human and nonhuman agents. Computational timekeeping provides an excellent source of examples for a reference application of the analysis of certainty for three main reasons. The first reason to turn to this system is to demonstrate the robustness of the taxonomy and its associated conceptual machinery in analyzing large, complex systems. In Chapter 4 I described how the recursive application of the taxonomy could allow a large analysis that could nevertheless end in a coherent way. This chapter, and specifically the example of computational timekeeping, is intended to demonstrate this.

The second reason to study computational time is similar to that which has brought computational artifacts to the fore in a number of fields, from sociology to media studies to science studies. But, in the terms of analysis I'm using, the importance of computational systems is that they are where we can most clearly observe the incorrigible default at work. If incorrigibility, empiricism, and defeasibility are seen as categories of memory practice, as ways to license forgetting, this means, then that computers forget more readily and completely than humans are accustomed to. The completeness and ubiquity of computational techniques of forgetting has led some to investigate the phenomenon as a consequence of computational methods, like Smith, or of digital data, like Couldry and Hepp. But I hope to show, following Bowker, that these are most fruitfully seen as continuations of phenomena and methods of enactment that predate them. This is not in itself an innovation. In addition to Bowker, others have traced the development of

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<sup>1</sup>Steve Sawyer and Mohammad Jarrahi, "Sociotechnical Approaches to the Study of Information Systems," in *Computing Handbook, Third Edition*, ed. Heikki Topi and Allen Tucker, vol. 19 (Chapman / Hall/CRC, May 2014), 5–1–5–27.



computers and the ways in which we use and conceive of them from earlier intellectual traditions. Chun's tracing of the impulse to find a biological 'code of life' from scientific figures like Schrödinger, before and in parallel with the development of the von Neumann architecture that has come to define modern computation, into the code-centric view of computers and programming as an activity stands out.<sup>2</sup> So, although the systems I'll examine in this chapter are (primarily) computational, they have been selected as exemplars of a phenomenon that predates them.

A final reason to analyze computational time in terms of the production of certainty is that the assemblage involves a mixture of human and nonhuman agents, both in promulgation and enactment. It thus realizes a major goal of my approach, handling agents symmetrically.

### Timekeeping & Computational Incorrigoibility

Why is computational incorrigoibility so pervasive? A simple answer is provided by my concept of the incorrigoible default: the practices that enable more nuanced techniques of forgetting have been only slowly and with great effort reimplemented in binary code. Computers consult and promulgate; these basic actions together are together a nearly complete description of the basic functionality of a Turing machine and describe how computers have the inherent potential of promulgating agents. Their output has always been enactable by human agents. As computational systems have become networked with devices with automotive capabilities, they increasingly can also move on in contemplation of what they consult, becoming enacting agents. The ability to and processes of consulting other systems, or the world directly, as is required by empirical or defeasible logics, is difficult and complicated to specify. So, in the absence of subsequent measurement or an ability to array claims, computers both promulgate and enact with incorrigoibility. They now do so at scale, and beyond the temporal limits of human perception. Efforts to add sensory capability to systems, or implement defeasible reasoning in artificial intelligence may make systems as enacting agents able to escape default incorrigoibility. But until and unless these memory practices are altered, computers enact their, and our promulgations, as incorrigoible certainties.

The No Fly list has been a running example, and was chosen to emphasize the interface between inert computational systems and the active humans which surround them and help shape lived reality to conform to their contents. The assemblage of computational timekeeping, we'll see, has a mixture of

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<sup>2</sup>Wendy Hui Kyong Chun, *Programmed Visions: Software and Memory* (Cambridge, MA: MIT Press, 2013).

human and non-human enacting agents and thereby allows us to understand more deeply what it might mean for computational systems to assume the role of enacting agents more pervasively. Ultimately, the reality described by an analysis of certainty in this system will be shown to be a result of the sum of its parts—parts which are mutable and therefore represent points of engagement. Information systems increasingly help enacting agents—human and nonhuman—shape social reality. Understanding the dynamics of these processes will allow us to realize both our own roles and the roles of the systems we use, design, and build. These roles produce social reality and yet offer a site of engagement to modulate it as well. Computational timekeeping is an information infrastructure, and its size and complexity may not make it the most promising site of engagement. At the end of the chapter and again in the Conclusion I'll describe future work on algorithms that might provide more fruitful and tractable sites for engagement with these dynamics.

## Part II Organization

Chapter 5 begins by describing the assemblage of computational timekeeping, a brief history of the standards which it operationalizes, its main constituent systems, its extent in the context of my analysis, and its operation. This is, roughly, an infrastructural inversion of an assemblage of systems, using a close reading of their linkages, which is normally invisible but critical to the modern world.<sup>3</sup> Computational time begins with atomic and astrological measurements, proceeds through scientific and administrative standards, enters network protocols and synchronization routines, and is reduced to a binary integer represented by electromagnetic charges on a disk or in RAM. This integer is directly consulted (and perhaps enacted, as we'll discuss) by computational systems, as in the most familiar application of translating it into human-readable datetimes.

With the system itself outlined, Chapter 6 selects three key instances of certainty-production within it, and analyze the roles played by involved systems in terms of the taxonomy of Chapter 4. These examples are chosen for the different and illustrative ways in which they employ the methods developed in Chapter 4. The analysis of certainty isn't, and can't be, the final word on any of these topics, but this final section shows how the approach I'm taking can engage with others.

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<sup>3</sup>Infrastructural inversion's relationship to my project was first discussed in Section 2.1 (page 48). See also Bowker and Star, *Sorting Things Out: Classification and Its Consequences*. On close readings of individual information systems see Melanie Feinberg, "Reading databases: Slow information interactions beyond the retrieval paradigm," *Journal of Documentation* 73, no. 2 (2017): 336–356.

## CHAPTER 5: COMPUTATIONAL TIMEKEEPING

Timekeeping is an ancient enterprise, originally primarily utilized in the context of determining the occurrence of days important to agriculture and religious festivals.<sup>1</sup> Computational timekeeping has enabled this practice to surround, structure, and unambiguously name essentially every instant of modern life. This chapter provides a short introduction to the topic to support the analysis of Chapter 6.

As might be expected, a system which promulgates and coordinates global standardized time is massively complex. Major (but by no means all) components of the assemblage of computational timekeeping are shown in Figure 5.1 (page 141). This shows the connection between scientifically defined and maintained time standards, the operating systems of individual devices, and network resources and protocols which synchronize computer clocks.<sup>2</sup> Also visible in the diagram is the Github code repository, which is where changes to the `tz` database are tracked for distribution into operating systems (discussed further with examples in Section 6.2). The exegesis in this chapter, though extensive, will still leave questions of how this assemblage of systems is able to produce certainty unanswered. The analysis of Chapter 6 will take this up by applying the techniques of Part I.

The chapter starts with a brief history of pre-computational Standard time before providing background on major components of the modern timekeeping assemblage. It concludes with remarks on the

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This chapter makes extensive use of preparatory material used in a previously published work, though to my knowledge little if any of the chapter's text is verbatim repetition. See Hauser, "UNIX Time, UTC, and Datetime: Jussivity, Prolepsis, and Incorrability in Modern Timekeeping." The sections on the `tz` database (especially Sections 5.3.3 and 6.2) have benefited greatly from unpublished collaborative research with Neal Thomas, to whom special thanks are due for a close annotated reading of the database's source code, which has made selecting examples from that codebase much easier.

<sup>1</sup>A longitudinal account of the history of timekeeping and calendars from ancient times onward is available from Anthony Aveni, *Empires of Time: Calendars, Clocks, and Cultures. Revised Edition* (Boulder, CO: University of Colorado Press, 2002).

effects of the deployment of scientific techniques to timekeeping, themes which are expanded upon in the analysis of Chapter 6.

## 5.1 A Brief History of Standard Time

This short history aims to contextualize the year 1972, when the modern form of Comprehensive Universal Time (UTC) was adopted. Prior to the adoption of the various forms of standardized time, which started in earnest during the 19<sup>th</sup> century, local time was determined by measuring the sun's apex at a given location, producing a practically infinite number of local times which varied according to longitude. The development of accurate timekeeping devices combined with the means of high-speed travel such as railroads produced a desire for standardization of times.<sup>3</sup>

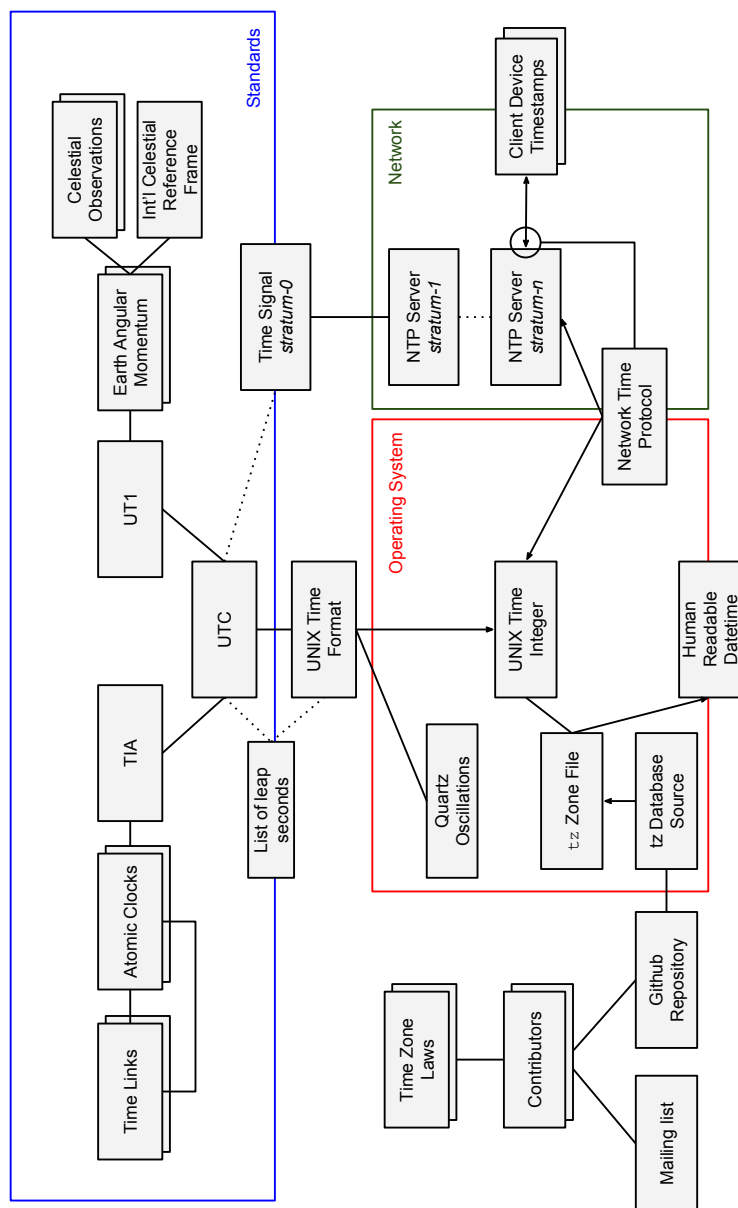
In the United States, one of the first such proposals came from Charles Dowd in the 1860s.<sup>4</sup> His proposal, though initially endorsed by railroad representatives, languished but was subsequently updated in the 1870s by Samuel Fleming. Fleming's expanded proposal involved dividing the world's 360 degrees of latitude into 24 segments, each of which would have its time standardized to be the mean local time across this expanse. In other words, local (solar) time in the middle of the region would be imposed upon all other locales within a given zone. This division conveniently divided the world into timezones each having an hour difference. Had the convention of time measurement been something other 24 hours per day, presumably the number of global time zones would've been selected differently. The proposal included the maintenance of local time alongside what Fleming called Terrestrial Time, a nod to many people's preference for maintaining local solar time. Under this proposal, clocks would have two sets of dials, one for local time and one for Terrestrial time. The latter would be used for railroad, telegraph, or other precision needs, while local time would be used for social appointments. This is striking in that it shows an amazing deference to the ingrained sense of local time, which is all but nonexistent in modern

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<sup>2</sup>For a technically and materially oriented approach centered on timekeeping devices, see James Jespersen and Jane Fitz-Randolph, *From Sundials to Atomic Clocks: Understanding Time and Frequency* (Mineola, NY: Dover Publications, Inc., 1999).

<sup>3</sup>Ian R Bartky, *Selling the True Time: Nineteenth-Century Timekeeping in America* (Stanford, CA: Stanford University Press, 2000).

<sup>4</sup>R Newton Mayall, "The Inventor of Standard Time," *Popular Astronomy* 50 (1942): 204.



**Figure 5.1:** A schematic representation of the assemblage of computational timekeeping.

times. The strangeness of the concept of Terrestrial Time to citizens of the 1870s is a mirror image in the strangeness of the notion of local solar time today.

Regardless, a version of Fleming’s proposal was adopted in 1883 at the General Time Convention in Chicago.<sup>5</sup> This council of railways agreed to all use the new system, replacing the various standardization systems member companies were using at the time. Though not mandated, synchronization of clocks to railway time became an important practical step to help rail passengers make their connections. This enabled the partial adoption of this new system throughout the United States.

In 1918, in the midst of World War I, the United States Congress passed the Standard Time Act, mandating the use of Standard Time for all laws and interstate commerce. While not prohibiting private, intra-state use of local time, this act further insinuated the standard into state legislative activities. The citizen user of local time became increasingly isolated in defining noon as the apex of the sun.

The Standard Time Act also instituted Daylight Saving Time in the United States, a controversial and (initially) short-lived provision that extended waking daylight hours in the summer months.<sup>6</sup> This will be discussed separately below, as its promulgation is much more complicated, especially until its final adoption in 1966. This was followed in 1972 by the adoption of Coordinated Universal Time (UTC).<sup>7</sup> Together, the promulgation of these various standards changed the behavior of ordinary people to accept standardized, easily comparable time denotations. They were direct preconditions for the development of the UNIX time data format and other computational timekeeping technologies, which have proliferated around the world.

## 5.2 Scientific Time Standards

The development and promulgation of scientific time standards predates the computational timekeeping enterprise, but is in retrospect its necessary precondition. Practices of computational timekeeping don’t

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<sup>5</sup>This is memorialized in the `tz` database, we’ll see below, as the first entry in most US zone definitions used to generate human-readable datetimes in computers.

<sup>6</sup>On the topic of Daylight Saving Time see Michael Downing, *Spring Forward: The Annual Madness of Daylight Saving* (Berkeley, Ca: Counterpoint, 2009); David Prerau, *Seize the Daylight: The Curious and Contentious Story of Daylight Saving Time* (New York, NY: Avalon Publishing Group, 2005).

<sup>7</sup>For more on the development of standard time globally, Bartky has produced perhaps the most compelling and scholarly accounts of the development of standard time movements in the US and Europe. Ian R Bartky, *One Time Fits All: Campaigns for Global Uniformity* (Stanford, CA: Stanford University Press, 2007).

always merely recapitulate scientific standard time, but practically all methods in modern use utilize them as a kind of shared backbone, the terms in which their work is stated. So, as a prelude to considering major components of computational timekeeping, this section will describe major components of scientific standard time, and detail the methods of its promulgation.

### 5.2.1 Empirical Time: TAI & UT1

UTC is a boundary object produced by the promulgators of scientific standard time, professional metrologists at the BIPM. The standards utilized in its creation, TAI and UT1, are rarely considered by those not involved in metrology or the production of standards and, consequently, don't carry UTC's negotiated meanings in political, computational, and quotidian contexts. In the terms of the present investigation, UTC is a place to be moved on from, designed for the enactment of certainty. Like all promulgations, TAI and UT1 instantiate a technique of forgetting which collapses the complexity of their creation into publications like *Circular T* or electromagnetic signals of precise frequencies.<sup>8</sup> Produced as it is by the scientific community, this technique of forgetting bottoms out in measurements.

### 5.2.2 Calculating Duration with TAI

TAI is constructed through the incorporation of empirical measurements of duration from around 100 time laboratories collectively containing several hundred high-precision clocks around the globe (a map is provided in Figure 6.2 (page 158)). According to the BIPM,

The long-term stability of TAI is assured by weighting the participating clocks. The scale unit of TAI is kept as close as possible to the SI second by using data from those national laboratories which maintain the best primary caesium standards.<sup>9</sup>

The SI standard second (discussed further on page 159) supports the act of incorrigible declaration of this unit with one of reconcilable measurement. Scientific techniques of forgetting govern this change, which evinces the metrological instinct to base scientific units on as few, and as accurate, measurements as possible.

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<sup>8</sup>B G Quinn and E J Hannan, *The Estimation and Tracking of Frequency* (Cambridge, UK: Cambridge University Press, 2001) provides a technical introduction to the measurement of frequency.

<sup>9</sup>“International Atomic Time (TAI),” BIPM, accessed October 9, 2019, <https://www.bipm.org/en/bipm-services/timescales/tai.html>

### 5.2.3 Locating the Earth in Spacetime with UT1

Duration, however is insufficient for the provision of time. While seconds are defined precisely as a specific duration, other units of time important to daily life are not evenly or reliably composed of a fixed number of seconds. A day, the duration of a single revolution of the earth, traditionally held to consist of 86400 seconds, does not exactly equal this duration (this is a more obscure corollary to the fact that years are not composed of exactly 365 days). What's more, the precise duration of a day varies over time with the angular momentum of the earth, which is currently slowing. Cultural practices that rely on the assumption of even divisibility of days into seconds and years into days are enabled by the invisible efforts of metrologists and the faithful enactment of their promulgations by computational timekeeping devices.

The measurement of the earth's angular momentum (*i.e.*, how fast it is turning on its axis) requires establishing an invariant frame of reference. This frame of reference is established by the International Celestial Reference Frame (ICRF), itself produced by the astronomical observation of the quasars and other stable extragalactic sources of radiation.<sup>10</sup> In short, UT1 precisely tracks the orientation of earth so as to determine when a full revolution has occurred.<sup>11</sup>

### 5.2.4 Coordinating Duration and Location: UTC

Given that the the number of SI seconds isn't evenly divisible into the length of a day, a process of coordinating these two values is required to maintain a calendrical system which declares that there are 86,400 seconds in a day. This is accomplished with the periodic insertion of 'leap seconds,' designed to keep TAI and UT1 within  $\pm 0.9s$  of each other, which produces UTC. The BIPM describes UTC on its website as follows.

Coordinated Universal Time (UTC), maintained by the BIPM, is the time scale that forms the basis for the coordinated dissemination of standard frequencies and time signals. The UTC scale is adjusted by the insertion of leap seconds to ensure approximate agreement with the time derived from the

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<sup>10</sup>Chopo Ma and Martine Feissel, eds., *Definition and realization of the International Celestial Reference System by VLBI astrometry of extragalactic objects*, technical report {IERS Technical Note 23} (Central Bureau of IERS – Observatoire de Paris, 1997). See also "The International Celestial Reference Frame (ICRF)," ICRF, accessed October 9th, 2019, <https://www.iers.org/IERS/EN/DataProducts/ICRF/ICRF/icrf.html>.

<sup>11</sup>This improves upon earlier efforts from the 18<sup>th</sup> and 19<sup>th</sup> centuries to calculate the duration of a second using observations of the Moon to establish a reference frame.



rotation of the Earth. These leap seconds are inserted on the advice of the International Earth Rotation and Reference Systems Service (IERS).

Physical realizations of UTC – named UTC(k) – are maintained in national metrology institutes or observatories contributing with their clock data to the BIPM.<sup>12</sup>

The earth’s rotation is currently slowing, so all 38 leap seconds to date have been positive. If metrologists are still actively maintaining these standards when the earth’s rotation speeds up, negative leap seconds will be added to keep TAI and UT1 within  $\pm 0.9s$ .

#### 5.2.5 The Current State of Universal Standard Time

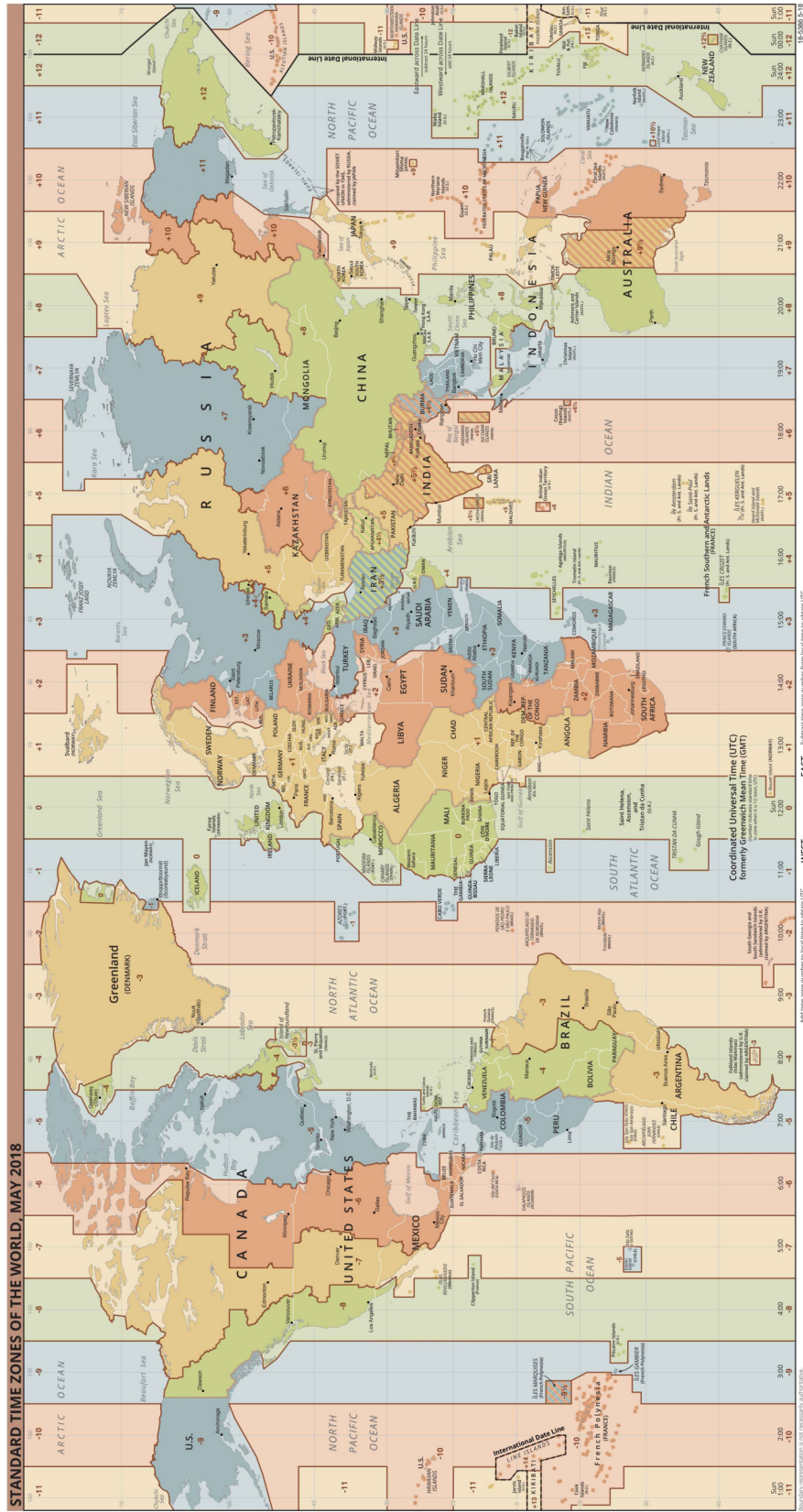
Standard time, which could be seen as a set of synchronization behaviors, grew into the various officially promulgated Universal Time standards. The availability of scientifically defined universal time formed a substrate for a proliferating array of administratively declared time zones, which encode synchronization behaviors but have a social reality beyond them. Figure 5.2 on the following page shows the resulting complexity.

This complexity has been enabled by both the scientific definition of standard time and techniques of computational timekeeping, particularly the `tz` database (discussed in Section 6.2). Standard time was historically envisioned as neat lines drawn along the map at regular intervals according to longitude, so that all world timezones would be exactly 1 hour from each other, and, on average, equidistant from their local solar times. But the substrate of universal standard time when combined with computational timekeeping has enabled a practically endless array of variations from this ideal, which are plainly visible by the interruptions and articulations of the straight vertical lines in Figure 5.2.

With a history of standard time and a basic description of modern universal time standards completed, we can now turn to the components of computational time. The adoption of UTC in 1972 was portentous for the development of computational timekeeping. Computational timekeeping, and networked computing more broadly, has in turn influenced and accelerated the adoption of standardized time to its current near-ubiquitous state.

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<sup>12</sup>“Approximation to UTC”, BIPM, accessed October 9, 2019, <https://www.bipm.org/en/bipm-services/timescales/time-server.html>



**Figure 5.2:** Standard time zones of the world as of May 2018. (Central Intelligence Agency, *The World Factbook 2019*, <https://www.cia.gov/library/publications/resources/the-world-factbook/>. US Public Domain.)

### 5.3 Major Components of Computational Timekeeping

The scientific standards define what is kept by the activities of timekeeping. As such, they are integral to the practices of computational timekeeping, but they are themselves insufficient. This section highlights key standards and technologies which articulate computational processes to time standards, enabling computational timekeeping as a simultaneously global (network-scale) and local (device-scale) activity. Standardized time was initially promulgated via published records, telegraph, and radio waves: whatever the then-current state of the art communication technology might be. Networked promulgation of standardized time will be shown to be merely the latest in a line of promulgation practices.

#### 5.3.1 UNIX Time Integers: Device-Scale Time

Initially conceived as a linear-time count of the number of seconds since an epoch, the standard was quickly revised to be defined an encoding of UTC. Since the latter is a periodically reconciled approximation of International Atomic Time (TAI) through the use of leap seconds calculated from the actual variation in the speed of rotation of the earth, there is considerable complexity in the modeling. Formally, UNIX time is the number of SI seconds elapsed since 1 January 1970, minus the number of UTC leap seconds. This makes the system incapable of unambiguously distinguishing leap seconds from their preceding seconds. In other words, leap seconds are not added to a UNIX time integer when they are declared. It is unclear if this inherent ambiguity has any practical consequences, but leap seconds are accounted for in the `tz` database, so that accurate UTC-based datetimes can be displayed.

The initial implementation of this time defined an epoch of Jan 1, 1971, and stored the number of 1/60th seconds since that epoch. This was shortsighted, as a 32 bit integer for this representation would overflow (see below) after less than two years. In connection with the adoption of UTC in 1972, the epoch was re-defined to 1972 and the format was changed to store seconds, providing an overflow date much further in the future.

The representation of this number as a signed 32 bit binary integer in some systems has the interesting consequence of creating an inevitable overflow error in the year 2038, which is  $2^{32}$  seconds after Jan 1, 1970. Systems which represent time in this way, instead of the increasingly more common 64 bit binary integer, would erroneously display the date as December 13th, 1901 after the overflow. The space probe Deep Impact was lost in 2013, seven years after its 2005 launch, due to a similar problem. The software

on the spacecraft likely represented the tenth-seconds since an epoch of Jan 1, 2000 as a 32 bit integer, resulting in an overflow on September 20, 2013.<sup>13</sup>

### 5.3.2 Network Time Protocol (NTP): Network-Scale Time

Modern networked devices utilize synchronization servers to adjust their record of local time periodically. Utilizing the Network Time Protocol (NTP), phones configured to do so will send their inventories of seconds to a server that will average the times reported by its clients and respond to each client with a correction delta, which each phone will then use to adjust its local time.<sup>14</sup> The synchronization server treats each time source's timestamp as a measurement, which is then averaged into a correction value via a ledger process determined by its calibration formula. This synthesized time is then reduced into an instantaneous time integer and sent back alongside the timestamp included in the original NTP client requests. The clients take this correction value as directed by their settings, which could use a single server as a roster of calibration, or utilize multiple servers, arrayed as ledger entries, to distinguish *truechimers* and *falsetickers* (discussed further on page 170). The certainty if the NTP server's calibration deltas is established by the clients that treat it as such.

#### *A History of NTP*

David Mills published a first-person account of the development and spread of NTP as of 2003.<sup>15</sup> In it, he traces the first development of the protocol's ideas to 1979, and was involved in writing one of the first implementations of the protocol, which came to be known as NTP Version 0, in 1985.<sup>16</sup> This history is presented as a personal recollection, but gives an excellent overview of the many factors influencing the protocol's development.

For instance, the methods which individual computers used to keep their integers ticking at 1 Hz (by definition, one cycle per second) varied over time in ways that forced the protocol to evolve. Part of NTP's operation is in so-called *clock discipline*, adjustments to the logical or hardware state of a local

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<sup>13</sup>Dan Vergano, "NASA Declares End to Deep Impact Comet Mission," *National Geographic*, September 2013,

<sup>14</sup>David L Mills, *Computer Network Time Synchronization: The Network Time Protocol on Earth and in Space*, Second Edition (Boc Raton, FL: CRC Press, 2010).

<sup>15</sup>David L Mills, "A Brief History of NTP Time: Memoirs of an Internet Timekeeper," *SIGCOMM Comput. Commun. Rev.* (New York, NY, USA) 33, no. 2 (April 2003): 9–21.

<sup>16</sup>*Ibid.*, 9-10.

timekeeping device. “In the early days most computer hardware clocks were driven by the power grid as the primary timing source,” and the nature of the synchronous power grids in use in many regions, “so all NTP had to do was calibrate the constant offsets.”<sup>17</sup> As quartz oscillators were introduced, the variations in clock speed between machines required that “the NTP clock discipline algorithm was modified to adjust the frequency as well as the time.”<sup>18</sup> As the clock discipline algorithm grew in complexity, and in pursuit of ever higher temporal resolution, companies like Sun and DEC incorporated parts of it into the kernel of their computers’ operating systems. In another case, the material conditions of transatlantic Internet required modifying the evolving algorithm to utilize nonlinear methods to suppress spikes.

The growth of the network has also changed the network topology of the system. Originally, all NTP servers connected directly to servers attached to high-precision time signals. As the demand for network time has grown, layers of secondary servers have grown up to handle client requests that would otherwise overwhelm the primary servers. The degradation of fidelity associated with this change has been partially mitigated by the potential for clients to connect to a large number of secondary servers, which can theoretically produce higher accuracy than any single secondary server. The proliferation of servers has also demanded that NTP incorporate algorithms for clients to select amongst the many servers and determine which might be mis-calibrated. This process is revisited in the analysis of certainty in Section 6.3.

Mills concludes by speculating about the future of network timekeeping in the 21st century. Writing in 2003, he saw that present practices had all but maximized the potential of then-current hardware. Mills and Kamp were able to demonstrate consistency of tens of nanoseconds with a single computer directly receiving a time signal from a cesium clock,<sup>19</sup> but Mills speculates (rightly, it would seem) that few applications would demand this level of precision. Mills concludes by speculating that authenticated timestamping services, perhaps as a fee-for service provided by NIST or other timekeeping agencies, might play a role in security or authentication practices. While this interestingly recalls Bartky’s history

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<sup>17</sup>Ibid., 14.

<sup>18</sup>Ibid.

<sup>19</sup>David L Mills and Poul-Henning Kamp, “The nanokernel,” in *Proceedings of the Precision Time and Time Interval (PTTI) Applications and Planning Meeting* (Reston, VA, November 2000), 423–430.

of fee-for-service time signals in the 19th century,<sup>20</sup> it seems that the NIST Authenticated Time Service remains free, albeit with a required postal correspondence to receive cryptographic keys.<sup>21</sup>

### 5.3.3 `tz` Database: From Time to Datetime

UNIX time itself is based on a duration in seconds from a fixed starting point. Pure duration, though complicated in the ways discussed above, is still considerably less complex than the designation of dates and clock times by various administrative authorities around the world. The modeling of administrative time zones has developed into a massive undertaking due to the complexity of administrative time zones. IANA maintains a timezone database which contains a historical account of timezones intended for practical usage. This timezone database is subsequently used in most UNIX-like systems' time and date programs for the translation of UNIX time into human-readable dates and times. As a model of administrative designations, the database can be incomplete or even erroneous in places, but serves as an essential tool for displaying the correct time and date for a specific timezone. An introduction to the theory and pragmatics of the `tz` database from documentation in the source code is provided as Appendix A.

Interestingly, the database is inherently historical. That is, it accounts for the changing designations of timezones alongside changes in administrative policy, allowing it to model, for instance, the change in Daylight Saving time, as extended in the US in 2005. The code which accomplishes this is provided in Table 5.1 on the next page.<sup>22</sup> The maintainers of the database extensively document their changes in comments within the code. In some cases, like that shown in Table 5.2 on the facing page, excerpts of laws are included verbatim in the code.

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<sup>20</sup>Bartky, *Selling the True Time: Nineteenth-Century Timekeeping in America*.

<sup>21</sup>"NIST Authenticated Time Service," NIST, accessed October 9, 2019, <https://www.nist.gov/pml/time-and-frequency-division/time-services/nist-authenticated-ntp-service>.

<sup>22</sup>Citations of `tz` database source will use the following format: (tzdb/filename). Citations of the `tz` database's contents in this paper use the 2017c version of the software, downloaded from <https://www.iana.org/time-zones>; see Paul Eggert, *IANA Time Zone Database*, October 2017. For ease of reference, the plaintext files are served at [http://elliotthausser.com/tzdb/\[filename\]](http://elliotthausser.com/tzdb/[filename]), so for example `theory.html` is available at <http://elliotthausser.com/tzdb/theory.html>. Line numbers, when specified, are indicated by LXXX–YYY. Lines prefixed with # indicate comments, which are designed to be human-readable and are ignored during compilation. Readers can also consult a download the source directly or refer to the official project repository at <https://github.com/eggert/tz>.

#	Rule	NAME	FROM	TO	TYPE	IN	ON	AT	SAVE	LETTER/S
Rule	US		1918	1919	-	Mar	lastSun	2:00	1:00	D
Rule	US		1918	1919	-	Oct	lastSun	2:00	0	S
Rule	US		1942	only	-	Feb	9	2:00	1:00	W # War
Rule	US		1945	only	-	Aug	14	23:00u	1:00	P # Peace
Rule	US		1945	only	-	Sep	lastSun	2:00	0	S
Rule	US		1967	2006	-	Oct	lastSun	2:00	0	S
Rule	US		1967	1973	-	Apr	lastSun	2:00	1:00	D
Rule	US		1974	only	-	Jan	6	2:00	1:00	D
Rule	US		1975	only	-	Feb	23	2:00	1:00	D
Rule	US		1976	1986	-	Apr	lastSun	2:00	1:00	D
Rule	US		1987	2006	-	Apr	Sun>=1	2:00	1:00	D
Rule	US		2007	max	-	Mar	Sun>=8	2:00	1:00	D
Rule	US		2007	max	-	Nov	Sun>=1	2:00	0	S

**Table 5.1:** `tz` database rules tracking United States Daylight Savings time. The most recent update to US Daylight Savings time was due to the Energy Policy Act of 2005 and took effect in 2007, moving the start of Daylight Savings to the second Sunday of March (second to last line) and the end to the first Sunday of November (last line). See Table 5.2 for an excerpt of the relevant Act reproduced in the `tz` database source. (tzdb/northamerica, L149–162)

```
# From Arthur David Olson, 2005-08-09
# The following was signed into law on 2005-08-08.
#
# H.R. 6, Energy Policy Act of 2005, SEC. 110. DAYLIGHT SAVINGS.
# (a) Amendment.--Section 3(a) of the Uniform Time Act of 1966 (15
# U.S.C. 260a(a)) is amended--
# (1) by striking "first Sunday of April" and inserting "second
# Sunday of March"; and
# (2) by striking "last Sunday of October" and inserting "first
# Sunday of November".
# (b) Effective Date.--Subsection (a) shall take effect 1 year after the
# date of enactment of this Act or March 1, 2007, whichever is later.
# (c) Report to Congress.--Not later than 9 months after the effective
# date stated in subsection (b), the Secretary shall report to Congress
# on the impact of this section on energy consumption in the United
# States.
# (d) Right to Revert.--Congress retains the right to revert the
# Daylight Saving Time back to the 2005 time schedules once the
# Department study is complete.
```

**Table 5.2:** Excerpt from the Energy Policy Act of 2005 reproduced in the source of the `tz` database. (tzdb/northamerica, L265–283)

The source of the `tz` database goes into great detail about often obscure administrative decisions about time zones and Daylight Savings time. As an example, Table 5.3 shows the code which memorializes this administrative decree, citing a US Department of Transportation publication and a news article from a nearby paper. The resulting `America/North_Dakota/Beulah` entry allows computer clocks in this region to both display the correct Datetime for the region currently and accurately reflect the Datetime of historical timestamps before this change.

```
# From Josh Findley (2011-01-21):
# ...it appears that Mercer County, North Dakota, changed from the
# mountain time zone to the central time zone at the last transition from
# daylight-saving to standard time (on Nov. 7, 2010):
# https://www.gpo.gov/fdsys/pkg/FR-2010-09-29/html/2010-24376.htm
# http://www.bismarcktribune.com/news/local/article_1eb1b588...4c03286.html

# From Andy Lipscomb (2011-01-24):
# ...according to the Census Bureau, the largest city is Beulah (although
# it's commonly referred to as Beulah-Hazen, with Hazen being the next
# largest city in Mercer County). Google Maps places Beulah's city hall
# at 47 degrees 15' 51" N, 101 degrees 46' 40" W, which yields an offset
# of 6h47'07".

Zone America/North_Dakota/Beulah -6:47:07 - LMT 1883 Nov 18 12:12:53
                                -7:00   US      M%sT   2010 Nov  7  2:00
                                -6:00   US      C%sT
```

**Table 5.3:** Comments and definition for the `America/North_Dakota/Beulah` zone in the `tz` database. (tzdb/northamerica, L404–420)

The note from Andy Lipscomb justifies naming the Zone after Beulah, the largest town in the region, and records using Google Maps to calculate the longitude used to determine the offset of -6:47:07 UTC representing local solar time before the adoption of standard time in 1883.

The `tz` database will be analyzed further in Section 6.2.

## 5.4 Timekeeping as the Infrastructure of Temporal Rationality

The ‘coordination’ of duration and the phenomena of night and day via UTC is necessitated by the fact that a day is not, in fact 86,400 seconds long. Similarly, the periodic insertion of leap days into the calendar is a technique demanded by the fact that the duration of a revolution of the earth around the sun is not divisible by the duration of a rotation of the earth around its axis. The extremely complex coordination which constructs scientific standards of time projects the rationality of integers, *i.e.*, ratios, onto the



continuity of spatiotemporal phenomena, where they do not natively exist. That science is mobilized to enable and account for this process shows the interesting role it plays in rendering phenomena of spacetime comprehensible. Discussed earlier as *divisibility*, this process quite literally enables time to be *rational*: composed of whole number ratios. That the various units of time are not, in fact, rational, has become as hidden and foreign a concept as that of solar noon.

Colloquially, days are used as a fixed unit of duration. In many contexts, the fact that there are small and continuous changes in the earth's angular momentum doesn't matter: the temporal unit of a day as it is used colloquially is sufficient. Scientific techniques of measurement, precision, and standardization render the past usage of human-scale durations such as days, weeks, or years as actions of satisficing: more precision is possible, but not profitable. With the adoption of scientific standards, colloquial usage of these terms is articulated to a backbone of scientific precision, allowing any colloquial usage of conventional human-scale durations to be restated in terms of scientific temporal standards. There is immense power in enabling this translation, and in the fact that modern computers are all equipped to carry it out. The mapping of duration onto human circadian experience is the key technical work performed by scientific time standards, and a key component of the system's role in producing certainty, to which we'll now turn.

## CHAPTER 6: COMPUTATIONAL TIMEKEEPING & THE PRODUCTION OF CERTAINTY

Chapter 5 provides an infrastructural inversion of several interconnected systems constituting computational timekeeping along with historical and technical exegesis. This has prepared the way for the analysis of certainty in this chapter. As discussed in Chapter 4, the taxonomy can be applied in conjunction with a range of methods of articulating systems. In the case of computational time, a primarily historical and artifactual approach to the systems has provided inroads to a complicated and manifold subject.<sup>1</sup> The limitations of my investigation into these systems notwithstanding, the contours are visible enough to apply the taxonomy to specific subsystems of the assemblage. Chapter 5 plays the role that any initial account of a system or assemblage of systems might, letting this chapter serve as a model for the analysis of certainty with the taxonomy.

### Three Subsystems, Three Analyses

The three subsystems analyzed here have distinct profiles when analyzed with the taxonomy. TAI begins with measurements and ends with an incorrigible Roster, suitable for incorporation into other time standards such as UTC. The  $\mathfrak{t}\mathfrak{z}$  database takes the incorrigible declarations of governments and other authorities which institute time zones, jussively reduces them to computational rules, and maintains a mechanism for attributing each change (*i.e.*, enabling the system to be given-as a Roster). NTP constitutes a method of synchronizing network clients' UNIX time integers through the estimation of temporal drift and network latency between them. Yet, as we will see, the techniques of historically licensed forgetting

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<sup>1</sup>On the methodology of materiality for technical artifacts, see David Ribes, "Materiality Methodology, and Some Tricks of the Trade in the Study of Data and Specimens," in *digitalSTS*, ed. Janet Vertesi and David Ribes (Princeton, NJ: Princeton University Press, 2019), 43–60. A subsequent ethnography of human actors involved in producing scientific time standards, network synchronization protocols, or the  $\mathfrak{t}\mathfrak{z}$  database would undoubtedly yield further insight (and, thereby, constitute a full *trace ethnography* of those portions of the assemblage, as described in R. Stuart Geiger and David Ribes, "Trace Ethnography: Following Coordination through Documentary Practices," in *2011 44th Hawaii International Conference on System Sciences* (January 2011), 1–10).

employed by the  $\tau z$  database ultimately are taken-as a Roster by the computational systems which enact them.

That so many of the systems within the assemblage of computational timekeeping are ultimately given-as Rosters should be understandable. The goal of timekeeping is to unambiguously provide an answer the question, “what time is it?”, and as discussed above this question demands a kind of standing declaration. Yet we’ll see inventories of empirical measurement installed at the base of these processes, a configuration that distinguishes the peculiarly scientific nature of the standards which form the substrate of timekeeping practice. The techniques of forgetting active at various stages of this process and the differing licenses these techniques claim show that the *possibility* of recovery of what is lost in the jussive production of unambiguous standards has cultural importance for the maintainers of timekeeping infrastructure. What this possibility consists in, and the production of inscriptions required to claim the license to enact forgetting will differ across all of these systems. A final example of the enactment of time will show how the final collapse of enactment at a personal level can render all of this deep history, the *potential* of remembering, distant and practically inaccessible.

## **6.1 From Inventory to Ledger to Roster: The Construction of TAI**

The ultimate product of timekeeping utilized by non-technical users is UTC, and UTC (or the various local timezones that it scaffolds) forms a boundary to most inquiry into timekeeping. Yet, as is appropriate to an analysis of certainty, we can continue on and trace the techniques that inform the promulgation of UTC. The techniques of forgetting employed in the construction of UTC lead to standards themselves constructed from hundreds or thousands of empirical measurements and leaving massive amounts of documentation, protocols, and justifications in their wake. That the techniques ‘bottom out’ in empirical measurement is precisely what makes these standards scientific. That is, the forgetting inherent in the promulgation of an incorrigible standard is licensed by the corrigibility and techniques of reconciliation employed at the level of the measurements themselves.

The reconciliation of anomalies accomplished by weighting and adjusting the various measurements produced by the world’s atomic clocks is hidden from consumers of UTC by its complexity and invisible

ubiquity to most users of computationally driven clocks.<sup>2</sup> The precision with which the techniques of forgetting it instantiates are documented and described are, however, what make its forgetting *scientifically licensed*.

### 6.1.1 Why TAI?

TAI is a particularly fruitful site of the analysis of certainty, in that it requires the use of all three classes of the Roster, Inventory, and Ledger taxonomy to appropriately describe its construction. The output of any single atomic clock is given as an inventory, a reconcilable quantity of atomic vibrations observed by the clock. This value is then taken-as a ledger-entry to form a formal report of the measurements of each atomic clock. These attributed claims are then mathematically processed into what is given-as Roster, the TAI standard as broadcast in electromagnetic symbols and as published in BIPM *Circular T*.

### 6.1.2 The Promulgation of TAI

TAI is promulgated via the publication of electronic documents called *Circular T* and numbered serially, with the first *Circular T* published in March, 1988. The BIPM describes the publications on their website as follows.

BIPM *Circular T* is the monthly publication of the Time Department that provides traceability to Coordinated Universal Time (UTC) for the local realizations  $UTC(k)$  maintained by national institutes. *Circular T* provides the values of the differences  $[UTC - UTC(k)]$  every five days, for about 80 institutes regularly contributing clock and clock comparison data to the BIPM. It includes also other information relevant to the computation of these values.

BIPM *Circular T* has been published without interruption since 1 March 1988. The quality of the results has increased progressively following the progress made in clocks and time and frequency transfer techniques, in parallel with the constant improvement in the treatment of the data at the BIPM. The contents and presentation of *Circular T* have also evolved; from January 2016 an interactive HTML version gives access to complete information about the local time scales and the time links used for clock comparison.<sup>3</sup>

While the contents of *Circular T* are human-readable (see Figure 6.1 on the facing page), a guide is provided for the automatic extraction of data from these files.<sup>4</sup> Some of the content is provided in PDF or

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<sup>2</sup>The weights of each individual clock used in the calculation of TAI are given in monthly reports available via FTP at <ftp://ftp2.bipm.org/pub/tai/other-products/weights/>.

<sup>3</sup>“FTP server of the BIPM Time Department,” BIPM, accessed October 9, 2019, <https://www.bipm.org/en/bipm-services/timescales/time-ftp/Circular-T.html>.

<sup>4</sup>Aurélié Harmegnies, *Circular T ASCII Format Description for Automatic Reading*, technical report v0.1 (Bureau des Poids et Mesures, March 2017).

HTML format, styled for human readability, but many of the official reports are served via FTP, a protocol primarily used for the transfer of files between computers. Each of these consists in a promulgation of the standard, enabled for taking-as such by different kinds of agents.

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THE INTERGOVERNMENTAL ORGANIZATION ESTABLISHED BY THE METRE CONVENTION  
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The contents of the sections of BIPM Circular T are fully described in the document "Explanatory supplement to BIPM Circular T" available at [ftp://ftp2.bipm.org/pub/tai/publication/notes/explanatory\\_supplement\\_v0.2.pdf](ftp://ftp2.bipm.org/pub/tai/publication/notes/explanatory_supplement_v0.2.pdf)

1 - Difference between UTC and its local realizations UTC(k) and corresponding uncertainties.  
From 2017 January 1, 0h UTC, TAI-UTC = 37 s.

Date 2019	0h UTC	JUL 30	AUG 4	AUG 9	AUG 14	AUG 19	AUG 24	AUG 29	Uncertainty/ns			Notes
MJD		58694	58699	58704	58709	58714	58719	58724	uA	uB	u	
Laboratory k		[UTC-UTC(k)]/ns										
AOS (Borowiec)		-12.2	-9.3	-5.1	-0.4	1.7	3.5	4.4	0.3	4.1	4.2	
APL (Laurel)		-1.1	-0.4	-1.2	-1.6	-0.4	-0.1	0.1	0.3	11.1	11.1	
AUS (Sydney)		-240.9	-236.7	-253.2	-252.6	-253.4	-266.6	-281.7	0.3	6.5	6.5	
BEV (Wien)		-12.1	-3.4	4.9	10.0	19.8	27.6	37.4	0.5	3.3	3.4	
BIM (Sofiya)		11370.3	11396.4	11426.7	11441.9	11454.3	11477.8	11498.9	0.7	2.7	2.8	
BIRM (Beijing)		13.0	13.3	4.9	2.2	5.9	7.8	5.0	0.7	2.6	2.6	(1)
BOM (Skopje)		-2316.7	-2344.0	-2364.7	-2387.0	-2413.6	-2434.7	-2462.6	1.5	8.4	8.6	
BY (Minsk)		0.8	1.3	2.3	2.8	4.1	4.9	5.6	1.5	12.1	12.2	
CAO (Cagliari)		-	-	-	-	-	-	-				
CH (Bern-Wabern)		0.1	0.4	0.9	1.2	2.8	1.6	2.6	0.5	2.1	2.1	
CNES (Toulouse)		6.1	16.5	16.9	18.7	15.2	18.7	26.3	0.3	2.7	2.7	
CNM (Queretaro)		0.3	-2.1	5.5	8.8	8.8	2.7	6.5	2.5	11.2	11.5	
CNMP (Panama)		9.9	7.5	-1.3	-1.2	17.6	10.2	15.7	0.7	7.4	7.5	
DFNT (Tunis)		10085.7	10282.0	10486.3	10703.9	10894.5	11096.4	11310.2	0.7	20.0	20.0	
DLR (Oberpfaffenhofen)		861.0	882.2	892.3	905.3	919.8	933.4	947.0	0.7	3.3	3.4	
DMDM (Belgrade)		-15.2	-13.3	-8.6	-4.8	2.4	15.8	-	0.3	3.3	3.4	
DTAG (Frankfurt/M)		-93.3	-95.7	-95.2	-91.7	-88.7	-89.9	-90.8	0.3	20.0	20.0	
EIM (Thessaloniki)		6.2	9.0	2.7	8.4	7.8	-1.5	14.3	3.0	11.2	11.6	
ESTC (Noordwijk)		-0.6	0.3	0.8	0.6	1.2	1.7	1.2	0.3	3.0	3.1	
HKO (Hong Kong)		53.5	60.7	65.3	67.8	66.2	57.6	68.8	0.5	7.8	7.8	(2)
ICE (San Jose)		77.1	55.6	35.5	28.0	20.5	3.2	-4.2	5.0	20.0	20.6	
IDN (Serpong-Tangerang)		1361.2	1370.8	1375.8	1385.7	1393.5	1399.9	1404.1	0.7	2.7	2.8	(3)
IFAG (Wetzell)		-924.8	-940.4	-958.8	-956.8	-952.6	-947.7	-941.5	0.3	5.2	5.2	

**Figure 6.1:** A selection from *Circular T* #380, published on September 19, 2019. The various *Circular T* documents, served via FTP, are one way TAI is promulgated. Each *Circular T* scientifically justifies the simplification of this work into electromagnetic time signals, which is how TAI is electronically consulted by most automated systems. Full list of *Circular T* promulgations available at <ftp://ftp2.bipm.fr/pub/tai/publication/cirt/>

TAI is a worldwide scientific enterprise, with contributing labs on every continent except for Antarctica. Figure 6.2 on the next page shows the locations and link types (discussed further below) for the laboratories which contribute measurements used in the TAI standard, many of which operate multiple clocks.

[illegible]

**Figure 6.2:** Geographic locations of TAI-contributing clocks in 2018. (“BIPM Annual Report,” BIPM, December 2018 <https://www.bipm.org/en/bipm/tai/annual-report.html>, Table 4.)

### 6.1.3 A Ledger of Inventories, Used to Construct a Roster

*Circular T* reports are extremely thorough in identifying and describing each lab by a code (see Figure 6.1 (page 157)). This allows each participating lab's measurements to be tracked over time. The tracking even goes one layer deeper: since most labs have more than one clock in operation, each clock is also identified and tracked over time. This allows statistical methods to adjudicate the manifold measurements which constitute TAI as mathematical *claims*. Various factors, from the relativistic effects of elevation to uncertainty due to calibration can then be used to deterministically weight these claims.

### 6.1.4 Measurement Licenses Scientific Forgetting

Ultimately, TAI cannot be taken in its full constituent and licensing complexity. The network of cross-linked documentation, data, file servers, and data visualizations generated in its production are not suitable for enactment *as a standard*. Instead, TAI time signals are broadcast by governments and laboratories around the world, and for most purposes this form of promulgation is sufficient, notwithstanding the nanoseconds of estimated error that are part of any given realization of the standard. The efforts of the BIPM in incorporating evaluating, combining, calibrating, tuning, and weighting TAI's constituent measurements, and the voluminous descriptions it produces of these processes, are collapsed into a single unambiguous signal at each of these broadcast sites. The complexity which produced these signals must be materially forgotten during TAI's transduction into electromagnetic pulses. But the existence of the complexity underneath these signals, and the ability to, theoretically, follow the documentary traces as I have done, is what makes the process specifically *scientific*.<sup>5</sup> Raw declaration is, at times used in scientific metrology, as when the values of numbers like Planck's constant are stipulated.

As a field, metrologists seem to be pushing towards a minimal use of declaration in favor of computable derivation. In 2019, the SI second was re-defined to make this stipulation explicit. The second is represented by the equation

$$s = \frac{9,192,631,770}{\Delta\nu_{Cs}}$$

---

<sup>5</sup>Bruno Latour and Steve Woolgar, *Laboratory Life: The Social Construction of Scientific Facts* (Beverly Hills, CA: Sage Publications, 1979); Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1988).

This formulation creates a potential space for the re-definition of the second in response to more accurate measurements of the constant  $\Delta v_{Cs}$ , even as the redefinition itself transforms the unperturbed ground-state hyperfine transition frequency of the caesium-133 atom per second, the empirical referent of  $\Delta v_{Cs}$ , into an incorrigible declaration. This produces incorrigibility, a key characteristic of standards to which other aspects of the world must be reconciled. Because of this, though, re-definition of the second in response to more precise measurements of duration would constitute a *declaration*, not a correction. The possibility of re-defining in light of measurement, though, is core to the scientific approach to metrology.

#### 6.1.5 Deviation from What?

At several places in *Circular T* reports and in other BIPM publications, deviations from UTC are given (usually in nanoseconds). UTC(OP), the local realization of UTC in the Paris TAI-linked time lab, is used to construct TAI, which is in turn a constituent of UTC. How is UTC determined such that the constituent measurements which constitute it like UTC(OP) can be compared with it?

The Interactive Plot section of the BIPM Time Department’s online database<sup>6</sup> allows users to visualize the historical discrepancies between a specific laboratory’s local representation of UTC calculated using its local representation of TAI (denoted UTC(*k*), where *k* is the identifier of the lab), against global UTC. The graph for the Paris lab’s local UTC, UTC(OP) is shown in Figure 6.3 on the next page.

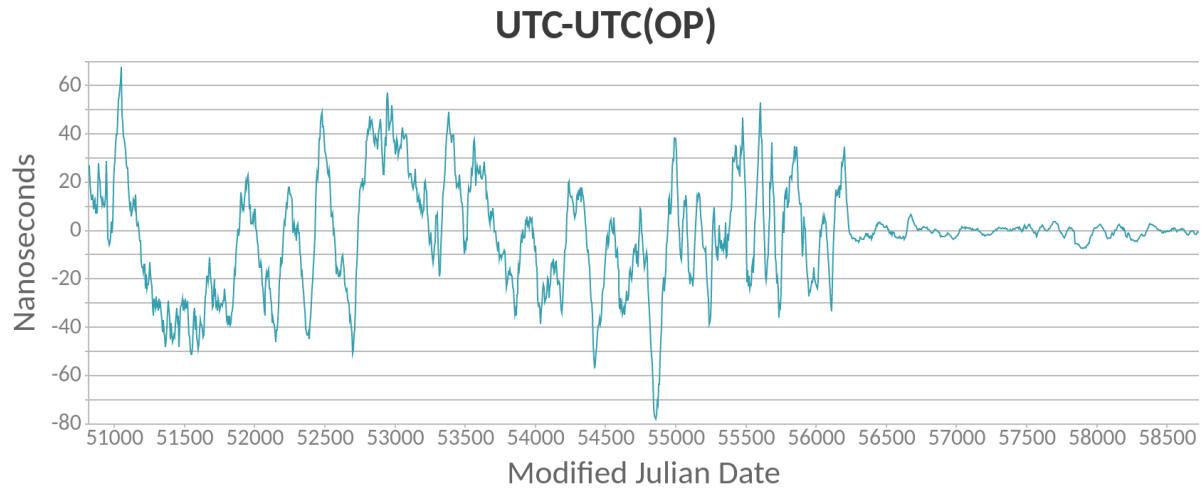
Atomic clocks used to promulgate TAI are connected by links, which allow comparison of their durations. Figure 6.4 (page 162) shows a BIPM-produced plot of one of these comparisons. Each promulgated *Circular T* contains a summary of similar results. The underlying data in Figure 6.4 is shown reduced into the summary data in *Circular T* 379 in Table 6.1 on the next page. As an example of the intensity of BIPM documentation, a file explaining the link comparison plots is included as Appendix B.

Statistical techniques of measuring uncertainty are used when combining the clocks, their links, the observed differences between links, uncertainty due to adjustments and calibrations, and a host of other factors, documented within the complex network of publications the BIPM produces as part of the promulgation of TAI. These uncertainties are combined and reported in *Circular T* and other BIPM-promulgated documents.

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<sup>6</sup>“BIPM Time Department Data Base,” BIPM, accessed October 9, 2019, [http://webtai.bipm.org/database/canvas\\_lab.html](http://webtai.bipm.org/database/canvas_lab.html).



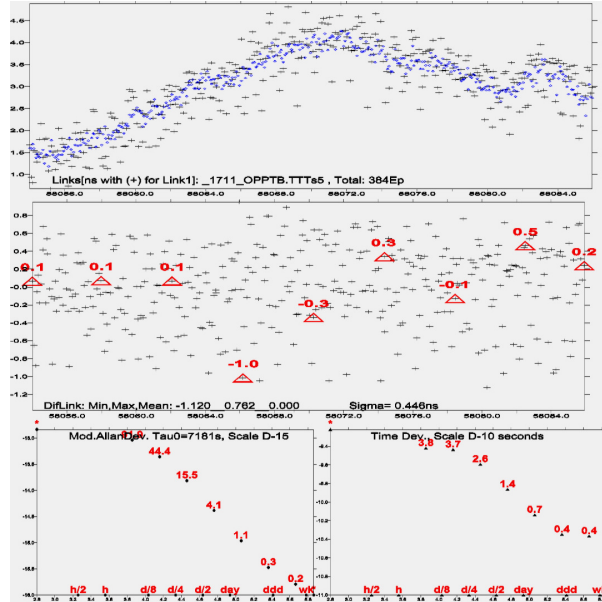


**Figure 6.3:** The difference between UTC and UTC(OP), the local representation of UTC calculated from the Paris time lab’s local TAI, from January 1, 1988 to August 29, 2019. (Generated on October 9, 2019, from “BIPM Time Department Data Base,” BIPM, [http://webtai.bipm.org/database/canvas\\_lab.html](http://webtai.bipm.org/database/canvas_lab.html))

Link	Type	Equipment	Cal_ID	uStb/ns	uCal/ns	uAg/ns	Al/ns	YYMM
CH	/PTB	TWGPPP	CH01 /PTB05	0284-2012	0.3	2.0	1.7	
IT	/PTB	TWGPPP	IT02 /PTB05	0434-2016	0.3	1.4	0.9	
NIST	/PTB	TWGPPP	NIST01/PTB05	0393-2015	0.3	1.9	1.2	
NPL	/PTB	TWGPPP	NPL02 /PTB05	NA_A1	0.5	3.2	0.0	0.0 1902
OP	/PTB	TWGPPP	OP01 /PTB05	0437-2016	0.3	1.4	0.9	
ROA	/PTB	TWGPPP	ROA01 /PTB05	0440-2016	0.3	1.6	0.9	
SP	/PTB	TWGPPP	SP01 /PTB05	0441-2016	0.3	1.4	0.9	
USNO	/PTB	TWGPPP	USNO01/PTB05	0395-2016	0.3	1.3	0.8	
VSL	/PTB	TWGPPP	VSL01 /PTB05	0295-2015	0.3	1.4	1.0	

**Table 6.1:** Link comparisons in *Circular T* 379 (August 2019). The comparison of the Paris link in Figure 6.4 on the next page is here reduced to the data shown on the line beginning with OP.

As discussed in Section 1.1.3, the concept of statistical uncertainty is orthogonal to the concept of certainty as operationalized within this dissertation, etymological similarities notwithstanding. Statistical uncertainties are determinate outputs of well-defined formulae. As they appear in publications like BIPM’s *Circular T*, the uncertainty values are precisely and unambiguously inscribed. They can thus be consulted and moved on in contemplation just as any promulgation might.



**Figure 6.4:** Plot of the link comparison between GPS Precise Point Positioning technique link and two-way satellite time and frequency transfer for the Paris time laboratory in August 2018. The linkages between clocks help establish a common baseline of comparison, and associated statistical measures of uncertainty which are inscribed into each *Circular T*. (Available via FTP at <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1908/opptb/lnc/opptb.tttts.gif>).

## 6.2 The $\mathfrak{tz}$ Database: Historical Techniques of Forgetting

The  $\mathfrak{tz}$  database is a fascinating combination of software and historical archive. It is interesting from the perspective of the analysis of certainty in that it represents a distinct technique of forgetting from that used in the production of scientific time standards. The maintainers of the database license the forgetting inherent in encoding administrative timezones into plaintext by documenting their sources and reasoning in source code comments directly within the database itself. This communicates to other developers, or anyone who reads the source, why administrative datetime decrees were encoded as they were. Each of these code changes is traceable to a specific author through the version control program Git. This process is analogous to the production of TAI from an attributed ledger of atomic clock measurements in that it produces a roster from a ledger, but where TAI is synchronic, the  $\mathfrak{tz}$  database is diachronic.<sup>7</sup> It differs, however, in what constitutes licensed forgetting.

<sup>7</sup>I am grateful to Ryan Shaw for this observation on the systems' contrasting chronicities.

### 6.2.1 Promulgation of the tz Database

The IANA Time Zone Database (tz database) is a volunteer-run effort to enable computers to produce human-readable labels out of the various binary integer formats used to represent time in digital computers.

From the project’s documentation:

The tz database attempts to record the history and predicted future of all computer-based clocks that track civil time. To represent this data, the world is partitioned into regions whose clocks all agree about timestamps that occur after the somewhat-arbitrary cutoff point of the POSIX Epoch (1970-01-01 00:00:00 UTC). For each such region, the database records all known clock transitions, and labels the region with a notable location. (tzdb/theory.html)

The tz database is widely used across mobile, desktop, and server operating systems, and forms a core part of modern network infrastructure. The database and its computational and social artifacts contain several specific artifacts of interest, including its source code (see page 150 n22), its open mailing list,<sup>8</sup> its policies and procedures,<sup>9</sup> its list of contributors (tzdb/README), and more. For the purposes of the analysis of certainty, its source code and the process of parsing and compiling this source to produce human-readable datetimes from UNIX time integers (*i.e.*, timestamps) will be the primary focus.

### 6.2.2 The tz Database as Jussive Archive

The tz database is an archive on at least three levels. As a code repository, its version-controlled incremental additions, deletions, and updates constitute an artifactual record of its construction.<sup>10</sup> Second, it is explicitly designed as an archive of administrative time zone declarations, though by its own admission this archive is necessarily incomplete. As noted in *e.g.*, tzdb/theory.html, tzdb/CONTRIBUTING, and elsewhere in the source, time zone declarations can at times be ambiguous, there is always a delay between the tz database maintainers becoming aware of time zone declarations, and there is a subsequent delay in distributing the modified tz database to the systems which use it. Finally, it is an archive of plaintext computer data, used to compile executable binaries that convert computer time (binary integers) to human-readable datetime (see, *e.g.*, tzdb/Makefile, which contains instructions for building various kinds

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<sup>8</sup>“The tz Archives,” ICANN, accessed October 9, 2019, <https://mm.icann.org/pipermail/tz/>

<sup>9</sup>Eliot Lear and Paul Eggert, *Procedures for Maintaining the Time Zone Database*, technical report BCP 175 (Internet Engineering Task Force, 2012).

<sup>10</sup>The project’s list of git commits can be seen at <https://github.com/eggert/tz/commits/master>. Selecting a commit link from the list will display the incremental changes to the source associated with it.

of binaries from the plaintext data files). Though these three senses of archive necessarily differ from each other, they each are amenable to analysis through Bowker's reading of Derrida: they are sequential, in that they have a commencement that forms an implicit horizon of their scope, and they are jussive in that they actively constrain, manipulate, and dictate their contents during accession.<sup>11</sup> The `tz` database encodes the relevant pieces of time zones in a format that computers can enact, the reasons for the encoding in human-readable contents, and all changes to this code as line-by-line changes to files tracked by Git. It combines three techniques of forgetting at the nexus of three interrelated technologies of remembering.

### 6.2.3 `tz` Database Source Given-as Ledger

The database's version-controlled, extensively commented source code is given-as a ledger. Thanks to the convention of extensive documenting of the source of specific rules or timezones in comments, it is often possible to see *why* a person created the rules that they did. The project's maintainers also attribute the supporting documentation they produce within the course code itself, as we saw in Table 5.3 (page 152). Regardless, since the codebase is under Git version control, it is possible to see which person is responsible for the state of each line of code, making attribution possible.

The maintainers of the project aim to provide as much context around the encoded zones as possible, essentially turning them into *claims*. Since the project's goal is to reflect the way that people within regions actually set their clocks, evidence is provided as to why the maintainers believe clocks in a region were set a specific way. Since these claims are expressed in the form defeasible logic, it's possible that new evidence or claims might defeat them in the future.

This is essential to the historical technique of forgetting that animates the enterprise. The project is obscure enough that most small jurisdictions (such as Beulah, North Dakota) likely do not seek out the database maintainers. Instead, the maintainers seek out evidence that new zones are being followed, or that existing zones have been changed, and document this evidence along with their updates to the code. To someone reading the source as a ledger, it should be relatively straightforward to understand if a new piece of evidence contradicts the existing claims and reasoning and whether an argument could be made to change the encoding of a time zone in the database.

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<sup>11</sup>Bowker, *Memory Practices in the Sciences*; Bowker, "The Archive."

#### 6.2.4 `tz` Database Taken-as Roster

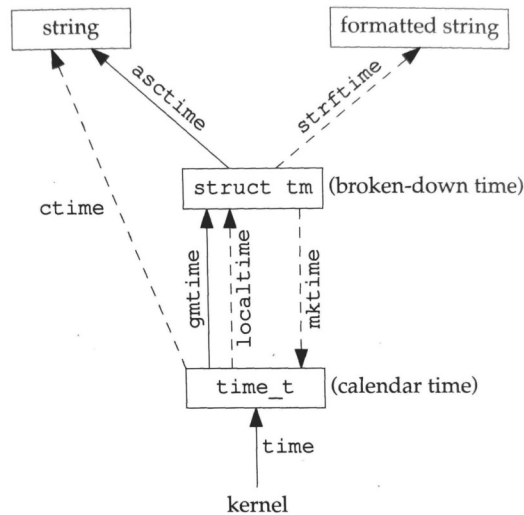
When parsed or compiled to translate UNIX time integers, the `tz` database rules are taken-as a Roster. Subsequent versions of the database may re-declare these rules, but they are computationally enacted as incorrigible certainties. In other words, the incorrigible default is active here, and no computational recourse to measurement or claims is possible.

The balance of this section takes a short but deep dive into the computational process of turning a UNIX time integer into a human-readable datetime, using the rules of the `tz` database. The materiality of this process is an excellent example of what computational enactment can be. There may not be an easily identifiable enacting agent (is it the CPU? the Operating System? daemonic processes?), but there is enactment, and the production of certainty, nonetheless.

##### *Material Transformation of Time to Datetime in C*

Figure 6.5 on the next page shows the relationship between various time-related functions in the standard `time.h` C library. The operating system kernel keeps track of how many seconds have passed since the computer has been in operation and, once a current time is set by the user or by a synchronization method such as Network Time Protocol (NTP), UNIX time can be provided. Most operating systems have a hard-coded minimum value for this other than 0, which prevents their time integers from starting at January 1, 1970 when they are first powered on. It is possible for some file metadata to contain a value of zero, which can lead to the creation date of files being listed as January 1st, 1970 (or December 31st 1969, depending on the system's current time zone). Negative values are also sometimes supported for proleptic indication of datetimes before the epoch.

In Figure 6.5 on the following page, `time_t` is the integer representing UNIX time. The `gmtime` and `localtime` functions can both convert UNIX time to a C data structure called `tm`, in a format called broken-down time (see below). The actual derivation of the broken-down time is exceedingly complex, requiring use of the full apparatus of time zone representation in the case of `localtime`. A broken-down time can be represented as human-readable text by the `asctime` or `strftime` functions, while the `ctime` function can produce a string directly from a UNIX time integer. Dotted lines in the



**Figure 6.5:** The relationship between various time-related functions in C. Adapted from Stevens, *Advanced Programming in the UNIX Environment*, 156.

graph represent that the given function call is dependent upon the `$TZ` environment variable, which may or may not be defined on a given system, depending on its configuration.<sup>12</sup>

```

struct tm { /* a broken-down time */
    int tm_sec; /* seconds after the minute: [0, 61] */
    int tm_min; /* minutes after the hour: [0, 59] */
    int tm_hour; /* hours after midnight: [0, 23] */
    int tm_mday; /* day of the month: [1, 31] */
    int tm_mon; /* month of the year: [0, 11] */
    int tm_year; /* years since 1900 */
    int tm_wday; /* days since Sunday: [0, 6] */
    int tm_yday; /* days since January 1: [0, 365] */
    int tm_isdst; /* daylight saving time flag: <0, 0, >0 */
};

```

**Figure 6.6:** The `tm` data structure in the C programming language. (Stevens, *Advanced Programming in the UNIX Environment*, 158)

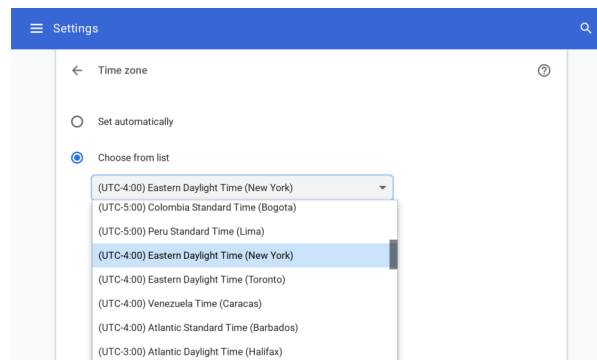
The elements of `tm` are shown in Figure 6.6. This data structure provides a substrate via which the UNIX time-integer can be represented in human-readable date format. The code within `gmtime` must process the integer into the correct broken-down values in this structure, in light of any leap seconds that have occurred since the epoch. The `localtime` function must further parse the specific timezone specification file to determine the GMT offset for the date’s state (including whether the timezone is in

<sup>12</sup>UNIX systems utilize *environment variables* extensively to describe the current state of a particular system so that programs can take such configurations into account. `$TZ` in this case would be set to the official name of a `tz` database time zone, such as `America/New_York`, the associated rules of which the dotted-line functions in Figure 6.5 would then utilize to translate between UNIX time integers and human-readable datetime. Rules for a specific zone were given in Table 5.3 (page 152).

Daylight Saving time and the corresponding offset it generates). `localtime` enacts certainty, taking the `tz` database as Roster.

### 6.2.5 `tz` Database in Everyday Life

To illustrate the jussivity of computational time in action, compare the granular nature of the journey we've taken through the `tz` database with its exposure to the user interface in Google's ChromeOS, shown in Figure 6.7. The `tz` database has thousands of zone definitions, any of which are selectable via the obscure command line interface presented on many systems. ChromeOS limits the choices presented, omitting, for instance the `America/North_Dakota/Beulah` zone in Table 5.3 (page 152). It's not immediately clear how, or whether it's possible to, select one of the more specific timezone definitions from the database: ChromeOS, though built upon Linux, fundamentally alters core features in service of a simpler user experience..

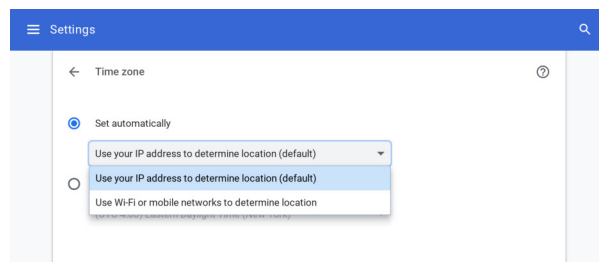


**Figure 6.7:** The time zone settings dialog in Chrome OS. This is the primary user interface to the `tz` database for this operating system, which is based upon Linux.

ChromeOS, like most modern operating systems, provides the option to have the operating system automatically select a timezone. Figure 6.8 on the following page shows the provided options for doing this. The options are to use the device's IP address as an estimate of location, presumably using some database of IP locations that Google maintains as a Roster, or to use WiFi or mobile networks to determine location. The later case likely also uses some Google-maintained database as a Roster, but the construction of the database is likely based upon data collected and taken as Inventory entries.

All of this discussion of timezone selection merely alters how the system displays a human-readable datetime from its system time integer. The `tz` database essentially maps such integers to datetimes, but how is this integer set for an individual device? In addition to setting the system time manually,

ChromeOS offers the ability to automatically set the system time from the network. We'll now turn to network time synchronization and its role in promulgating the binary integers that systems use to display datetimes to users.



**Figure 6.8:** ChromeOS location setting options for automatically selecting a timezone

### 6.3 NTP, Roughtime, and Certificate Security

NTP plays a role in generating the lock icon which browsers commonly use to indicate that a website was loaded securely via HTTPS.<sup>13</sup> Security certificates are designed to be valid during specific times. The capability of revoking a certificate guards against its use once stolen. Thus, to know whether a digital certificate is valid, one must know the current time. The question with which we've framed Part II, "what time is it?" is thus central to modern security practices. How do computers ask and answer this question?

Local (device) time, global (network) time, and the complex protocols which mediate between the two all produce roster-candidates, but computers must still select (or construct) a roster before moving on with a evaluation of certificate validity. This section discusses how computational incorrigibility regarding the current time has real consequences for information security, and reviews some proposals to mitigate these consequences via an analysis of certainty.

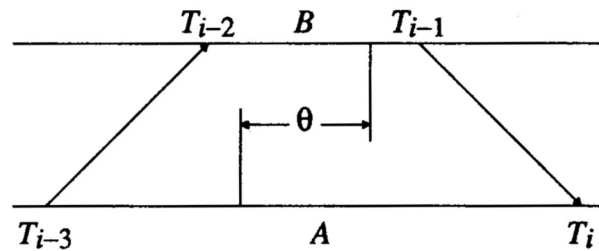
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<sup>13</sup>The HTTPS protocol utilizes a Secure Sockets Layer (SSL) or Transport Layer Security (TCS) certificate to encrypt and authenticate network traffic between a server and client. The cryptographic certificate is issued by a trusted Certificate Authority (CA) that has verified that the issuee owns the domain. The CA provides a cryptographic secret that the issuee can use to encrypt and sign outgoing packets. Th CA also attests to the validity of the certificate via publicly accessible databases. Each operating system and browser has a list of trusted certificate authorities it consults, and most will allow users to add or remove from this list, which is, incidentally, taken-as roster by the programs which utilize it.



### 6.3.1 NTP

Network time protocol is a clock based synchronization protocol developed by Mills.<sup>14</sup> The basic principles for clients to calculate their offset from a timecode received over a network are given in Figure 6.9. The diagram shows how the delay (transit time) and offset (response time) of a server are calculated by a NTP client. The client is then able to determine the range of possible correspondences of the timecode sent by the server to the client's local time. The results of this calculation to all NTP servers the client connects to are then synthesized and enacted into an update of the client's local time.



**Figure 6.9:** Calculating delay and offset in NTP.  $T_{i-3}$  represents the client's timestamp upon sending the request, while  $T_{i-2}$  represents the server timestamp when the request was received.  $T_{i-1}$  represents the timestamp provided by the NTP server immediately before responding. Each NTP packet will contain these three times, allowing both server and client to produce all four relevant times by calculating  $T_i$  upon receipt of the packet. Thus, both client and server can utilize the algorithm shown schematically here to estimate the true offset between their internal clocks, shown in the diagram as  $\Theta$ . (From Mills, "Internet time synchronization: the network time protocol," 1486, figure 3).

But how is the integrity of the network of NTP servers maintained? NTP defines *strata* of servers, from 0 through 16. Stratum-0 represents devices which directly receive frequency signals from high-precision clocks, such as the cesium clocks used to produce TAI, or other high-accuracy time signals such as GPS. Stratum-1 servers are connected directly to such devices. All other strata are similarly designated by the number of edges between them and stratum-0 servers, with stratum-16 reserved for unsynchronized clocks. Servers usually connect with peers in the same stratum, one or more servers in stratum- $n - 1$ , and a variety of servers of stratum- $n + 1$ . If a NTP server loses connection to all stratum- $n - 1$  servers, it can continue to operate through its connection to peers of stratum- $n$ , but its

<sup>14</sup>David L Mills, "Internet time synchronization: the network time protocol," *IEEE Transactions on Communications* 39, no. 10 (October 1991): 1482–1493; Mills, *Computer Network Time Synchronization: The Network Time Protocol on Earth and in Space*.

stratum will be changed to  $n + 1$  to indicate its new distance from stratum-0 timecodes. What does this mean for clients trying to determine the time?

While reliable clock synchronization has been studied using agreement algorithms, in practice it is not possible to distinguish the *truechimer* clocks, which maintain timekeeping accuracy to a previously published (and trusted) standard, from the *falseticker* clocks, which do not, on other than a statistical basis. In addition, the algorithms discussed in the literature do not necessarily produce the most accurate and precise time on a statistical basis and may produce unacceptable network overheads and instabilities in a large, diverse internet system.<sup>15</sup>

The distinction between *truechimer* and *falseticker* utilized here is worth exploring. The question of how to distinguish them is a key issue for the protocol.<sup>16</sup> NTP guidelines give a heuristic formula that a client (or stratum server) must be connected to  $2n + 1$  *truechimer* servers to be resilient against  $n$  *falseticker* servers. This is explained on in `ntp.org` support documentation as follows.

- If you list just one, there can be no question which will be considered to be “right” or “wrong”. But if that one goes down, you are toast.
- With two, it is impossible to tell which one is better, because you don’t have any other references to compare them with. This is actually the worst possible configuration – you’d be better off using just one upstream time server and letting the clocks run free if that upstream were to die or become unreachable.
- With three servers, you have the minimum number of time sources needed to allow ntpd to detect if one time source is a “falseticker”. However ntpd will then be in the position of choosing from the two remaining sources. This configuration provides no redundancy.
- With at least four upstream servers, one (or more) can be a “falseticker”, or just unreachable, and ntpd will have a sufficient number of sources to choose from.<sup>17</sup>

*falsetickers* are here revealed to be servers which don’t agree with  $2n$  or more of the other servers the client is connected to.<sup>18</sup> Collectively, then, the automated processes of NTP clients construct a *synthetic* Roster out of what the client perceives to be *truechimer* servers. The result is taken-as a Roster because the client’s local time is synchronized with its output (in other words, the NTP server’s declaration of what time it is is enacted by the client). The Roster is synthetic because, unlike an enumerative system like the No Fly list, the output is generated rather than referred to. For the purposes of the client, the

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<sup>15</sup>Mills, “Internet time synchronization: the network time protocol,” 1483.

<sup>16</sup>The examples that follow are from user-facing documentation and presented in simpler language. Mills’s explanation of distinguishing truechimers and falsetickers is much more dense: “The maximum error bound for any server is represented by an interval equal to the roundtrip delay with center the apparent time. A clique is formed from a number of servers whose intervals overlap. If there is a clique containing a majority of servers, those servers are truechimers. All the rest are falstickers. If no clique has a majority of servers, no decision is possible.” Mills, “A Brief History of NTP Time: Memoirs of an Internet Timekeeper,” 17

<sup>17</sup>“Selecting Offsite NTP Servers,” Network Time Foundation, accessed October 14<sup>th</sup>, 2019, <https://support.ntp.org/bin/view/Support/SelectingOffsiteNTPServers>

distinction is irrelevant: a promulgated value is consulted and enacted as the system time. But in the analysis of certainty we can note that the consulted value for a client connected to a specific set of NTP servers is constructed according to a set of rules, not looked up in a database.<sup>19</sup>

### 6.3.2 Certificate Security and Network Time

Cryptographic certificates are used widely to establish identity of users or systems and the authenticity of documents. A wide variety of practices exist, but most follow the same basic format: digital data is encrypted with a such that others can verify that only the possessor of that private key is likely to have encrypted the data.

Private keys are sometimes compromised, and best practices state that they should be periodically replaced for ideal security, similar to periodically changing one's password. Thus, many keys include specific dates within which they are valid. For an automated system to know whether a specific certificate is valid, it must determine the current time.

This situation links computational timekeeping to cryptographic security, and forms a potential attack vector. If a software developer such as Microsoft's obsolete signing keys are obtained by an attacker, and the attacker can control the apparent time within a specific machine, the attacker can create, sign and potentially install arbitrary software, which will appear to have come from the key's original owners, in this case Microsoft.

In normal cases, such attacks are improbable due to the prevalence of network time, and the existence of multiple robust public NTP servers maintained by governments and Internet companies.<sup>20</sup> These attacks are particularly important to consider for cases where a computer is being turned on and/or added to a network for the first time (*i.e.*, in cases of initial synchronization).

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<sup>19</sup>The possibility of synthetic information systems, generated through algorithmic processes, is another largely unexplored contact with a future analysis of certainty and algorithms, considered further in the Conclusion.

<sup>19</sup>This relation was originally proven in Leslie Lamport and P M Melliar-Smith, "Synchronizing Clocks in the Presence of Faults," *Journal of the Association for Computing Machinery* 32, no. 1 (1985): 52–78. This is the same Leslie Lamport of L<sup>A</sup>T<sub>E</sub>X fame, whose research interests coincidentally include network clock synchronization and program verification.

<sup>20</sup>See, for instance, the list of official NTP servers provided by NIST at <https://tf.nist.gov/tf-cgi/servers.cgi>, to which incoming traffic to <https://time.nist.gov> is routed on a round-robin basis.

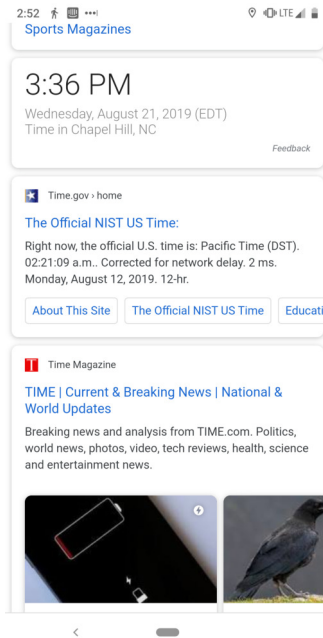
## 6.4 User Interfaces and Personal Enactment of Time

I'll conclude this chapter with a personal anecdote that just happens to demonstrate computational timekeeping in action in everyday life. While in the throes of writing this dissertation, I was fortunate to miss the bus because my phone displayed the wrong time. While inconvenient, this was fortunate in that it provided an example of production of certainty in daily life that helps illustrate the jussive nature of the production of certainty.

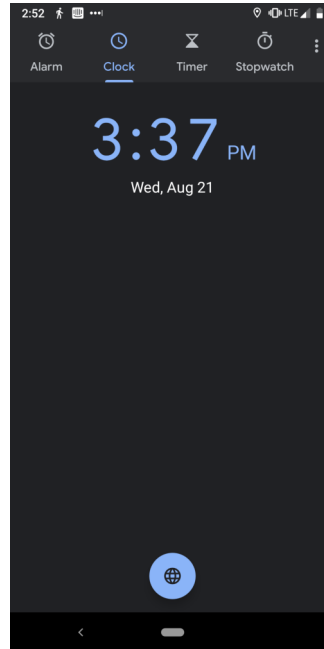
I was using a bus-tracking app to know when to go wait at the bus stop. It said the bus would be leaving at 3:06pm. My phone said the time was 2:52pm, so I set off at a leisurely pace. When I got to the stop I saw in the bus-tracking app that the bus was long gone, halfway to my stop. This didn't make sense to me, but I only has to wait 10-15 minutes for the next one, instead of the usual 25-30 minutes, for which I counted myself lucky. The bus tracking app is often wrong, so thought nothing of it and busied myself with reading until the next bus arrived. Once on the bus, I realized that my analog watch was off by nearly 30 minutes and immediately set it to match my phone's time. I knew that my phone was connected to NTP servers, and, though I love analog watches, they sometimes slow down when the battery needs changing. With all of these actions I was enacting certainty based upon the time displayed by my phone's user interface.

After taking these actions, though, I continued to investigate, in part because I was writing Part II of this dissertation. I Googled the time, the results of which are shown in Figure 6.10a on the facing page. As I investigated, I noticed that the displayed system time on my phone was not updating. My analog watch continued to increment, and helped me realize that the network-provided times from a search engine, the Clock app, and the system settings were correct (see Figures 6.10b and 6.10c). I realized that the *user interface display* to which I had synchronized my watch (also displayed on the phone's lock screen) was a static readout, not a representation of the phone's system time.

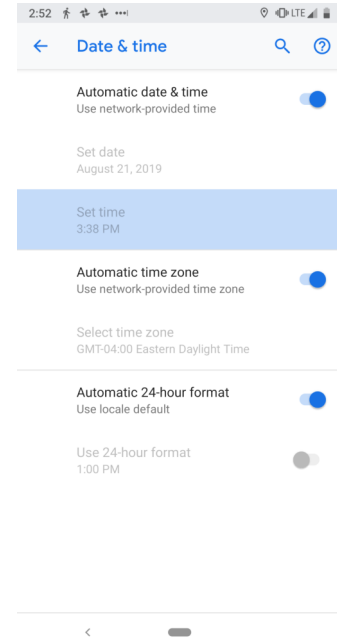
Even as someone with an above average knowledge of computational timekeeping, I had treated the user interface of my phone as a Roster of the current time by default, something to which to reconcile my watch. As I investigated, I came to see the user interface as kind of inventory, a measurement, of system time, and one that was *incorrect*. A bug in the interface had prevented the reconciliation process which normally keeps the pixels displayed in the status bar and lock screen of the phone from accurately reflecting the datetime the phone computes from the binary integer it receives from Google's NTP servers.



(a) A discrepancy between current time according to Google, 3:36pm, and the displayed system time of a smart phone, 2:52pm.



(b) A discrepancy between current time according to the Clock application, 3:37pm and the displayed system time of a smart phone, 2:52pm.



(c) Time zone and clock settings in the Android operating system, showing a current network-provided time of 3:38pm and a displayed system time of 2:52pm.

**Figure 6.10:** Time discrepancies in the user interface on an Android phone. The displayed time of 2:52pm is in the upper left of each screen, and does not change even as the system time increments. Each subfigure screenshot was taken one minute apart, during which the network-synchronized times updated while the display did not.

The breakdown of the software infrastructure required me to enact the reconciliation of consulting network time in the way that the user interface normally did automatically. I eventually discovered that certain arcane actions on the phone would cause the display to momentarily update, but the passage of time revealed that this was yet another static display. The glitch was resolved through the time-tested solution of rebooting the device, and I haven't been able to recreate this situation since.

This example also indicates precisely how the production of certainty engages with memory practices, which I've glossed as techniques of forgetting embedded in technologies of remembering. A user interface takes the time zone computation of a binary integer and displays it for me (a technology of remembering) such that it contains no trace of the processes that generated it (this being the last in a line of techniques of forgetting, many of which were discussed in this chapter). Breakdown in normal chains of promulgation of time resulted in a small but real breakdown in an information infrastructure I relied upon. I showed up to the bus stop, enacting the displayed time and *in fact* there was no bus, since the bus and everyone else around me was enacting the time promulgated from various network time servers. Despite all the complexity and history that we've surveyed in this chapter, the final collapse of time at the user interface was the only promulgation immediately available for me to consult. The ubiquitous memory practices of timekeeping demand collapses like this, but an analysis of certainty in information systems can provide insight from the resulting rubble.

## CONCLUSION

*I dreamt a line that would make a motto for a sober philosophy:  
Neither a be-all nor an end-all be.*

— J. L. Austin<sup>1</sup>

The preceding chapters have shown how the certainty produced using information systems shapes parts of social reality. Within computational timekeeping, the production of certainty forms a synthesized memory practice. The  $\mathfrak{t}z$  database projects manifold names generated by historical techniques of forgetting onto substrate durations produced by scientific techniques of forgetting. Bowker's memory practices can and should be identified within all information systems, especially those used in the production of certainty. Techniques of forgetting give certainty its character, and the historical and scientific methods of jussively producing certainty in timekeeping are only two possibilities of many. Couldry and Hepp recognized this potential, and identified the jussive nature of datafication as a core phenomenon of modern life. My hope is to situate memory practices, techniques of forgetting, and jussivity as core analytic frames for all technologies of remembering.

There is no way to get 'outside' of the process of the production of certainty. This key insight I draw from Wittgenstein's work on the topic. The net effect of the analysis proposed in this dissertation is not to hypothesize that just one more adjustment of where we stop will produce *more* certainty, but that certainty is orthogonal to capital-T Truth. It is, however, related to the small-t truth of propositional logic, taken as a description of linguistic practices of meaning-making .

Certainty, in information systems, is stopping upon a *fact* and moving on. That information systems which perform the role of roster produce facts, not claims or measurements, is one of the core arguments I'm making. My modifications of Searle's conception of fact make it suitable for describing this dynamic, discarding the incidental and extraneous realism inherent in so-called 'brute' facts. A re-examination of Anscombe's coining of the term reveals Searle's considerable license in attributing this concept to her. I then articulated a revived Anscombian conception of facts, which I dubbed *root facts* for clarity. The

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<sup>1</sup>John L. Austin, "Pretending," *Proceedings of the Aristotelian Society* Suppl. Vol. XXXII, no. 1 (1958): 279, n. 16

resulting account of facts is able to converse natively with the Wittgensteinian certainty which animates the entire approach I'm taking.

## **Taking on Certainty in Information Systems**

Approaching certainty the way that I have is more than an exercise in applied philosophy. The phenomenon of certainty in information systems can be observed at work in numerous sites of study in the field. This section will identify some of these fields and gesture towards ways in which an analysis of certainty might inform future inquiry.

### Language, Action, and Certainty

By utilizing philosophy of language so extensively, particularly Austin and Searle's Speech Act Theory, I have drawn near to the language/action perspective. Winograd and Flores in particular may have loomed large for some readers, but I hope that my approach has been distinct enough to justify my lack of engagement with their work. In a sense I hope my approach to affirm their focus upon language as an important locus of sociotechnical phenomena and the primary medium through which computers and humans interact.<sup>2</sup> But I share Suchman's worries that Winograd's approach was insufficiently attuned to the ethical and political consequences of the mechanisms he studied.<sup>3</sup> Though framed in terms of employer surveillance and common workplace information artifacts such as accounting systems, the debate they initiates reverberates into the present and into the themes of this dissertation. Agre's entry into the discussion called for a "fully rigorous ontological inquiry within [the] practices"<sup>4</sup> of systems used for control of other humans. I see this dissertation as in part responding to Agre's call in mobilizing

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<sup>2</sup>Terry Winograd and Fernando Flores, *Understanding computers and cognition : a new foundation for design* (Norwood, NJ: Ablex Pub. Corp., 1986).

<sup>3</sup>Lucy Suchman, "Do categories have politics?," *Computer supported cooperative work: CSCW: an international journal* 2, no. 3 (1993): 177–190.

<sup>4</sup>"We must cultivate a critical sensitivity to the full range of social factors that have made historically contingent and specific computational design methodologies seem so natural and irreplaceable. One crucial site for the investigation of these sociotechnical determinants is precisely the site of system implementation, the zone of participatory design to which Winograd appeals in his response. A fully rigorous ontological inquiry within these practices would recover a sense of computational ontology as an up-till-now foreshortened form of social theorization." Philip E Agre, "Accountability and discipline: A comment on Suchman and Winograd," *Computer supported cooperative work: CSCW: an international journal* 3, no. 1 (March 1994): 34.



the social ontology of John Searle and focusing on the speech act of declaration and the resultant social facts it produces. The Winograd–Suchman debate remains relevant, and open, and future work should position the analysis of certainty within this tradition.

### Blockchain, Cryptocurrency, and Distributed Ledgers

Blockchain technologies aim to use cryptographic techniques to provide an independently verifiable chain of ‘blocks’ of information. The most well known use of blockchain technology is in cryptocurrencies like Bitcoin and Ethereum, but the technology is being explored for use in a variety of distributed-consensus use cases such as inventory management, financial settlement, and royalties micropayments.

From the perspective of the production of certainty, the distributed ledger<sup>5</sup> architecture upon which blocks are added represents a novel and interesting method of promulgation. The lack of a single, centralized copy of the resulting ledger enables distributed enactment of the certainty it represents. The cryptographic robustness of the various blockchain currencies, combined with the ability to make independently verifiable transactions with them, accounts for their otherwise inexplicable monetary value. In essence, the scarcity of cryptocurrencies can be digitally verified, and scarcity (combined with fungibility and the ease of transfer to a counterparty) allows demand to produce a market price for the asset.

There are currently a variety of different system architectures for cryptocurrencies. Though all involve a distributed ledger, some currencies, like Ripple, choose to semi-centralize the validation of ledgers with corporations such as banks that partner with the company. Others, like Bitcoin, have an open protocol that anyone can attempt to *mine* (*i.e.*, computationally solve a difficult math problem which mints a new cryptographic block of transactions), and thereby receive a reward. Still other cryptocurrencies rely on methods such as proof-of-stake where existing holders of the currency digitally vote for the next block in the chain and receive a reward for doing so.

Each of these architectures can be seen as precise rules for promulgation of a block on the chain, designed to make automated enactment based on those promulgations (such as sending a payment to a counterparty) uniform within the network. Each has its risks. Mining-based currencies like Bitcoin

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<sup>5</sup>The idiomatic term *ledger* in cryptocurrency has the unfortunate potential to create confusion when combined with the taxonomy class of the same name. Though blockchain ledgers are often given-as ledgers in my sense, I will rely on context to distinguish the concepts.

are vulnerable to a so-called 51% attack where if 51% of the computational power devoted to mining new blocks were controlled by a single entity, that entity could theoretically forge transactions into the ledger. Semi-centralized systems like Ripple rely on an implicit trust in the corporate entities which run the system. And so on.

Despite these risks, blockchain technology does represent a real advance over prior methods of establishing distributed consensus. In contrast to centralized information systems (even those available over a network), the cryptographic safeguards around which participants may promulgate information into the shared ledger provides participants with far greater assurance than they would have with a traditional database. It seems likely that the use of blockchain technology will continue to proliferate, and I expect that some form of distributed consensus, shared ledger technology will play a large role in consumer and government services of the future.<sup>6</sup> If so, understanding how blockchain technology impacts the production of certainty will become increasingly important.

#### *Non-cryptocurrency use of blockchain technology: Smart contracts*

One area of non-cryptocurrency blockchain technology adoption with potential for major impacts on daily life is the development of smart contracts. Smart contracts are essentially bits of code embedded into blockchains that automatically execute when their triggers are met. Contracts themselves have been a critical technology for coordinating human behavior, by as precisely as possible stating an obligation and, through contract law, allowing counterparties to sue for performance in the courts. Smart contracts hold the promise of automating payments (and other consideration) upon the fulfillment of a contract's provisions by a counterparty.

Smart contracts are not infallible. Echoing Smith's discussion of program verification, Grimmelmann has argued that smart contracts can never specify anything beyond what is written into their code, and that it is impossible to translate a contractual obligation in natural language into code.<sup>7</sup> Grimmelmann's approach in places seems to echo our focus on *enactment*, though he doesn't use the term:

The meaning of a legal contract is a social fact. So too is the meaning of a smart contract. It does not depend directly on what people think it means when they read it, as a legal contract's meaning

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<sup>6</sup>Large technology services companies' websites claim that this day is already here for 'forward-thinking companies': "Each day, forward-thinking companies are transforming blockchain's promise into bottom-line business results. And they're doing it with IBM Blockchain." "IBM Blockchain," IBM, accessed November 4, 2019, <https://www.ibm.com/blockchain>.

<sup>7</sup>James Grimmelmann, "All Smart Contracts Are Ambiguous" (January 2019).

does. Instead, it depends indirectly on what people think about the computer systems on which it runs. Smart contracts may in fact be more predictable and consistent than legal contracts. Or they may not. But the argument that smart contracts are not ambiguous because they cannot be is false. Worse than that, it is dangerous, because it distracts attention from the hard work required to make smart contracts work in the real world.<sup>8</sup>

At first glance, Grimmelmann's approach seems to be at odds with Smith. The ambiguity which Grimmelmann denies smart contracts doesn't seem to square with the materiality of the code which runs it, especially when cryptographically verified as a part of a block chain. Grimmelmann's point, however, is made from *outside the system*. His example of a contract to deliver a certain amount of wholesale chicken brings this home: how can a smart contract have access to the world to know when chicken is delivered? Ultimately smart contracts can only observe on-chain values. Some variable in the system, say `chicken_was_delivered` must be set to `True`. The contract is unambiguous within its scope but, as Smith observed, this internal correspondence has only limited access to the world outside the system.

In our terms, some method for *promulgating* the chicken's delivery must be devised and enacted. This example fortuitously brings us back to Anscombe's grocer, and continues to frustrate Searle's dream of mind-independent reality as a reliable arbiter. For the smart contract, as for human actors, there is no access to 'brute facts' about chicken deliveries. Only, rather, candidates for places to consult, contemplate, and move on (or not) from. In other words, smart contracts are surrounded by potential *root facts* upon which enactment may be based, or not. These chains lead to promulgations of some form, whether they be a human pressing a "The Chicken Was Delivered" button or a deep learning algorithm analyzing a warehouse video feed. The upshot of any of these acts is the jussive datafication of what Smith would call the "infinite richness" of the world, wherein whether chicken was delivered is a sociolinguistically negotiated fact, into the unambiguous rationality of binary data.

This gesture towards the potential of an analysis of certainty in blockchain technology can do nothing but indicate future lines of inquiry. But the fortuitous convergence with themes and concepts developed in this dissertation is reason for optimism.

### Certainty and Artificial Intelligence

Artificial intelligence and algorithms more broadly have been a door we approached but never went through. Systems or system components which are generative, producing output for any input, rather than

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<sup>8</sup>Ibid., 2.

enumerative, returning what was stored within them, clearly introduce new and important capabilities. Section 3.4 got the closest, and offered the example of Body Mass Index as a minimal algorithm with which to explore their properties, particularly that of prolepsis.<sup>9</sup> Algorithms were also at the edges of the analysis in Chapter 6 (page 154) in the form of the statistical measures used to combine various TAI components, or for NTP clients to distinguish *truechimers* and *falsetickers* (see Figure 6.9 (page 169)). In the analysis of computational time, algorithms were considered as mere components of the systems and wider assemblages within which they are operative, as unopened black boxes. The system of timekeeping itself arrays names unto measured durations, a continuous activity that itself seems to mirror the generative potential of algorithms.

Future analyses should consider algorithms directly. Are they information systems? Promulgating agents? Enacting agents? It seems that they might reasonably play all three roles, and perhaps in some cases all three simultaneously. What might this mean? What does it mean for the production of certainty if an information system is generative rather than enumerative? I will leave this as a promising direction for future work.

## **Certainty, Power, and Ethics**

Notwithstanding the critique of Searle's conception of power in Section 3.2.2, there is much more to be said about the production of certainty and the operation of power. In that section, I approached power as the ability to expand the context  $C$  within which a fact was enacted. Direct exercise of power, such as an armed border control agent denying passage, is one form of this. But there are more subtle expansions of the contexts  $C$  within which facts are enacted.

This work intersects provocatively with the study of misinformation. The spread of climate change denial, or anti-vaccine activism, can be seen as the spread of the context  $C$  within which some collection of root facts, things which are stopped upon and moved on from, are enacted to produce certainty. There are several complexities here not addressed or considered in the development of the taxonomy of certainty in Chapter 4. The first is that, unlike running examples such as the No Fly list, or the systems of computational time in Part II, the facts, such as they are, are not equivalent to discrete inscriptions.

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<sup>9</sup>An initial exploration of these topics was presented in Elliott Hauser, *Algorithms, Incorrability, and Social Reality*, 14th Annual Social Informatics Research Symposium, Annual Meeting of the Association for Information Science and Technology, Vancouver, BC., 2018.

Rather, they're contained in diffuse and diverse articles, blog posts, and social media interactions. This is a challenge for the analysis of certainty insofar as the focus on the materiality of promulgations within information systems, and the selection of examples wherein facts are coextant with specific inscriptions, is not clearly applicable, at least not in the same way, to the *ad hoc* assemblage of misinformation utilized by these groups. In other words, there is no BIPM rigorously and unambiguously promulgating misinformation.

Neither of the two primary memory practices encountered in Chapter 6, scientific and historical, seem to be active in what I know of these communities. It is possible that there are yet other techniques of forgetting, and technologies of remembering, which underlie counter-cultural misinformation movements. Stated in these terms, the serious analysis of certainty within these contexts could have major implications for the method overall.

These certainties, nevertheless, have real consequences. Everything from parents not vaccinating children to specific acts of sharing misinformation online can be traced to certainty in these actors. That the framework has so little to say about these cases without further work is a result of the bracketing of specific practices of justification in Section 2.3.1. While this compromise enabled the progress made so far, this will clearly have to be revisited if the analysis of certainty is to be more directly applicable to misinformation and the study of online social behavior more broadly.

## **Certainty and Security**

The validation of digital certificates abutted the analysis of computational timekeeping in Section 6.3. But issues of cybersecurity have a much broader surface of overlap than I was able to indicate.

### DNS

The DNS system used to translate domain names into IP addresses is a promising example of this. The DNS system is essentially designed as a network of rosters, with 13 named entities managing the *root servers* which then define subsidiary nameservers for the proliferating number of top level domains (TLDs). TLD registrars can then issue registrations, which are replicated by DNS servers through a peering structure. It should become clear that the ability to promulgate within this information system, which is taken-as incorrigible by the vast majority of networked clients, confers massive amounts of

power. The US government utilized its promulgative access to the system to remove the DNS entry for wikipedia.org when Julian Assange published US State department cables, which meant that visitors to the site had to instead enter the site's IP address directly to visit it. Connecting this line of inquiry with blockchain technology, proposals for providing domain name resolution through blockchain ledgers have been made, and functional prototypes have been tested. The main goal of these modifications is to restrict promulgative access to the system, though, of course, encoding the rules for 'legitimate' access will be difficult for similar reasons as those discussed regarding smart contracts.

### **Reprise: Certainty and Its Consequences**

I'll end with a reprise of the subject of Chapter 1, and hope that the theme is now more complex. This dissertation has endeavored to demonstrate that the phenomenon of certainty in information systems is one worth exploring. Initially this was through running and one-off examples, but the deeper engagement with specific systems in Part II aimed to connect certainty to an array of consequences, from the validity of cryptographic certificates to catching my bus home. Along the way, certainty was operationalized into discrete components, and these components formed a new vocabulary with which to describe the phenomenon. I found traces of engagement with certainty and its components in a variety of existing literature, as would be expected of such a purportedly pervasive phenomenon. At times I was compelled to critique or modify existing work to be suitable for application to the study of certainty *in information systems* specifically. And, of course, the resulting Roster, Inventory, and Ledger taxonomy presented and developed in Chapter 4 presented a method of analysis purpose-built to this task. Part II applied the taxonomy alongside a more traditional infrastructural inversion to trace certainty through a massive global assemblage that not only keeps time but partially structures the experience of temporality. The massive complexity of the enterprise results from the basic (and literal) irrationality of the durations which compose human experience. And the upshot of the entire system is that we can rely on the construction of the 86,400 second day, and the eventuality of a 86,401 second or 86,399 second day can be safely ignored.

There's another set of consequences of the phenomenon certainty that I'll end by emphasizing. These are the methodological consequences which I've reacted to throughout. Wittgenstein's "To be sure there is justification, but justification must come to an end somewhere" was a starting point for my investigation,

but it has morphed into a larger methodological principle. The analysis of certainty, like certainty itself, is an inherently *jussive* process. It is a memory practice, a technique of forgetting animating a technology of remembering. Like infrastructural inversion, it focuses on and reveals things ordinarily rendered invisible. But it must, and does stop somewhere. This is of course a limitation, but for those of us who have ceased searching for what Haraway critiqued as the god trick,<sup>10</sup> this is enough. The methodological question relevant here is: does the analysis stop alongside the actors?

The analysis of complex systems like computational timekeeping involved many sets of actors, human and non-human, with disjoint practices of justification, consultation, contemplation, and distinct resulting certainties. The analysis of these actors will not stop in the same place. It might shed additional light on *why* a promulgation is the way it is, and how a promulgating agent might thereby influence an enacting agent. But *any* analysis of certainty is complete if it follows the actor. The black box of the promulgation consulted, and everything jussively excluded from that inscription, may be relevant to the wider analysis. But a ‘full’ account of a promulgation does nothing to explain the certainty of the promulgating agent herself. In this way, the recursive application of the taxonomy can assemble a collage of produced certainties that can render a complex assemblage as a series of interconnected agents. But the investigator is *licensed* to stop at any point that the set of actors she is describing does. It is merely a question of the scope of certainties which are relevant to the investigation. The investigator’s contribution is combining certainties which are only tenuously, jussively, connected through inscription.

The analysis of certainty I’ve proposed is complete in a way that Wittgenstein hoped for in his philosophy:

The real discovery is the one that makes me capable of stopping doing philosophy when I want to.—The one that gives philosophy peace, so that it is no longer tormented by questions which bring *itself* into question.—Instead, we now demonstrate a method, by examples; and the series of examples can be broken off.<sup>11</sup>

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<sup>10</sup>“Vision in this technological feast becomes unregulated gluttony; all seems not just mythically about the god trick of seeing everything from nowhere, but to have put the myth into ordinary practice. And like the god trick, Question in Feminism and the Privilege of Partial Perspective,” *Feminist studies: FS* 14, no. 3 (1988): 581. An example of applying Haraway’s situated knowledges to information studies is in Melanie Feinberg, “Hidden bias to responsible bias: an approach to information systems based on Haraway’s situated knowledges,” *Information Research* 12, no. 4 (2007): 12–14.

<sup>11</sup>Wittgenstein, *Philosophical Investigations*, §133.

This dissertation is not a work of philosophy, but the field of sociotechnical analysis faces a similar problem of not being able to stop. How do we know that an analysis is *complete*? How can we be *certain*? The simple answer is that a consequence of certainty as we're approaching it here is that *every* analysis can produce certainty. Certainty is after all a stopping and moving on. The methodological question is not *whether* it's possible to move on, but rather exactly which techniques of justification we employ as we do. The circularity of this construction is something I've come to take as an indication of depth in a theoretical framework. An approach which is able to contemplate itself without, in Wittgenstein's words, "bringing *itself* into question," is complete. Other analyses await, but ours can and shall end here.



## **APPENDIX A: THEORY AND PRAGMATICS OF THE TZ DATABASE**

The following is the contents of `theory.html` from the source of the `tz` database. It describes the basics of the project's aims and how these aims are accomplished. Issues of accuracy and limitations are addressed. The document ends by expressing an aspiration that the `tz` database will one day be capable of expressing time zones on other planets.

This material is in the public domain.

# Theory and pragmatics of the tz code and data

## Outline

- [Scope of the tz database](#)
- [Names of time zone rules](#)
- [Time zone abbreviations](#)
- [Accuracy of the tz database](#)
- [Time and date functions](#)
- [Interface stability](#)
- [Calendrical issues](#)
- [Time and time zones on other planets](#)

## Scope of the tz database

The tz database attempts to record the history and predicted future of all computer-based clocks that track civil time. To represent this data, the world is partitioned into regions whose clocks all agree about timestamps that occur after the somewhat-arbitrary cutoff point of the POSIX Epoch (1970-01-01 00:00:00 UTC). For each such region, the database records all known clock transitions, and labels the region with a notable location. Although 1970 is a somewhat-arbitrary cutoff, there are significant challenges to moving the cutoff earlier even by a decade or two, due to the wide variety of local practices before computer timekeeping became prevalent.

Clock transitions before 1970 are recorded for each such location, because most systems support timestamps before 1970 and could misbehave if data entries were omitted for pre-1970 transitions. However, the database is not designed for and does not suffice for applications requiring accurate handling of all past times everywhere, as it would take far too much effort and guesswork to record all details of pre-1970 civil timekeeping.

As described below, reference source code for using the tz database is also available. The tz code is upwards compatible with POSIX, an international standard for UNIX-like systems. As of this writing, the current edition of POSIX is: [The Open Group Base Specifications Issue 7](#), IEEE Std 1003.1-2008, 2016 Edition.

## Names of time zone rules

Each of the database's time zone rules has a unique name. Inexperienced users are not expected to select these names unaided. Distributors should provide documentation and/or a simple

selection interface that explains the names; for one example, see the 'tzselect' program in the tz code. The [Unicode Common Locale Data Repository](#) contains data that may be useful for other selection interfaces.

The time zone rule naming conventions attempt to strike a balance among the following goals:

- Uniquely identify every region where clocks have agreed since 1970. This is essential for the intended use: static clocks keeping local civil time.
- Indicate to experts where that region is.
- Be robust in the presence of political changes. For example, names of countries are ordinarily not used, to avoid incompatibilities when countries change their name (e.g. Zaire → Congo) or when locations change countries (e.g. Hong Kong from UK colony to China).
- Be portable to a wide variety of implementations.
- Use a consistent naming conventions over the entire world.

Names normally have the form *AREA/LOCATION*, where *AREA* is the name of a continent or ocean, and *LOCATION* is the name of a specific location within that region. North and South America share the same area, 'America'. Typical names are 'Africa/Cairo', 'America/New\_York', and 'Pacific/Honolulu'.

Here are the general rules used for choosing location names, in decreasing order of importance:

- Use only valid POSIX file name components (i.e., the parts of names other than '/'). Do not use the file name components '.' and '..'. Within a file name component, use only ASCII letters, '.', '-' and '\_'. Do not use digits, as that might create an ambiguity with POSIX TZ strings. A file name component must not exceed 14 characters or start with '-'. E.g., prefer 'Brunei' to 'Bandar\_Seri\_Begawan'. Exceptions: see the discussion of legacy names below.
- A name must not be empty, or contain '//', or start or end with '/'.
- Do not use names that differ only in case. Although the reference implementation is case-sensitive, some other implementations are not, and they would mishandle names differing only in case.
- If one name *A* is an initial prefix of another name *AB* (ignoring case), then *B* must not start with '/', as a regular file cannot have the same name as a directory in POSIX. For example, 'America/New\_York' precludes 'America/New\_York/Bronx'.
- Uninhabited regions like the North Pole and Bouvet Island do not need locations, since local time is not defined there.
- There should typically be at least one name for each ISO 3166-1 officially assigned two-letter code for an inhabited country or territory.
- If all the clocks in a region have agreed since 1970, don't bother to include more than one location even if subregions' clocks disagreed before 1970. Otherwise these tables would become annoyingly large.

- If a name is ambiguous, use a less ambiguous alternative; e.g. many cities are named San José and Georgetown, so prefer 'Costa\_Rica' to 'San\_Jose' and 'Guyana' to 'Georgetown'.
- Keep locations compact. Use cities or small islands, not countries or regions, so that any future time zone changes do not split locations into different time zones. E.g. prefer 'Paris' to 'France', since France has had multiple time zones.
- Use mainstream English spelling, e.g. prefer 'Rome' to 'Roma', and prefer 'Athens' to the Greek 'Αθήνα' or the Romanized 'Athína'. The POSIX file name restrictions encourage this rule.
- Use the most populous among locations in a zone, e.g. prefer 'Shanghai' to 'Beijing'. Among locations with similar populations, pick the best-known location, e.g. prefer 'Rome' to 'Milan'.
- Use the singular form, e.g. prefer 'Canary' to 'Canaries'.
- Omit common suffixes like '\_Islands' and '\_City', unless that would lead to ambiguity. E.g. prefer 'Cayman' to 'Cayman\_Islands' and 'Guatemala' to 'Guatemala\_City', but prefer 'Mexico\_City' to 'Mexico' because the country of Mexico has several time zones.
- Use '\_' to represent a space.
- Omit '.' from abbreviations in names, e.g. prefer 'St\_Helena' to 'St.\_Helena'.
- Do not change established names if they only marginally violate the above rules. For example, don't change the existing name 'Rome' to 'Milan' merely because Milan's population has grown to be somewhat greater than Rome's.
- If a name is changed, put its old spelling in the 'backward' file. This means old spellings will continue to work.

The file 'zone1970.tab' lists geographical locations used to name time zone rules. It is intended to be an exhaustive list of names for geographic regions as described above; this is a subset of the names in the data. Although a 'zone1970.tab' location's longitude corresponds to its LMT offset with one hour for every 15 degrees east longitude, this relationship is not exact.

Older versions of this package used a different naming scheme, and these older names are still supported. See the file 'backward' for most of these older names (e.g., 'US/Eastern' instead of 'America/New\_York'). The other old-fashioned names still supported are 'WET', 'CET', 'MET', and 'EET' (see the file 'europe').

Older versions of this package defined legacy names that are incompatible with the first rule of location names, but which are still supported. These legacy names are mostly defined in the file 'etcetera'. Also, the file 'backward' defines the legacy names 'GMT0', 'GMT-0' and 'GMT+0', and the file 'northamerica' defines the legacy names 'EST5EDT', 'CST6CDT', 'MST7MDT', and 'PST8PDT'.

Excluding 'backward' should not affect the other data. If 'backward' is excluded, excluding 'etcetera' should not affect the remaining data.

## Time zone abbreviations

When this package is installed, it generates time zone abbreviations like 'EST' to be compatible with human tradition and POSIX. Here are the general rules used for choosing time zone abbreviations, in decreasing order of importance:

- Use three or more characters that are ASCII alphanumerics or '+' or '-'. Previous editions of this database also used characters like ' ' and '?', but these characters have a special meaning to the shell and cause commands like 'set `date`' to have unexpected effects. Previous editions of this rule required upper-case letters, but the Congressman who introduced Chamorro Standard Time preferred "ChST", so lower-case letters are now allowed. Also, POSIX from 2001 on relaxed the rule to allow '-', '+', and alphanumeric characters from the portable character set in the current locale. In practice ASCII alphanumerics and '+' and '-' are safe in all locales. In other words, in the C locale the POSIX extended regular expression `[ -+[:alnum:]]{3,}` should match the abbreviation. This guarantees that all abbreviations could have been specified by a POSIX TZ string.
- Use abbreviations that are in common use among English-speakers, e.g. 'EST' for Eastern Standard Time in North America. We assume that applications translate them to other languages as part of the normal localization process; for example, a French application might translate 'EST' to 'HNE'.
- For zones whose times are taken from a city's longitude, use the traditional xMT notation, e.g. 'PMT' for Paris Mean Time. The only name like this in current use is 'GMT'.
- Use 'LMT' for local mean time of locations before the introduction of standard time; see "[Scope of the tz database](#)".
- If there is no common English abbreviation, use numeric offsets like -05 and +0830 that are generated by zic's %z notation.
- Use current abbreviations for older timestamps to avoid confusion. For example, in 1910 a common English abbreviation for UT +01 in central Europe was 'MEZ' (short for both "Middle European Zone" and for "Mitteleuropäische Zeit" in German). Nowadays 'CET' ("Central European Time") is more common in English, and the database uses 'CET' even for circa-1910 timestamps as this is less confusing for modern users and avoids the need for determining when 'CET' supplanted 'MEZ' in common usage.
- Use a consistent style in a zone's history. For example, if a zone's history tends to use numeric abbreviations and a particular entry could go either way, use a numeric abbreviation.

[The remaining guidelines predate the introduction of %z. They are problematic as they mean tz data entries invent notation rather than record it. These guidelines are now deprecated and the plan is to gradually move to %z for inhabited locations and to "-00" for uninhabited locations.]

- If there is no common English abbreviation, abbreviate the English translation of the usual phrase used by native speakers. If this is not available or is a phrase mentioning the country (e.g. "Cape Verde Time"), then:

- When a country is identified with a single or principal zone, append 'T' to the country's ISO code, e.g. 'CVT' for Cape Verde Time. For summer time append 'ST'; for double summer time append 'DST'; etc.
- Otherwise, take the first three letters of an English place name identifying each zone and append 'T', 'ST', etc. as before; e.g. 'CHAST' for CHAtham Summer Time.
- Use UT (with time zone abbreviation '-00') for locations while uninhabited. The leading '-' is a flag that the time zone is in some sense undefined; this notation is derived from Internet RFC 3339.

Application writers should note that these abbreviations are ambiguous in practice: e.g. 'CST' has a different meaning in China than it does in the United States. In new applications, it's often better to use numeric UT offsets like '-0600' instead of time zone abbreviations like 'CST'; this avoids the ambiguity.

## Accuracy of the tz database

The tz database is not authoritative, and it surely has errors. Corrections are welcome and encouraged; see the file CONTRIBUTING. Users requiring authoritative data should consult national standards bodies and the references cited in the database's comments.

Errors in the tz database arise from many sources:

- The tz database predicts future timestamps, and current predictions will be incorrect after future governments change the rules. For example, if today someone schedules a meeting for 13:00 next October 1, Casablanca time, and tomorrow Morocco changes its daylight saving rules, software can mess up after the rule change if it blithely relies on conversions made before the change.
- The pre-1970 entries in this database cover only a tiny sliver of how clocks actually behaved; the vast majority of the necessary information was lost or never recorded. Thousands more zones would be needed if the tz database's scope were extended to cover even just the known or guessed history of standard time; for example, the current single entry for France would need to split into dozens of entries, perhaps hundreds. And in most of the world even this approach would be misleading due to widespread disagreement or indifference about what times should be observed. In her 2015 book *The Global Transformation of Time, 1870-1950*, Vanessa Ogle writes "Outside of Europe and North America there was no system of time zones at all, often not even a stable landscape of mean times, prior to the middle decades of the twentieth century". See: Timothy Shenk, [Booked: A Global History of Time](#). *Dissent* 2015-12-17.
- Most of the pre-1970 data entries come from unreliable sources, often astrology books that lack citations and whose compilers evidently invented entries when the true facts were unknown, without reporting which entries were known and which were invented. These books often contradict each other or give implausible entries, and on the rare occasions when they are checked they are typically found to be incorrect.

- For the UK the tz database relies on years of first-class work done by Joseph Myers and others; see "[History of legal time in Britain](#)". Other countries are not done nearly as well.
- Sometimes, different people in the same city would maintain clocks that differed significantly. Railway time was used by railroad companies (which did not always agree with each other), church-clock time was used for birth certificates, etc. Often this was merely common practice, but sometimes it was set by law. For example, from 1891 to 1911 the UT offset in France was legally 0:09:21 outside train stations and 0:04:21 inside.
- Although a named location in the tz database stands for the containing region, its pre-1970 data entries are often accurate for only a small subset of that region. For example, Europe/London stands for the United Kingdom, but its pre-1847 times are valid only for locations that have London's exact meridian, and its 1847 transition to GMT is known to be valid only for the L&NW and the Caledonian railways.
- The tz database does not record the earliest time for which a zone's data entries are thereafter valid for every location in the region. For example, Europe/London is valid for all locations in its region after GMT was made the standard time, but the date of standardization (1880-08-02) is not in the tz database, other than in commentary. For many zones the earliest time of validity is unknown.
- The tz database does not record a region's boundaries, and in many cases the boundaries are not known. For example, the zone America/Kentucky/Louisville represents a region around the city of Louisville, the boundaries of which are unclear.
- Changes that are modeled as instantaneous transitions in the tz database were often spread out over hours, days, or even decades.
- Even if the time is specified by law, locations sometimes deliberately flout the law.
- Early timekeeping practices, even assuming perfect clocks, were often not specified to the accuracy that the tz database requires.
- Sometimes historical timekeeping was specified more precisely than what the tz database can handle. For example, from 1909 to 1937 Netherlands clocks were legally UT +00:19:32.13, but the tz database cannot represent the fractional second.
- Even when all the timestamp transitions recorded by the tz database are correct, the tz rules that generate them may not faithfully reflect the historical rules. For example, from 1922 until World War II the UK moved clocks forward the day following the third Saturday in April unless that was Easter, in which case it moved clocks forward the previous Sunday. Because the tz database has no way to specify Easter, these exceptional years are entered as separate tz Rule lines, even though the legal rules did not change.
- The tz database models pre-standard time using the proleptic Gregorian calendar and local mean time (LMT), but many people used other calendars and other timescales. For example, the Roman Empire used the Julian calendar, and had 12 varying-length daytime hours with a non-hour-based system at night.
- Early clocks were less reliable, and data entries do not represent clock error.
- The tz database assumes Universal Time (UT) as an origin, even though UT is not standardized for older timestamps. In the tz database commentary, UT denotes a family of time standards that includes Coordinated Universal Time (UTC) along with other variants such as UT1 and GMT, with days starting at midnight. Although UT equals UTC for

modern timestamps, UTC was not defined until 1960, so commentary uses the more-general abbreviation UT for timestamps that might predate 1960. Since UT, UT1, etc. disagree slightly, and since pre-1972 UTC seconds varied in length, interpretation of older timestamps can be problematic when subsecond accuracy is needed.

- Civil time was not based on atomic time before 1972, and we don't know the history of earth's rotation accurately enough to map SI seconds to historical solar time to more than about one-hour accuracy. See: Stephenson FR, Morrison LV, Hohenkerk CY. [Measurement of the Earth's rotation: 720 BC to AD 2015](#). *Proc Royal Soc A*. 2016 Dec 7;472:20160404. Also see: Espenak F. [Uncertainty in Delta T \( \$\Delta T\$ \)](#).
- The relationship between POSIX time (that is, UTC but ignoring leap seconds) and UTC is not agreed upon after 1972. Although the POSIX clock officially stops during an inserted leap second, at least one proposed standard has it jumping back a second instead; and in practice POSIX clocks more typically either progress glacially during a leap second, or are slightly slowed while near a leap second.
- The tz database does not represent how uncertain its information is. Ideally it would contain information about when data entries are incomplete or dicey. Partial temporal knowledge is a field of active research, though, and it's not clear how to apply it here.

In short, many, perhaps most, of the tz database's pre-1970 and future timestamps are either wrong or misleading. Any attempt to pass the tz database off as the definition of time should be unacceptable to anybody who cares about the facts. In particular, the tz database's LMT offsets should not be considered meaningful, and should not prompt creation of zones merely because two locations differ in LMT or transitioned to standard time at different dates.

## Time and date functions

The tz code contains time and date functions that are upwards compatible with those of POSIX.

POSIX has the following properties and limitations.

- In POSIX, time display in a process is controlled by the environment variable TZ. Unfortunately, the POSIX TZ string takes a form that is hard to describe and is error-prone in practice. Also, POSIX TZ strings can't deal with other (for example, Israeli) daylight saving time rules, or situations where more than two time zone abbreviations are used in an area.

The POSIX TZ string takes the following form:

`stdoffset[dst[offset]][, date[/time], date[/time]]`

where:

*std* and *dst*



are 3 or more characters specifying the standard and daylight saving time (DST) zone names. Starting with POSIX.1-2001, *std* and *dst* may also be in a quoted form like '<UTC+10>'; this allows "+" and "-" in the names.

*offset*

is of the form '[ $\pm$ ]hh:[mm[:ss]]' and specifies the offset west of UT. 'hh' may be a single digit;  $0 \leq hh \leq 24$ . The default DST offset is one hour ahead of standard time.

*date[/time], date[/time]*

specifies the beginning and end of DST. If this is absent, the system supplies its own rules for DST, and these can differ from year to year; typically US DST rules are used.

*time*

takes the form 'hh:[mm[:ss]]' and defaults to 02:00. This is the same format as the offset, except that a leading '+' or '-' is not allowed.

*date*

takes one of the following forms:

*Jn* ( $1 \leq n \leq 365$ )

origin-1 day number not counting February 29

*n* ( $0 \leq n \leq 365$ )

origin-0 day number counting February 29 if present

*mm.n.d* ( $0[\text{Sunday}] \leq d \leq 6[\text{Saturday}]$ ,  $1 \leq n \leq 5$ ,  $1 \leq m \leq 12$ )

for the *d*th day of week *n* of month *m* of the year, where week 1 is the first week in which day *d* appears, and '5' stands for the last week in which day *d* appears (which may be either the 4th or 5th week). Typically, this is the only useful form; the *n* and *Jn* forms are rarely used.

Here is an example POSIX TZ string for New Zealand after 2007. It says that standard time (NZST) is 12 hours ahead of UTC, and that daylight saving time (NZDT) is observed from September's last Sunday at 02:00 until April's first Sunday at 03:00:

```
TZ='NZST-12NZDT,M9.5.0,M4.1.0/3'
```

This POSIX TZ string is hard to remember, and mishandles some timestamps before 2008. With this package you can use this instead:

```
TZ='Pacific/Auckland'
```

- POSIX does not define the exact meaning of TZ values like "EST5EDT". Typically the current US DST rules are used to interpret such values, but this means that the US DST rules are compiled into each program that does time conversion. This means that when US time conversion rules change (as in the United States in 1987), all programs that do time conversion must be recompiled to ensure proper results.
- The TZ environment variable is process-global, which makes it hard to write efficient, thread-safe applications that need access to multiple time zones.

- In POSIX, there's no tamper-proof way for a process to learn the system's best idea of local wall clock. (This is important for applications that an administrator wants used only at certain times – without regard to whether the user has fiddled the TZ environment variable. While an administrator can "do everything in UTC" to get around the problem, doing so is inconvenient and precludes handling daylight saving time shifts - as might be required to limit phone calls to off-peak hours.)
- POSIX provides no convenient and efficient way to determine the UT offset and time zone abbreviation of arbitrary timestamps, particularly for time zone settings that do not fit into the POSIX model.
- POSIX requires that systems ignore leap seconds.
- The tz code attempts to support all the `time_t` implementations allowed by POSIX. The `time_t` type represents a nonnegative count of seconds since 1970-01-01 00:00:00 UTC, ignoring leap seconds. In practice, `time_t` is usually a signed 64- or 32-bit integer; 32-bit signed `time_t` values stop working after 2038-01-19 03:14:07 UTC, so new implementations these days typically use a signed 64-bit integer. Unsigned 32-bit integers are used on one or two platforms, and 36-bit and 40-bit integers are also used occasionally. Although earlier POSIX versions allowed `time_t` to be a floating-point type, this was not supported by any practical systems, and POSIX.1-2013 and the tz code both require `time_t` to be an integer type.

These are the extensions that have been made to the POSIX functions:

- The TZ environment variable is used in generating the name of a file from which time zone information is read (or is interpreted a la POSIX); TZ is no longer constrained to be a three-letter time zone name followed by a number of hours and an optional three-letter daylight time zone name. The daylight saving time rules to be used for a particular time zone are encoded in the time zone file; the format of the file allows U.S., Australian, and other rules to be encoded, and allows for situations where more than two time zone abbreviations are used.

It was recognized that allowing the TZ environment variable to take on values such as 'America/New\_York' might cause "old" programs (that expect TZ to have a certain form) to operate incorrectly; consideration was given to using some other environment variable (for example, TIMEZONE) to hold the string used to generate the time zone information file name. In the end, however, it was decided to continue using TZ: it is widely used for time zone purposes; separately maintaining both TZ and TIMEZONE seemed a nuisance; and systems where "new" forms of TZ might cause problems can simply use TZ values such as "EST5EDT" which can be used both by "new" programs (a la POSIX) and "old" programs (as zone names and offsets).

- The code supports platforms with a UT offset member in `struct tm`, e.g., `tm_gmtoff`.
- The code supports platforms with a time zone abbreviation member in `struct tm`, e.g., `tm_zone`.

- Since the TZ environment variable can now be used to control time conversion, the daylight and timezone variables are no longer needed. (These variables are defined and set by tzset; however, their values will not be used by localtime.)
- Functions tzalloc, tzfree, localtime\_rz, and mktime\_z for more-efficient thread-safe applications that need to use multiple time zones. The tzalloc and tzfree functions allocate and free objects of type timezone\_t, and localtime\_rz and mktime\_z are like localtime\_r and mktime with an extra timezone\_t argument. The functions were inspired by NetBSD.
- A function tzsetwall has been added to arrange for the system's best approximation to local wall clock time to be delivered by subsequent calls to localtime. Source code for portable applications that "must" run on local wall clock time should call tzsetwall; if such code is moved to "old" systems that don't provide tzsetwall, you won't be able to generate an executable program. (These time zone functions also arrange for local wall clock time to be used if tzset is called – directly or indirectly – and there's no TZ environment variable; portable applications should not, however, rely on this behavior since it's not the way SVR2 systems behave.)
- Negative time\_t values are supported, on systems where time\_t is signed.
- These functions can account for leap seconds, thanks to Bradley White.

Points of interest to folks with other systems:

- Code compatible with this package is already part of many platforms, including GNU/Linux, Android, the BSDs, Chromium OS, Cygwin, AIX, iOS, BlackBerry 10, macOS, Microsoft Windows, OpenVMS, and Solaris. On such hosts, the primary use of this package is to update obsolete time zone rule tables. To do this, you may need to compile the time zone compiler 'zic' supplied with this package instead of using the system 'zic', since the format of zic's input is occasionally extended, and a platform may still be shipping an older zic.
- The UNIX Version 7 timezone function is not present in this package; it's impossible to reliably map timezone's arguments (a "minutes west of GMT" value and a "daylight saving time in effect" flag) to a time zone abbreviation, and we refuse to guess. Programs that in the past used the timezone function may now examine localtime(&clock)->tm\_zone (if TM\_ZONE is defined) or tzname[localtime(&clock)->tm\_isdst] (if HAVE\_TZNAME is defined) to learn the correct time zone abbreviation to use.
- The 4.2BSD gettimeofday function is not used in this package. This formerly let users obtain the current UTC offset and DST flag, but this functionality was removed in later versions of BSD.
- In SVR2, time conversion fails for near-minimum or near-maximum time\_t values when doing conversions for places that don't use UT. This package takes care to do these conversions correctly. A comment in the source code tells how to get compatibly wrong results.

The functions that are conditionally compiled if `STD_INSPIRED` is defined should, at this point, be looked on primarily as food for thought. They are not in any sense "standard compatible" – some are not, in fact, specified in *any* standard. They do, however, represent responses of various authors to standardization proposals.

Other time conversion proposals, in particular the one developed by folks at Hewlett Packard, offer a wider selection of functions that provide capabilities beyond those provided here. The absence of such functions from this package is not meant to discourage the development, standardization, or use of such functions. Rather, their absence reflects the decision to make this package contain valid extensions to POSIX, to ensure its broad acceptability. If more powerful time conversion functions can be standardized, so much the better.

## Interface stability

The tz code and data supply the following interfaces:

- A set of zone names as per "[Names of time zone rules](#)" above.
- Library functions described in "[Time and date functions](#)" above.
- The programs `tzselect`, `zdump`, and `zic`, documented in their man pages.
- The format of `zic` input files, documented in the `zic` man page.
- The format of `zic` output files, documented in the `tzfile` man page.
- The format of zone table files, documented in `zone1970.tab`.
- The format of the country code file, documented in `iso3166.tab`.
- The version number of the code and data, as the first line of the text file 'version' in each release.

Interface changes in a release attempt to preserve compatibility with recent releases. For example, tz data files typically do not rely on recently-added `zic` features, so that users can run older `zic` versions to process newer data files. [Sources for time zone and daylight saving time data](#) describes how releases are tagged and distributed.

Interfaces not listed above are less stable. For example, users should not rely on particular UT offsets or abbreviations for timestamps, as data entries are often based on guesswork and these guesses may be corrected or improved.

## Calendrical issues

Calendrical issues are a bit out of scope for a time zone database, but they indicate the sort of problems that we would run into if we extended the time zone database further into the past. An excellent resource in this area is Nachum Dershowitz and Edward M. Reingold, [Calendrical Calculations: Third Edition](#), Cambridge University Press (2008). Other information and sources are given in the file 'calendar.s' in the tz distribution. They sometimes disagree.

## Time and time zones on other planets

Some people's work schedules use Mars time. Jet Propulsion Laboratory (JPL) coordinators have kept Mars time on and off at least since 1997 for the Mars Pathfinder mission. Some of their family members have also adapted to Mars time. Dozens of special Mars watches were built for JPL workers who kept Mars time during the Mars Exploration Rovers mission (2004). These timepieces look like normal Seikos and Citizens but use Mars seconds rather than terrestrial seconds.

A Mars solar day is called a "sol" and has a mean period equal to about 24 hours 39 minutes 35.244 seconds in terrestrial time. It is divided into a conventional 24-hour clock, so each Mars second equals about 1.02749125 terrestrial seconds.

The prime meridian of Mars goes through the center of the crater Airy-0, named in honor of the British astronomer who built the Greenwich telescope that defines Earth's prime meridian. Mean solar time on the Mars prime meridian is called Mars Coordinated Time (MTC).

Each landed mission on Mars has adopted a different reference for solar time keeping, so there is no real standard for Mars time zones. For example, the Mars Exploration Rover project (2004) defined two time zones "Local Solar Time A" and "Local Solar Time B" for its two missions, each zone designed so that its time equals local true solar time at approximately the middle of the nominal mission. Such a "time zone" is not particularly suited for any application other than the mission itself.

Many calendars have been proposed for Mars, but none have achieved wide acceptance. Astronomers often use Mars Sol Date (MSD) which is a sequential count of Mars solar days elapsed since about 1873-12-29 12:00 GMT.

In our solar system, Mars is the planet with time and calendar most like Earth's. On other planets, Sun-based time and calendars would work quite differently. For example, although Mercury's sidereal rotation period is 58.646 Earth days, Mercury revolves around the Sun so rapidly that an observer on Mercury's equator would see a sunrise only every 175.97 Earth days, i.e., a Mercury year is 0.5 of a Mercury day. Venus is more complicated, partly because its rotation is slightly retrograde: its year is 1.92 of its days. Gas giants like Jupiter are trickier still, as their polar and equatorial regions rotate at different rates, so that the length of a day depends on latitude. This effect is most pronounced on Neptune, where the day is about 12 hours at the poles and 18 hours at the equator.

Although the tz database does not support time on other planets, it is documented here in the hopes that support will be added eventually.

Sources:

- Michael Allison and Robert Schmunk, "[Technical Notes on Mars Solar Time as Adopted by the Mars24 Sunclock](#)" (2012-08-08).
- Jia-Rui Chong, "[Workdays Fit for a Martian](#)", Los Angeles Times (2004-01-14), pp A1, A20-A21.
- Tom Chmielewski, "[Jet Lag Is Worse on Mars](#)", The Atlantic (2015-02-26)
- Matt Williams, "[How long is a day on the other planets of the solar system?](#)" (2017-04-27).

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This file is in the public domain, so clarified as of 2009-05-17 by Arthur David Olson.

## APPENDIX B: BIPM TAI TIME LINK COMPARISON

The following is BIPM's provided documentation for TAI time link comparison data and graphs, such as that in Figure 6.4 (page 162). Like many such BIPM publications, it utilizes a range of conceptual and literal links to other documents, which themselves contain still further linkages. A further analysis of certainty could trace the links between promulgated documents, noting the roles each promulgations plays for documents which link to it. Though the *existence* and production of such links is paramount to the cultural logic of scientific metrology, little if any of these documents are ever viewed or consulted by those not engaged in the enterprise of producing a scientific time standard. The most easily conceivable use of these products might be another scientific enterprise which consumes a specific TAI time signal as a roster of duration and consults the more detailed uncertainty values for use in statistical calculations involving time units shorter than the monthly values published in *Circular T*.

This material is in the public domain.

## TM137 BIPM TAI Time Link Comparison on ftp

Version 1: Oct. 2004 by ZJ

Version 6 Last edit: 27 May 2005 by AF/GP

Version 7 Last edit: 26 May 2008: Comparison including GPS PPP by GP

Version 8 Last edit: 10 June 2009: Comparison including GLONASS by ZJ,

Version 9 Last edit: 21 Jan. 2011 by ZJ: Link combinations: GPS+GLN, TW+PPP/P3:

[ftp://tai.bipm.org/TimeLink/LkC/ReadMe\\_LinkComparison\\_ftp\\_v9.doc](ftp://tai.bipm.org/TimeLink/LkC/ReadMe_LinkComparison_ftp_v9.doc)

Version 10 Last edit 17 March 2016 by GP.

Version 11 Last edit 19 January 2018 by GP;

Contact: [tai@bipm.org](mailto:tai@bipm.org)

This is the Read Me file of the ftp site on the TAI time link results calculated by the BIPM Time Section. The comparison results since January 2005 are published each month after the BIPM Circular T in <ftp://ftp2.bipm.org/pub/tai/publication/timelinks/lkc>

Version 6 is characterized by the comparisons of the time transfer methods: GPS common view and all in view.

Version 7 is characterized by the comparisons between TW and **GPS PPP** for TAI and non-TAI time links. Important modifications vs. version 6 are in red colour. Version 7 is mis en pratique since TAI 0804. The monthly GPS PPP computation solutions are on <ftp://ftp2.bipm.org/pub/tai/publication/timelinks/taippp>

Version 8 is based on the version 7 and characterized by including **GLONASS** and long term (yearly) data comparisons. SU-PTB GLN has been used in UTC since Nov. 2009.

Version 9 includes the link combinations of GPS+GLN and TW+GPSPPP. Cf. TM185: [ftp://ftp2.bipm.org/pub/tai/publication/timelinks/lkc/tm185\\_new-in-tsoft\\_lnkcombination.doc](ftp://ftp2.bipm.org/pub/tai/publication/timelinks/lkc/tm185_new-in-tsoft_lnkcombination.doc), and the Figures 7, 8, 9 and 10 in the end of this doc. Combined links have been used in UTC for SU, UME, CH, NIST, OP and SP since Jan. 2011

Version 10 includes optical fiber links, as of January 2016 the two links AOS-PL and BEV-TP. It also includes experimental computation of GPS PPP with integer ambiguities (IPPP) which, as of January 2016, concerns the link AOS-PL. Although the principle of IPPP is equivalent to the classical GPS PPP, its results are presently computed and treated by the BIPM software as if they were two way links. Therefore they are classified below, and they appear in the ftp site, as TW links.

Version 11 incorporates the possibility to publish TW SDR links and link comparisons, as well as Galileo (GAL) and BeiDou (BDS) dual frequency links and link comparisons. It also clarifies the presentation in section 2 and provides new accompanying figures.

**Warning:** The monthly LkC directories are intended to provide all links available on a given month but only "official" links that are used for UTC computation can be considered as calibrated. These links and the calibration information are listed in Circular T section 5. Therefore users are warned that the comparison between two links does not necessarily reflect the relative accuracy of the links. On the other hand, the comparison is expected to reflect the



relative stability of the links. Similarly long solutions that can be assembled by stacking monthly files are not certified to be continuous.

Starting with version 7, neither mean value nor slope will be removed in the plots as was the case in the version 6. Cf. TM151 for details:

[ftp://ftp2.bipm.org/pub/tai/publication/timelinks/lkc/tm151\\_twcalib.doc](ftp://ftp2.bipm.org/pub/tai/publication/timelinks/lkc/tm151_twcalib.doc)

## 1. Introduction and directory structure

The monthly comparisons are in \LkC\YYMM where YYMM corresponds to the year and month of the calculated Circular T, for example, 0501 is for 2005 January. They contain plots and data files for link values and link comparisons for all measurement dates. See section 2.

The general directory tree looks like:

<ftp://ftp2.bipm.org/pub/tai/publication/timelinks/lkc>

```

ReadMe
|
+---0501      : results for 2005 January
|   |
|   +---Dlk0501.sum
|   |   |
|   |   +---Lab2Lab1: results for link Lab2-Lab1 of 0501
|   |   |   |
|   |   |   +---Dlk: Link comparisons for Lab2-Lab1
|   |   |   |   |
|   |   |   |   +---Lnk: Link results for Lab2-Lab1
|   |   |   |   |
|   |   |   |   +---... ..
|   |   |   |
|   |   |   +---... ..
|   |   |
|   |   +---... ..
|   |
|   +---0502      : results for 2005 February
|   |
|   +---... ..
|
+---... ..

```

A link, Lab2Lab1 is always defined as:  $Link = UTC(Lab2) - UTC(Lab1)$ . Here Lab1 is usually the so called pivot laboratory.

A comparison of links is always defined as  $dLink = Link1 - Link2$

By default, the unit for all the tables and plots is 1 ns.

The link results are computed without any time or receiver jumps introduced.

## 2. The Monthly Comparison

### 2.0 Summary of statistics of link comparisons

File DlkYYMM.sum in subdirectories \LkC\YYMM\ provides the summary of the statistics of all link comparisons in the subdirectory \YYMM. For each link comparison data file one line summarises the statistics (see example in section 2.2). Comments may be added for each link to indicate special features that may affect the statistics e.g. data gaps, known or suspected time steps, known or suspected outliers, etc...

## 2.1 The file naming conventions

In each sub-directory of \LkC\YYMM\Lab2Lab1\, there are two sub-directories: The Link subdirectory contains the Link files and the dLink subdirectory contains the dLink (link comparisons) files:

### 2.1.1 Link files

The Link files are ASCII data files (for GNSS) with the name **Lab2Lab1.ABCDc.dat** and plots in Gif format with the name **Lab2Lab1.ABCDc.gif**, where

**C** is the **Link type**

**D** is the **Link computation type**

**c** is an additional identifier of the link computation type

If the **Link type C** indicates a single technique, then

**A** is the **Observation type** of Lab2

**B** is the **Observation type** of Lab1

If the **Link type C** indicates a combination of techniques, then

**A** is the **Link type** of the first technique

**B** is the **Link type** of the second technique

- **Observation types** and single-technique **Link types** are

**S** = GPS Single Channel C/A code

**M** = GPS Multi-Channel C/A code

**R** = GLONASS C/A code

**P** = GPS dual frequency P3 code

**C** = BDS dual frequency, as defined in CGGTTS version 2E (B1I and B2I codes)

**E** = GAL dual frequency, as defined in CGGTTS version 2E (E1 and E5a codes)

**3** = GPS PPP

**T** = Two way time transfer techniques, e.g. through satellites on Ku band or through optical fibers. For practical reasons, this also includes links obtained with IPPP computations.

Although the codes are the same for the two fields, they have different meanings, e.g. a "Link type" S can result from two data files with "Observation type" M and S, or S and S. Only the "Link type" is retained to name the dLink (link comparison) files.

- **Link types** of combinations of techniques are

**B** = **GNSS and TW combination**

- The **Link computation types** are

- For single-technique **Link types**:

**C** = Common View for GNSS links

**A** = All in View for GNSS links (also applies to PPP)

**B** = **GNSS and TW combination**

**T** = Two way time transfer. For Ku band, the computation follows ITU-Rec1153; other types are identified by the additional identifier **c** (see below).


- For **Link types** of combinations of techniques:  
**1** = Average of two techniques  
**3** = Combined Vondrak smoothing of two techniques














Note that GNSS links are always computed with data corrected for IGS precise ephemerides and solid Earth tides. **S** and **M** types are also corrected for ionospheric delay from IGS maps

- The additional identifier of the link computation type is  
**\_** = no additional identifier needed, e.g. for GNSS or TW time transfer Ku band  
**o** = two way by optical fiber  
**i** = link obtained with IPPP computations  
**s** = TW time transfer Ku band with Software Defined Radio (SDR) receiver

See in Figure 1 an example of directory with link files.

Index de <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/lnc/>

 Vers un rép. de plus haut niveau

Nom	
 opptb.333a_.dat	333a_ = GPSPPP link from two PPP results files
 opptb.333a_.gif	
 opptb.mmma_.dat	mma_ = GPS MC link from two multi-channel C1 GPS files, All-in-view
 opptb.mmma_.gif	
 opptb.pppa_.dat	pppa_ = GPS P3 link from two dual-frequency GPS files, All-in-view
 opptb.pppa_.gif	
 opptb.rrrc_.dat	rrrc_ = GLN MC link from two multi-channel C1 GLONASS files, Common-view
 opptb.rrrc_.gif	
 opptb.t3b3_.dat	t3b3_ = TWGPPP link, from combined smoothing of TW and GPSPPP links
 opptb.t3b3_.gif	
 opptb.tttt_.gif	tttt_ = TWSTFT link, from standard Ku-band TW on geo satellites
 opptb.tttts.dat	
 opptb.tttts.gif	tttts = TWSTFT link, from Ku-band TW on geo satellites with SDR

**Fig. 1:** Directory of link files for the link OP-PTB for November 2017, available at <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/lnc/>, with explanatory notes on the filenames.

### 2.1.2 Link comparison files

The dLink (link comparison) files are data in ASCII format and plots in Gif format. The file name is **Lab2Lab1.ABCD5** for a data file and **Lab2Lab1.ABCD5.gif** for a plot file, where

**A** is the Link type of the first link

**B** is the Link type of the second link


**C** is the Link computation type of the first link if the additional identifier is ‘\_’, or the additional identifier if it is not ‘\_’.

**D** is the Link computation type of the second link if the additional identifier is ‘\_’, or the additional identifier if it is not ‘\_’.

WARNING: Until November 2017, some errors in the nomenclature occurred, where the ‘C’ or ‘D’ codes were not correctly attributed.

See in Figure 2 an example of directory with link comparison files

Index de <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/dlk/>

 Vers un rép. de plus haut niveau



















Nom	
 opptb.b33a5	b33a5 = Comparison of TWGPPP combination to GPSPPP link
 opptb.b33a5.gif	
 opptb.p3aa5	p3aa5 = Comparison of GPS P3 to GPSPPP link
 opptb.p3aa5.gif	
 opptb.rmca5	rmca5 = Comparison of GLN MC link (common view) to GPS MC link (All-in-view)
 opptb.rmca5.gif	
 opptb.rtct5	rtct5 = Comparison of GLN MC link (common view) to TWSTFT link
 opptb.rtct5.gif	
 opptb.t3sa5	t3sa5 = Comparison of TWSTFT SDR link to GPSPPP link
 opptb.t3sa5.gif	
 opptb.t3ta5	t3ta5 = Comparison of TWSTFT link to GPSPPP link
 opptb.t3ta5.gif	
 opptb.tbt35	tbt35 = Comparison of TWSTFT link to TWGPPP combination
 opptb.tbt35.gif	
 opptb.tpta5	tpta5 = Comparison of TWSTFT link to GPS P3 link
 opptb.tpta5.gif	
 opptb.ttts5	ttts5 = Comparison of TWSTFT link to TWSTFT SDR link
 opptb.ttts5.gif	

Fig. 2: Directory of link comparison files for the link OP-PTB for November 2017, available at <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/dlk/>, with explanatory notes on the filenames.

## 2.2 The data files

### 2.2.1 Link data files

A GNSS link data file **Lab2Lab1.ABCD\_.Dat** has three parts: the header, the link data body and the plot data body. We ignore here the first and the 3<sup>rd</sup> parts. The link data body has four columns: MJD, link value, Vondrak smoothing value and their difference, as displayed in the table below. The TW link data files are not included. The complete TW link data values can be found in the link comparison file, see below section 2.2.2.

MJD	Link	Smth	Resid
54552.00000	91.820	92.140	0.320
54552.00347	91.942	92.167	0.225
54552.00694	91.980	92.195	0.215
54552.01042	92.075	92.224	0.149
54552.01389	92.083	92.254	0.171
54552.01736	92.157	92.285	0.128
54552.02083	92.313	92.316	0.003
54552.02431	92.378	92.348	-0.030

## 2.2.2 Link comparison data files

An example of link comparison data is shown below, the comparison between the TW link (Link1) and GPS single channel CV link (Link2): NISTPTB.TSTC5.

! 0502	Mjd	Link1	Link2	dLink	Jump1	Jump2	dLink_
1	53397.0347	-5.879	7.420	-13.299	0.000	0.000	-13.299
2	53397.3680	-6.051	7.264	-13.315	0.000	0.000	-13.315
...	...	...	...	...	...	...	...
130	53430.6180	-0.170	12.480	-12.650	0.000	0.000	-12.650
131	53430.7014	-0.703	12.371	-13.074	0.000	0.000	-13.074
! Combined dLink Statis. NISTPTB.TSTC5 :							
N,Min,Max,Mean,RMS,SD= 131 -15.539 -10.240 -12.850 12.896 1.085							

Data lines are numbered consecutively and contain

Mjd = Date of measurement

Link1, Link2 = Link values

dLink = Link1 - Link2

Jump1, Jump2 : optional time correction applied to Link1 or Link2

dLink\_ = (Link1+Jump1) - (Link2+Jump2)

Information in the last line:

N = total number of measurements

Min = minimum value of dLink

Max = maximum value of dLink

Mean = mean value of dLink

RMS = Root Mean Square of the dLink values

SD = Standard Deviation of the dLink values

The values following this line are only used to produce the corresponding stability plots and are not described here.

In general, the first link is chosen as the less dense and the denser second link is interpolated to the epochs of the first link.

## 2.3 The Plots of links and link comparisons

### 2.3.1 The plot of a link

See examples Figures 3 and 4.

The plot contains 4 figures:

- the top figure represents the link measured values (ns) with red numbers indicating the link values computed on the standard TAI dates.<sup>1</sup>
- the middle figure represents the residuals = measured - smoothed: For GNSS 'smoothed' is the result of Vondrak smoothing. For TW, it is the linear interpolation of the two adjacent point.
- the bottom left figure : the Modified Allan Deviation of the link measured values.
- the bottom right figure : the Time Deviation of the link measured values.

Description of the legends in the plots

- Bottom line of the top figure indicates, the type of the link, the year and month, the two laboratories and their TAI codes, the total number of points and the time and date of the processing.
- Bottom line in the middle figure indicates the maximum value and the standard deviation of the residuals, and (for GNSS links) the power of the Vondrak smoothing.
- Top line of the bottom figures indicates Tau0, the averaging time for the first point of the deviations, and Scale, the unit for the indicated values.
- Bottom line of the bottom figures, d/8, d/4 and d/2 stand for day/8, day/4 and day/2; dd and ddd stand for 2 and 3 days; wk means a week

### 2.3.2 The plot of a link comparison (dLink)

See an example Figure 5.

The plot contains 4 figures:

- the top figure represents the measured values (ns) of the two links to be compared Link1(black crosses) and Link2(blue circles)<sup>2</sup>. If the maximum absolute value of the difference dLink exceeds 100 ns, the mean value of dLink (shown in the middle figure) will be subtracted from the Link1 before plotting and the keyword "MeanRmved" will appear.
- The middle figure is the differences  $dLink = Link1 - Link2$ . Note that the red numbers represent real points chosen "at random" to indicate the order of magnitude of the values and their variations. They are not intended to represent special points.
- the bottom left figure : the Modified Allan Deviation of the dLink values.
- the bottom right figure : the Time Deviation of the dLink values.

Description of the legends in the plots

- Bottom line of the top figure indicates the year and month, the name of the dLink data file, the total number of points. MeanRmved appears if the mean value has been removed.
- Bottom line in the middle figure indicates the maximum, minimum and average value of dLink and its standard deviation.
- Legends in the bottom figures are similar to the Link plot.

<sup>1</sup> For a IPPP link, the mention « IPPP reset » indicates that there is no intrinsic connection between the sections before and after the reset. In this case the two sections have been connected using external information, usually another available link.

<sup>2</sup> See note 1, preceding page.

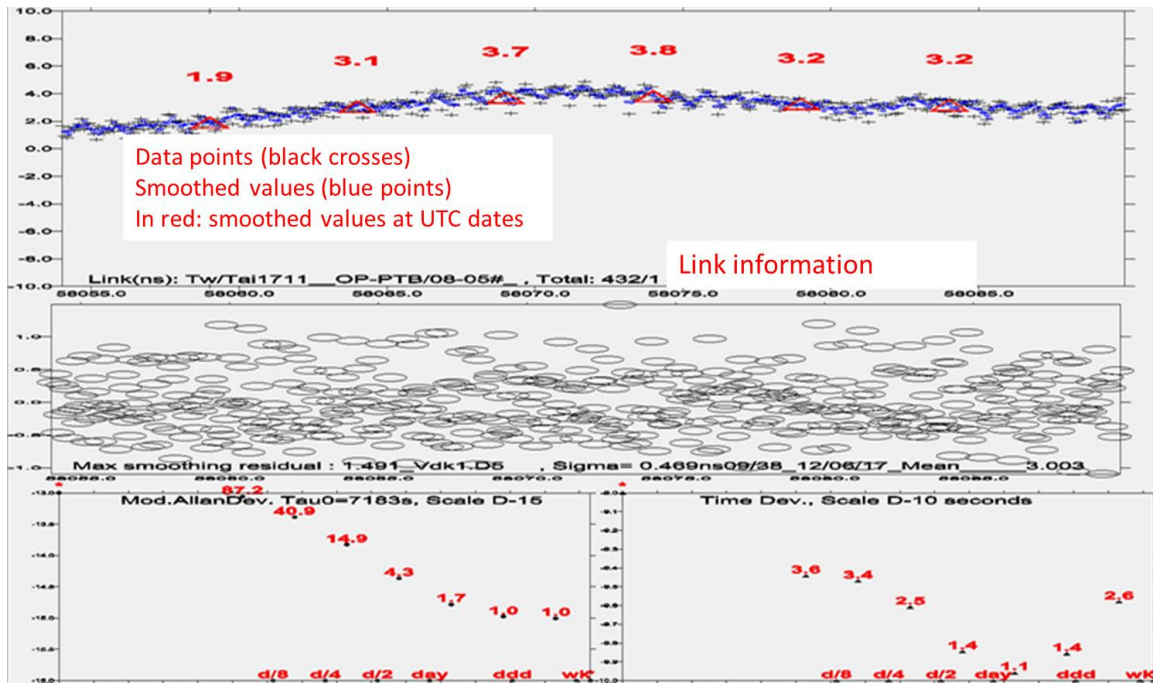


Fig. 3: Plot of the link TWSTFT OP-PTB for November 2017, available at <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/lnc/>. See text for details.

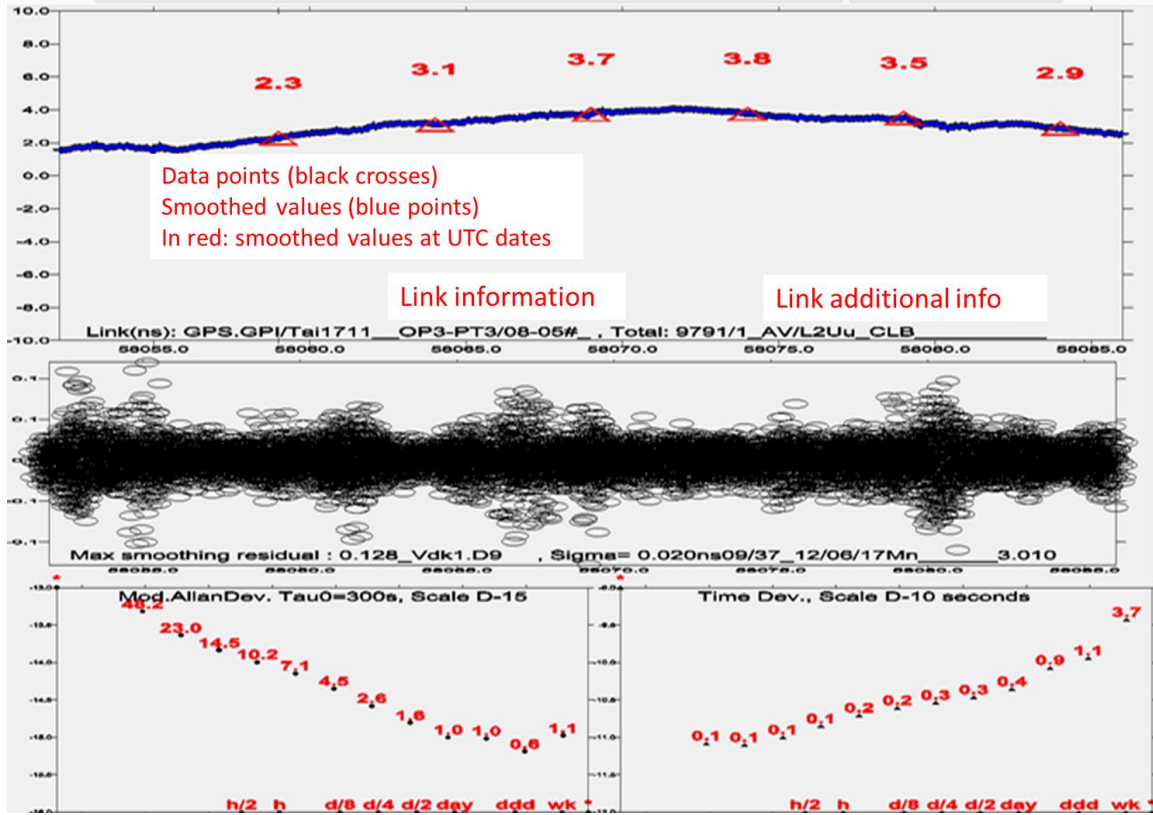


Fig. 4: Plot of the link GPSPPP OP-PTB for November 2017, available at <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/lnc/>. See text for details. Note that the data points and the smoothed values are indiscernible in the top plot. The ‘link additional info’ indicates whether additional corrections were added to the link results to access UTC(k), please contact Time department for details.



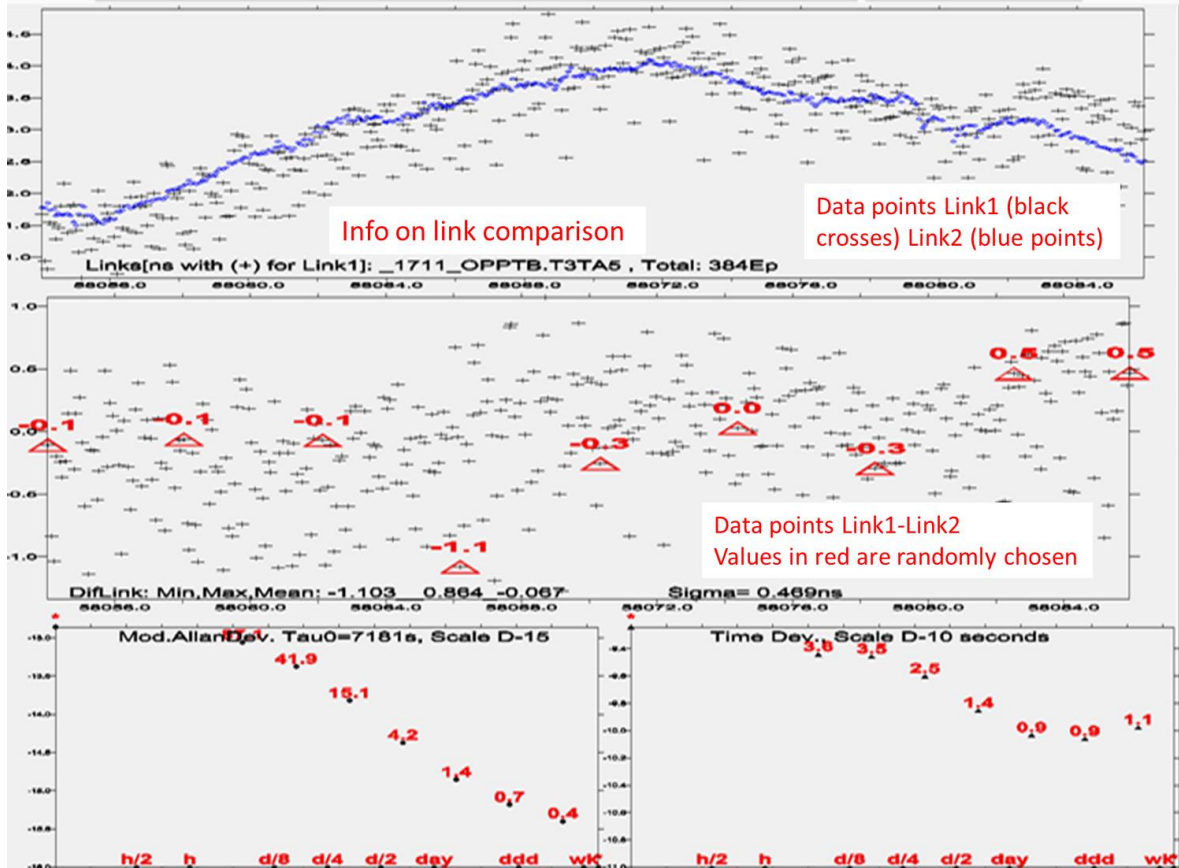


Fig. 5: Plot of the link comparison TWSTFT - GPSPPP of OP-PTB for November 2017, available at <ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/1711/opptb/dlk/>. See text for details.

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