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Solar discrepancies : Mars exploration and the curious problem of inter-planetary time

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Solar discrepancies:
Mars exploration and the curious problem of inter-planetary time

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy

in

Communication (Science Studies)

by

Zara Lenora Mirmalek

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Professor Yrjö Engeström
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2008

The dissertation of Zara Lenora Mirmalek is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

University of California, San Diego

2008

Dedicated to Carol Robideau, Veda Talat, & Aaron Hossein

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ACKNOWLEDGEMENTS

Many individuals and several institutions have supported my efforts to reach this moment in which I can share my perspectives on the ways in which people work together. The support of my department, committee members, colleagues, friends, and family has helped me to understand how it is that I work.

As a member of the Department of Communication and the Science Studies Program at the University of California of San Diego, I have received both intellectual and financial support, affording me the time and space within which to produce this dissertation. The relay work of my committee members allowed me to take a few turns in my research and from each I have received a different impression. As guides, mentors, and friends, members of my committee have figured strongly in shaping my understanding of inter-disciplinary conversations. I am grateful for the time that I have been able to spend with each of them: Yrjö Engeström, Robert Horwitz, Ed Hutchins, Andy Lakoff, Leigh Star, and Sharon Traweek. In the last few years, my advisor Val Hartouni has introduced me to the bright side of patience. Her deftness in sifting multiple ways of knowing without missing a beat has been one of the most astonishing feats to witness.

While working on this dissertation, there have been several forums in which I have been able to converse and to receive impressions: the Society of the Sociology of Science Studies, the National Communication Association, American Anthropology Association, and International Society for the Study of Time. There were a few forums in particular that I would like to acknowledge: (1) my summer internship with Jeanette

Blomberg in Human Systems Research at IBM Almaden Research Center, (2) the presentation and methods workshop with John O'Neill and Leoni Warner which provided me with a chance to learn more about notions of time in conversation with perspectives on organizations and teams from a site down under, (3) the workshops on Managing Identities in Complex Organizations held at Lund University, Sweden and hosted by Mats Alvesson and Robyn Thomas; (4) and Kanna Rajan and the scientists and engineers at MBARI to consider changing the clock at work.

I am grateful to the community of NASA's Mars Exploration Rovers mission for all the permissions and access that were granted to me and for the very special work that they do. I hope that my insights on inter-planetary work processes serve, in part, to support their future work. And I am thankful to Steve Squyres, John Callas, Deborah Bass, and Steve Gorevan for fostering the mission on many levels and the participation of ethnographers. My membership in this community would not have been possible without the work of Human Centered Computing colleagues from NASA Ames Research Center. In particular, I have a special appreciation for Bill Clancey, Charlotte Linde, Chin Seah, and Valerie Shalin. The sense of awe and gratitude that I have for Roxana Wales, the lead ethnographer without whom my time on MER would never have happened, is not easy to express. Her equanimity continues to inspire me.

My experience at UCSD has been enriched by the relationships formed while navigating the landscape and language of graduate school with cues, conversation, and humor shared by Gayle Aruta, Kristen Clark, Kathleen Casey, Claudia Dametz, Ryan Ellis, Liz Floyd, Bruce Jones, Bea Velasco, Jaime Lloyd, Lori McFadden, Matt Ratto, Jenifer Vernon, Cindy Svacina, and Judy Wertin; and, particular to my time in Pasadena: Paul Bartlett, Phil Chu, Kiel Davis, Saina Ghandchi, and Jack Wilson. As well, I am indebted to my peers who would, with only a moment's notice, set aside their own work to help me work out a point in writing or in conversation: Kinda Al-Fityani, Sophia Efstathiou, and Katrina Hoch. Their intelligence and sensitivity have carried me through many a long night. Often separated by distance but always close in heart, I wish to acknowledge the support of my pre-doctoral friends, Matt Chavez, Mary Corona, Sandy Plechaty, Carol Pfeifer, and Wende Rae.

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VITA

EDUCATION

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CONFERENCE PAPERS AND POSTERS

Monterey Bay Research Institute, Monterey, California, *Changing the Clock at Work,* Summer 2007 (invited).

Defense Science and Technology Organization, Canberra, Australia, *Managing multiple temporalities: infrastructure and maintenance work*, Summer 2005 (invited).

NASA Ames Research Center, *Inside a Minute and a Half: Participant Observation in Work Systems Design,* Fall 2000 (invited).

National Communication Association, San Diego. *Anthropomorphizing the Mars Rovers through discourse and time,* Fall 2008 (refereed).

National Communication Association, Chicago. *Dreaming of space, representations of time and work*, Fall 2007 (refereed).

International Society for the Study of Time, Monterey, California. *Solar Discrepancies: Mars exploration and the curious problem of interplanetary time*, Fall 2007 (refereed).

Managing Identities in Complex Organizations, Institute of Economic Research, Lund University, Sweden. *Organization identities and NASA's Mars Exploration Rovers mission,* Spring 2006 (refereed).

Society for the Social Studies of Science, Rotterdam. *Membering the Mars Rovers*, August 2008. (unable to attend)

Society for the Social Studies of Science, Montreal, B.C. *Grounded in Space: opening up the future to multiplicity*. Session organizer: "Stabilizing Multiplicity," Fall 2007.

Society for the Social Studies of Science, Vancouver, B.C. The *maintenance of invisible work on NASA's Mars Exploration Rovers mission*, 2006.

Society for the Social Studies of Science, Pasadena, California. *Multiple temporalities of interplanetary work system: a sociotechnical examination of time*, 2005.

Organization Design NSF conference, New York University. *Organizational design as design of invisible infrastructures*, co-authored with Professor Y. Engeström, 2004 (poster).

Society for the Social Studies of Science, Atlanta, Georgia. *Social infrastructures in the era of on-demand services*, co-authored with Dr. J. Blomberg, 2003.

030303 Collective Play, *Gaming identities and multiplicity,* University of California Berkeley, 2003.

Infrastructures of Digital Design, University of California San Diego, plenary presentation with Professor S. L. Star, 2003.

American Anthropology Association, *Negotiations, dilemmas, and social compensation when travel breaks down at the airport*, co-authored with Dr. R. Wales, 2002.

TEACHING EXPERIENCE

Technoscience and Society, instructor, Department of Communication, University of California San Diego, Fall 2008.

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ABSTRACT OF THE DISSERTATION

Solar discrepancies:

Mars exploration and the curious problem of inter-planetary time

by

Zara Lenora Mirmalek

Doctor of Philosophy in Communication (Science Studies)

University of California, San Diego 2008

Professor Valerie Hartouni, Chair

The inter-planetary work system for the NASA's Mars Exploration Rovers (MER) mission entailed coordinating work between two corporally diverse workgroups, human beings and solar-powered robots, and between two planets with asynchronous axial rotations. The rotation of Mars takes approximately 24 hours and 40 minutes while for Earth the duration is 24 hours, a differential that was synchronized on Earth by setting a clock forward forty minutes *every* day. The hours of the day during which the solar-powered rovers were operational constituted the central consideration in the relationship between time and work around which the schedule of MER science operations were organized. And, the operational hours for

the rovers were precarious for at least two reasons: on the one hand, the possibility of a sudden and inexplicable malfunction was always present; on the other, the rovers were powered by solar-charged batteries that could simply (and would eventually) fail. Thus, the timetable for the inter-planetary work system was scheduled according to the daily cycle of the sun on Mars and a version of clock time called *Mars time* was used to keep track of the movement of the sun on Mars.

While the MER mission was a success, it does not necessarily follow that all aspects of mission operations were successful. One of the central problems that plagued the organization of mission operations was precisely this construct called "Mars time" even while it *appeared* that the use of Mars time was unproblematic and central to the success of the mission. In this dissertation, Zara Mirmalek looks at the construction of Mars time as a tool and as a social process. Of particular interest are the consequences of certain (ostensibly foundational) assumptions about the relationship between clock time and the conduct of work that contributed to making the relationship between Mars time and work on Earth appear operational. Drawing on specific examples of breakdowns of Mars time as a support technology and of the technologies supporting Mars time, Mirmalek explores some of the effects that follow from failing to recognize time as a socio-cultural construction that emerges, fundamentally, in and through a physical relationship between the environment and the human body. In this investigation of Mars time as a phenomenon comprised of several contradictory logics, Mirmalek takes into account several aspects of the social, technical, and cultural processes constituting the relationship between time and work at NASA and specifically on the MER mission.

Introduction

In August of 2003, Mars and Earth came within approximately 34,646,418 miles of one another, the closest proximity in 60,000 years. Taking advantage of this window of opportunity, NASA launched two Delta rockets carrying identical space vehicles to opposite sides of Mars. In January of 2004, the space vehicles commonly referred to as the "rovers" bounced to rest on the Martian surface and with this landing the Mars Exploration Rovers mission (MER) put the United States' space exploration organization and the public on a new and as yet unexplored planet. The first rover, "Spirit," came to rest at the Gusev Crater and the second rover, "Opportunity," at Meridiani Planum. Within a few days, the rovers emerged from their protective shells to travel across the planet's rocky surface in search of evidence that water was once present. As luck would have it, I made it through this window of opportunity as well, arriving at NASA's Jet Propulsion Laboratory in Pasadena, California to conduct ethnographic research among scientists and engineers who were remotely operating the rovers in the production of Martian science.

Once on Mars and in the years since, the rovers have returned thousands of images, soil composition, atmosphere readings, and information on the interactions between terrestrial objects. These visual projections of the physical conditions on Mars provided people on Earth with sensory perceptions of being on Mars. And compressing the visceral distance between the planets even further were enthralling animations of the rovers traversing and working on Mars (Maas, 2002). One particular animation that was repeatedly and almost exclusively played by popular news media depicted the flight of the Delta rocket from Earth to Mars. It portrayed the stages of the rocket breaking apart and entering the Martian atmosphere, the parachute and airbag drop of the lander containing the rover, the rover's egress from the lander, and the rover's movements on Mars. Adding to the sense of realism were the sensory cues in the animation that were familiar to humans on Earth – the sound of wind, for example, that might follow the rover as it drove across Mars in addition to depicting the passage of time. Audiences "watched" the rover end its workday, slowly coming to a stop and lowering "its head" as the color of the sky darkened and the sun set.

One reason that the animation of the rover's work on the MER mission was fascinating to me as an ethnographer on-site at JPL had to do with the limited portrayal of humans: humans were only heard during the countdown for the launch of the Delta rocket at the beginning of the animation. Even if there were no humans actually present on Mars, the rovers were by no means independent agents. Instrumentally, they had been fashioned as "*robot* geologists" and, as such, required data collection commands and daily guidance by scientists, engineers, and administrators on Earth. The animation's account of the rover conducting its work alone on Mars offered no hint of the hundreds of humans, the myriad work practices, and the complex socio-technical processes that were essential to the production of Mars exploration.

The inter-planetary work system for the MER mission entailed coordinating work between two corporally diverse workgroups, human beings and solar-powered robots, and between two planets with asynchronous axial rotations. The rotation of

Mars takes approximately 24 hours and 40 minutes while for Earth the duration is 24 hours, a differential that was synchronized on Earth by setting a clock forward forty minutes *every* day. The hours of the day during which the solar-powered rovers were operational constituted the central consideration in the relationship between time and work around which the schedule of MER science operations was organized. The operational hours for the rovers were precarious for at least two reasons: on the one hand, the possibility of a sudden and inexplicable malfunction was always present; on the other, the rovers were powered by solar-charged batteries that could simply (and would eventually) fail. Thus, the timetable for the inter-planetary work system was scheduled according to the daily cycle of the sun on Mars and a version of clock time called *Mars time* was used to keep track of the movement of the sun on Mars.

While the MER mission was a success, it does not necessarily follow that all aspects of mission operations were successful. One of the central problems that plagued the organization of mission operations was precisely this construct called "Mars time" even while it *appeared* that the use of Mars time was unproblematic and central to the success of the mission. In this dissertation, I look at the construction of Mars time as a tool and as a social process. Of particular interest to me are the consequences of certain (ostensibly foundational) assumptions about the relationship between clock time and the conduct of work that contributed to making the relationship between time on Mars and work on Earth appear operational. Drawing on specific examples of breakdowns of Mars time as a support technology and of the technologies supporting Mars time, I explore some of the effects that follow from failing to recognize time as a socio-cultural construction that emerges, fundamentally, in and through a physical relationship between the environment and the human body.

When I began my one year at the Jet Propulsion Lab as a participant-observer[1] on the MER mission (August, 2003 – August, 2004), I was aware of having been granted privileged access into *the* organization that produces technology and science upon which are constructed some of our grandest narratives about the relationships between humans and the universe, nature, and progress. Like many people, I had grown up seeing NASA as a symbol of human ingenuity. With respect to space exploration, however, my sense of wonderment was not organized by the possibility of life in outer-space or personally traveling to distant planets or stars. What captivated me were the operational processes of a large-scale organization that coordinated people and work across continents and between inner and outer space: how were these processes produced, organized, and sustained?

I joined NASA's MER mission as a member of the Work Systems Design and Evaluation (WSD & E) workgroup, within Human Centered Computing and Intelligent Systems at NASA Ames Research Center, to conduct ethnographic research of work practices among scientists and engineers.[2] My job was to examine the ways

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[1] For this position, I would like to extend special thanks to Dr. Roxana Wales and Dr. Michael Shafto. Dr. Wales' efforts to place me on the mission were successful with support from Dr. Michael Shafto (Human Centered Computing, Intelligent Systems of NASA Ames). Dr. William J. Clancey was the head of HCC and Dr. Wales was the research lead for WSD&E on MER. In addition, WSD & E members included Charlotte Linde, Chin Seah, and Valerie Shalin (Wright State University). There were additional teams from NASA Ames participating on MER and with whom we were often in discussion, including a team of computer scientists who developed and managed MAPGEN, software for planning science commands (Ai-Chang et al., 2004).

[2] NASA Ames' WSD&E researchers spent three and a half years, from January of 2001 to June of 2004, supporting the MER mission. Working closely with both the Athena Science team and the

these work processes were carried out and to offer feedback on the ways in which work could be better supported by changes to social or technical processes. In principle, contributions from my workgroup would aid mission members in planning the many events that had to take place and better facilitate the exchange of information—that peculiar form of boundary object—across work groups, disciplines, and an unusual timetable.[3] In addition to my work on the mission, it was understood that I would also collect data for my thesis. At the time, I imagined the thesis would entail an organizational ethnography and a cultural anthropology of the science and technology of a community bound together in the production of interplanetary scientific knowledge.[4] I was interested in exploring the every day work practices

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Science Operations Support Team, members of WSD &E were involved in the design and development phase of the mission as well as the surface operations phase that began after the successful landing of two rovers. The WSD&E research focus was on the interactions between the human, technological, and engineering systems, which was used to contribute to the enhancement of the tele-robotic scientific process and related mission surface operations, and the design of computer technologies used for planning, collaboration and information exchange.

[3] In an interview conducted for Computational Sciences Division, NASA Ames Research center website (Blumenberg, 2004), Professor Squyres was asked to share his perspective on the contributions of WSD&E: "Oh, I think it was necessary. I think it was absolutely necessary …There's no textbook that you go to look up how to operate a robot on Mars. So we had to work that out as we went along and what the human factors folks did, the social scientists in particular, was look at how we interacted with one another and help us find ways of streamlining that, making it efficient, making sure that information doesn't get lost along the way. And what they helped us with was taking that sort of visceral intuitive feel that we had for how to do the science and translate it into things that could actually be turned into commands downstream without losing stuff in the process."

[4] As a mission member, I wanted to support the work of the team and to contribute to mission operations; and, as a graduate student, I wanted to immerse myself in gathering ethnographic data and practicing grounded theory, in order to identify a set of interesting questions through which to investigate the socio-technical processes of day-to-day work practices carried out by scientists, engineers, and administrators. These two roles were co-constitutive. By engaging in the cultural aspects of the community as a participant, as a mission member, I was able to learn about the meanings made in carrying out the values and beliefs that brought the community together (Geertz, 1973). And I was able to offer something more than a researcher gathering notes on mission members' ways of knowing by virtue of the perspectives that I had on sociotechnical work support, cross-cultural communication, and information trajectories, from

involved in the production of scientific knowledge through the collaborations of scientists, engineers, and technologies. I was also interested in examining the role of technologies – or the instruments of science used for data collection and communication – in the conduct of group collaboration and scientific discovery. And, finally, I hoped to investigate the ways in which the organization and its members were shaped by the cultural narratives of space exploration.

As a mission member, I accepted without contest the relationship between time and work established by the organization and I worked closely in stride with the ever-fluctuating timetables for science operations and my research group. Like most people, I took for granted certain aspects of clock time, the process of telling time, for example, and of learning the temporal rhythm of conducting work for a particular organization, a sense of timing that typically develops while carrying out work rather than training for or designing it. When I learned that the timetable for MER was going to be set according to Mars time, I anticipated that prolonged exposure to a time zone asynchronous with the local time zone in which I would be residing would, in all likelihood, alter my physical sense of local time and some of the time-related socio-cultural practices of a community to which I had only just become familiar (graduate school).[5] I accepted my immersion into an organizational context where standard time

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previous ethnographic work in organizations (Mirmalek, 2001) and coursework and conversations in my doctoral program in the Department of Communication at UCSD. And, as a result, I was able to have frank conversations with and pose frank questions to mission members (often, though not always, without annoying them) their ways of understanding and making meaning.

[5] My anticipation about the experience of time changes on the MER mission and its effects was grounded in three temporal experiences: (1) a multi-time zone upbringing, which required keeping track of time between two countries separated by twelve hours (or half a day in the future); (2) a résumé of employment, across which the demands for time management were as

is a given, where time drives work in the relationship between time and work, and where work is scheduled according to clock time.

From the start, I noticed time management breakdowns in situ were experienced and managed in unexpected ways. And, I was intrigued by the absence of formal acknowledgements of the ways in which these breakdowns affected either the production process of Martian science or the socio-cultural practices of decision-making among over three dozen scientists and engineers on a daily basis. The relationship between time and work on the MER mission, as I mentioned earlier, employed a temporal standard called Mars time and to this standard was set the timetable of coordinating work processes between Earth and Mars. Mars time was a numerical representation of the progression of sunlight during one axial rotation of Mars and, it *appeared* to function in the same manner as the technology that it was based on – clock time. The inadequacies of the formal tools that were provided to manage Mars time in relation to work began almost immediately, though this did not prevent operations from successfully moving forward. Informal tools were developed by mission members to deal with the many breakdowns of the formal tools in place on site, but these too proved inadequate for setting time and work to a consistent temporal rhythm.

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varied as the work, such as late-shift restaurant work, punctual 8:00 a.m. to 5 p.m. administrative work, construction hours of home improvement retail, and the deadline driven, campaign cycle hours of pollster work; and (3) finally, the experience of participating in religious rituals that were not in sync with the rituals of the local community; specifically, managing the temporal rhythms of Muslim practices that included prayer three times a day and fasting for one month a year (wherein no food or water is consumed while the sun is up and one's entire allotment of food for the day must be consumed minutes before sun-rise). These experiences provided me with the sense that no matter how arduous, it would be quite possible to manage the multiple temporalities of MER's inter-planetary work system.

While mission members did express some frustration over the difficulties of managing Mars time, by and large the issue of time management was treated as it is in any organization, as an individual problem. And, I witnessed media coverage, both inside NASA and outside the organization, that depicted a functional relationship between scientists and Mars time and that failed to treat time-management issues as anything more than a humorous glitch or heroic challenge. I began to wonder about the possible conditions contributing to the processes by which an organization like NASA, where technological inventiveness and ingenuity were synonymous with the organization, would have time management difficulties and be unable to resolve such issues through innovation. Just a few years prior to MER, following two failed missions (1988, 2003) that took the lives of fourteen astronauts, scholars and the popular news media had brought to the public's attention NASA's problem in allowing schedules to drive decision-making, rather than safety. On MER, the time management problems that I was observing in situ, and participating in, were in some sense even more basic than the organization's rigidity with respect to schedules. On the MER mission, the problem that mission members faced was knowing precisely what time it was. An expression of this problem is depicted in Figure 1, a post-it note that was hung in a hallway and was only one of a series of humorous but anonymously posted commentaries on the time management problems plaguing the mission: in the words of one mission member, "We can send a robot to Mars, but we [the mission members] don't know what time it is."

Figure 1 Calling attention to time in a post-it note: the various time standards that were in use for the conduct of the MER mission are scattered across this post-it note.

During the mission, I was practicing the reflexive process of "grounded theory (Glaser & Strauss, 1967)," an approach that entails working through one's data while still in the field in order to locate and address reoccurring themes while still on-site. Maintaining this practice was particularly crucial for me because, as I mentioned, the field site of the MER mission had an expiration date. If the issue of time management was a reoccurring question that puzzled me while on site, it remained a question even after leaving the mission to return to my doctoral program. Why did the schema of the inter-planetary work system make it necessary to conduct work according to Mars time? Why did it appear that mission members who experienced temporal breakdowns were not talking about these breakdowns? Why had it appeared that some of the experiences of Mars time management breakdowns were displayed by individuals as a sign of valor rather than pointed out as an indication of a weak component within the organizational infrastructure? I was not satisfied with the customary reasons given for time management breakdowns – human failure – or for inadequate support technologies – poor design.

In this dissertation, I present the results of an investigation into the socio-technical and cultural processes constituting the relationship between Mars time and the work of making Martian science, an investigation that led me to construe Mars time as a phenomena comprised of several contradictory logics. MER presents a unique opportunity to consider what happens in an organization when the ability to take time for granted has been removed even while the keeping of time is critical to the production process. In such a setting, what might we learn about the operations of time to which we have otherwise become inured and that are treated as given or as simply part of the fabric of fact? By understanding the management of Mars time as a failure, I am setting up an examination of a socio-technical process by first immediately disturbing the assumption that time is always operational. Seen as a failure, a close critical scrutiny of the social processes and technologies of support becomes clearly necessary. But, rather than pursue a single cause, as is often done in post-mortems of a particular technology, my approach takes into account several aspects of the social, technical, and cultural processes constituting the relationship between time and work at NASA and specifically on the MER mission. In the following chapters, I engage these and other questions from four angles. In Chapter 1, *The Inter-planetary Workspace: the Organization of Community*, I give an account of the MER mission using the traditional categories of ethnographic investigations in organizations: I set out the boundaries of the space-oriented communities, identify some of the key members and research teams constituting the communities, and generally enumerate the values, beliefs, and artifacts through which knowledge is shared within and between them.

Chapter 2, *Mars Exploration and the Curious Problem of Inter-planetary Time*, constructs the schema of MER's inter-planetary work system and the on-site configuration of multiple temporalities. Specifically, I describe the conditions that supported the perception that the time schedule for MER *had* to be run according to the time of day on Mars. I foreground the observed breakdowns and technological drift of some of the formal and informal work support technologies that emerged as a result. I do not claim that there was a "right way" to manage Mars time and that the right way was for some reason ignored. Instead of regarding time management breakdowns as failures of human practices, culture, or technology design, as is often the approach of organizational investigations, I pursue foregrounding the connections between social processes, technologies, and socio-cultural history in the time/work relationship.

Proceeding from the layout of MER mission operations and multiple temporalities and having problematized Mars time management, I consider the role that mission members played in operating according to Mars time and representing Mars time as unproblematic. In Chapter 3, *Dreaming of Space, Imagining Membership*, I argue that the same media representations that might be considered "responsible" for inspiring people to work in space exploration provide preconceptions of normative work practices that in critical ways contradict the actual work of space exploration. However, the collective investment in reproducing the preconceptions of normative work practices—as in the case of time management, for example—overrides an interest in dealing with discrepancies between imagined and on-the-job work conditions or the ways in which time management appears to and "actually" operates in complex organizations. Precisely because NASA and space exploration have tremendous and fairly homogenous sets of work representations in the media, it is possible to locate narratives carried into the organization by members. Furthermore, through Goffman's theory of stigma management, I foreground the point of intersection at which preconceptions of work and the actual experience of work meet and members opt to perform to standards located in (shared) preconceptions of work in order to avoid on-site stigmatization. Curiously, in an organization like NASA, which is driven by the imagination, members were decidedly unimaginative and recalcitrant when it came to devising alternative work practices to address infrastructural work breakdowns. This investigation of socio-cultural practices on the Mars mission draws attention to the ways in which NASA is locked into a negative feedback loop, reproducing past (ineffective) practices even while engaged in the very work of forging new ones (as in assisting in the human endeavor of exploring new outer spaces beyond the earth). While dreaming of space offers one explanation as to the reproduction of century old narratives of space exploration work, it avoids placing the responsibility of time mismanagement entirely on the shoulders of human actors.

My position that organizations stand as particular theoretical configurations, on par with society and the individual, led me to adopt another angle in order to explain the schema of time and work on MER: What unchallenged assumptions about the relationship between time and work shaped the organization's work practices and processes? In Chapter 4, *The Sound of No Clock Ticking: Mars Mission Operations in an Agrarian Era*, I move under the phenomena to foreground two incongruous notions supporting the breakdowns in the time/work relationship that appear, on the surface, as human failures or technological design flaws in time management. One primary incongruity, I argue, is that central aspects of the relationship between time and work on the MER mission reflected a tension between earlier work structures established in an agrarian era and those of a post industrial age: in other words, doing mission work required a physical sense of sunlight but the work itself was planned and carried out under organizational conditions that severed the physical sense of sunlight from the work of scientists. This leads me to the second incongruity, the assumption that humans know what time it is by merely processing the numerical representations presented in timepieces. Only if this assumption is at play does it logically follow that scientists on Earth can know what time it is on Mars, by looking at a timepiece that numerically represents Mars time, mimicry of timepieces that represent clock time. In an effort to disrupt this logic, based on my findings, I argue that the notion that time is exclusively known through a numerical representation ignores the important contribution of human experience in constituting such knowledge, specifically the experience of knowing time in its pre-numerical representation (as in through sunrise and sunset). What this means to the constitution of Mars time is that a temporality based on a representation of the terrestrial human experience of sunlight was employed to represent an extra-terrestrial relationship between robots and sunlight. One problem with trying to fit the experience of solar time on Mars into the same framework that produces clock time is that the role of human physical experience is all but missing from the arrangement. In order to open up this problem, I turn to Hubert Dreyfus' account of why computer scientists failed to produce artificial intelligence – his argument that the phenomenology of human experience cannot be represented in a set of values. Mars time was a representation of a representation, a copy of a copy that presupposed the first copy was independent of human enactment. Making time on Mars without centralizing the human physical experience of receiving a translated version of the movement of sunlight on Mars effectively lays a discursive claim to new territory, but it does not support the relationship between time and work in an inter-planetary work system.

Having established a different view of the MER mission, of rovers and scientists engaged in the temporal rhythms of agrarian work with a version of clock time that is out-of-synch with the temporal patterns of inter-planetary work, I take up the final theme of the dissertation in Chapter 5 and consider the relationship between the robots (rovers) and humans. By foregrounding this relationship, I want to call attention to the significance of the anthropomorphization of the Mars rovers in constituting the temporal rhythm of inter-planetary work (it might otherwise be categorized as a perspective salient only to cultural anthropologists). In Chapter 5, *Membering the Rover*, I demonstrate the ways in which the rovers, first categorized as artifacts, were culturally constituted as collaborators through discourse and work practice. This ontological shift disrupts the traditional methodology of ethnographic data collection and the categories employed to map domains, people, artifacts, and processes (Spradley, 1980). The shift is critical if one hopes to pay attention to emerging phenomena in the process of collecting data (Clarke, 2005; Glaser & Strauss, 1967), and to enact practices from the vantage point of the community members of study (Geertz, 1973). During the course of the MER mission, I observed scientists anthropomorphizing the rovers by imbuing them with human characteristics of kinship, emotion, appendages, and death. Re-configuring the rovers as interlocutors rather than commanded and controlled objects brings some of the temporal implications of this relationship to the fore.

In this dissertation, *Solar discrepancies: Mars Exploration and the Curious Problem of Inter-Planetary Time,* I question the positioning of time in organizations as an information communication technology and the processes by which clock time has come to be accepted as both natural and self-evident, as though we found clock time waiting for us here and on another planet. I argue that the consideration of clock time is but one aspect constituting temporal rhythms of work in an organization. The relationship between time and work employed in the operations of MER provides an important case for furthering our understanding of how time works at work, on Earth; by providing a perspective that does not take for granted "a natural" evolution of the temporal progress in post-industrial organizations. Paying attention to the distinction between time and temporality, between numerical and experiential representations of the natural world interrupts the momentum of clock time as an immutable mobile and returns it to its status as a mutable technology.

Chapter 1

The Inter-planetary Workspace: the Organization of Community

NASA's Mars Exploration Rovers mission was conducted at the Jet Propulsion Laboratory (JPL),[11] one of eleven NASA centers,[12] and the site where NASA's robotic missions are conducted.[13] Each center has a specialty of operation. Some are

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[11] The Mars Exploration Rover mission was managed by the Jet Propulsion Laboratory, for NASA's Office of Space Science, Washington, D.C. At NASA Headquarters, Dr. Edward Weiler was associate administrator for space science, Orlando Figueroa was Mars program director, Dr. Jim Garvin was the lead scientist for the Mars Exploration Program, David Lavery was Mars Exploration Rover program executive and Dr. Catherine Weitz was Mars Exploration Rover program scientist. At the Jet Propulsion Laboratory, Dr. Firouz Naderi was the Mars program manager, Dr. Dan McCleese was Mars chief scientist, Peter Theisinger was Mars Exploration Rover project manager and Dr. Joy Crisp was Mars Exploration Rover project scientist. Dr. Steve Squyres was principal investigator for Mars Exploration Rover's Athena suite of science instruments (NASA, 2003).

[12] The ten other centers and states of location are: Ames Research Center, California; Dryden Flight Research Center, California; Glenn Research Center, Ohio; Goddard Space Flight Center, Maryland; Johnson Space Center, Texas; Kennedy Space Center, Florida; Langley Research Center, Virginia; Marshall Space Flight Center, Alabama; NASA Headquarters, Washington, D.C.; and Stennis Space Center, Mississippi. The geographic range of these centers would look differently, larger, if this list included the private companies with contractual relationships with NASA.

[13] Unique to JPL is the organizational arrangement that it is managed by California Institute of Technology. JPL began in 1940 at the behest of a group of Cal Tech graduate students (Rudolph Schott, Apollo Milton Olin Smith, Frank Malina, Ed Forman and Jack Parsons) who had formed a rocket club. Their professor, Theodore von Karmen, received funding from the Army to support their experimental efforts (Chang, 1995; JPL, 2007; McDougall, 1985). The origin of their funding source, the Army, lays at the heart of a collision that Wernher von Braun claimed was the reason that the Soviet Union was first to launch an orbital space craft. Pre-NASA, rocket development was taking place within the Navy and the Army, two branches of the same organization that competed for resources. In response to Sputnik (1957), the Soviet's orbiting spacecraft that flew overhead every ninety-eight minutes reminding the United States that they were lagging behind in rocket science, the National Advisory Committee for Aeronautics, NACA (1915-1958) became NASA and the Army transferred control of JPL to NASA, though it would remain managed by Cal Tech.

specifically concerned with human space flight, and others with robotic space exploration, and still others with aeronautical research and development. And, as with any community, there are values, beliefs, and practices specific to each center (Geertz, 1973). It is against this background that I present one of the first membership rituals that I encountered in the course of gaining access to the MER mission field site: individuals working for NASA often identified their center affiliation before any other information, including their name. While JPL is accessible both to members of the public and of NASA, which category one belonged to determined whether a person could walk past the security guards with a flash of the badge or had to submit paperwork days (sometimes weeks) in advance, entering the lab only after gaining clearance through one of three receptionists and a prearranged escort. Still, even a badge indicating membership status at one of NASA's centers was subject to further scrutiny. "So, where are you from?" was the question asked to procure the name of the NASA center from which an individual originated. This information could be understood as a way to identify whether individuals were on site to investigate a given center's activities or to participate in their activities; and, if as a participant, whether they were on site to work or to get in the way. For my research, mission membership was critical in gaining physical access as well as intellectual access to the norms, values, beliefs, and assumptions used to make meaning and guide behavior among members of the MER mission community.

The original workspace for MER mission operations, during the nominal mission from January 2004 through April 2004, no longer exists as it did when I conducted my fieldwork, from August 2003 through August 2004. While the community of MER has continued to thrive, April 2004 marked the end of the nominal mission. Many of the mission members who had worked together assembled across several floors of one building at JPL began returning to their home institutions to conduct MER operations through a distributed work system. The transition of the physical space to support other projects was a regular part of organizational life at JPL. In fact, I had been told to expect the mission workspace would be transformed once the nominal mission was over. In this chapter, I describe the community of the MER mission as it was when I was in the field using the explanatory categories of people, artifacts, and processes that traditionally guide organizational ethnography (Kunda, 1992; Orr, 1996; Schein, 1992; Spradley, 1980; Van Mannen, 1988; Yanow, 1998).

Community members

The MER mission community was comprised of scientists, engineers, and administrators, whom I refer to collectively as mission members, see Figure 2. Over one hundred and fifty scientists and engineers were selected, some of whom had waited for decades to participate in a Mars mission while others had participated in some capacity on one of NASA's previous Mars missions.[14] The principal investigator for the MER mission was Professor Steve W. Squyres from Cornell University, Ithaca,

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[14] Between the years of 1964 – 2001, NASA attempted fifteen Mars missions with a 60% success rate; of the nine successful missions, three involved operational landers on Mars (Viking I & II and Pathfinder). Russia, Japan, and the European Space Agency have attempted Mars missions, though only Russia has had two completely successful missions (out of 18 attempts).

Figure 2 Athena Science team. In addition, an attempt to provide a complete list of MER mission members appears in Professor Squyres (2005) autobiography of the mission.

New York. Squyres' Athena Science Team included twenty-two co-investigators, many of whom had their own teams, and numerous instrument teams. Some of the members of the Athena Science team were affiliated with Squyres' primary organization, Cornell University, and other members came from various public and private organizations such as the U.S. Geological Survey, University of Washington, Honeybee Robotics, Max Planck Institute, and University of Arizona (to name only a few). Although some members of the Athena Science team were relocating from primary locations within a few hours of airplane travel, the majority were relocating from distances that required crossing time zones. Most of the engineers and administrators, on the other hand, were members of the JPL and Cal Tech community and had been selected to work on the MER mission in the course of their regular work.

Among mission members, the demographic age range was broad: from recent college graduates, graduate students, and mid-career scientists to scientists who had participated in NASA's 1976 Mars mission, Viking I & II. Also, initially, by sight there was a great deal of homogeneity. The participants appeared to be mostly Caucasian males from 19 to 65+ years of age. More than a few had at one time applied to be an astronaut. More than a few were published, science-fiction authors. One of the first indelible moments that highlighted the demographic diversity and merit based social relationships on the mission was a conversation between Dr. Mike H. Carr, a geologist born in 1935, who had participated in two previous Mars missions, Viking and Pathfinder, and Justin Wick, a not-yet twenty-one years old undergraduate who was developing software for the mission. Standing in a narrow hallway, their faces a few inches apart, and standing at about the same height, each sought information and assistance from the other. What caught my attention was the lack of formality or hierarchy in their exchange. There appeared to be just earnest talking and listening and I did not see or hear any disdainful or condescending affect or speech from either in response to mistakes or frustrations. Not wanting to introduce myself through an invasive interruption, I did not take a picture, even while it would have been permissible for me to do so. I had only been on the mission for a few days and I had yet to become a familiar member of the mission community.

Together, in the main space of mission operations, the one hundred and fifty plus members worked in a context of shared values, meanings, and hierarchy that had been developed for two years. The hierarchy among mission members had been established in the years prior to the nominal mission (the 90 days of the mission that began when the rovers landed on Mars) and formal agreements had been made as to the responsibilities of each of the lead scientists. Rules of conduct were explicit and presented in a formal document called the "Rules of the Road," a document that provided the guidelines for, among other things, the timeline of publication and the authorship. In addition, rules of conduct were learned in situ and demonstrated in public recriminations and congratulations (e.g. it was whispered that one scientist, quoted in a newspaper, briefly commenting on a matter of scientific analysis, had been "sent away" for a few days).

For each rover, scientists were organized into five theme groups: Atmosphere, Geochemistry/Mineralogy, Geology, Long Term Planning, and Soil. While scientists took a primary assignment in one of the five workgroups, these roles did not stand as boundaries preventing them from participating in other theme groups. In addition to working with the scientists within their theme group, across theme groups, and across rovers, there were additional workgroups for each of the rovers' suite of instruments and to these rover specific workgroups I will return shortly. Figure 3 depicts various scientists and engineers at work. For each of the five science workgroups there was a designated workspace within the main science work room, image b Figure 3.[15] Many

a b c

Figure 3 MER mission members: (a) engineers working in the mission control room; (b) scientists working in the main science working room; (c) some members of the Rock Abrasion Tool instrument team at work.

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[15] A bit about the badges: membership in the community was displayed via the significant artifact of the security badge. To receive one necessitated filling out a range of forms and completing several processes through JPL and NASA security offices. It was not an easy process, it required several months advance application and the right signatures in the right order. It was the only way to enter the grounds of JPL. In addition to the security badge there was a special MER badge that indicated "extra" special status. And badges were not just for people. Equipment needed badges too. In some cases, the badges for the equipment included a picture of the equipment on the face of the badge, just like for people.

of these teams were comprised of members who shared a work culture developed outside of MER. While the cultural norms and values of the community of MER was primarily constituted by Professor Squyres' Athena Science team and the NASA scientists and engineers, each instrument team constituted a subculture organized around the specificity of their work, separate workspaces, and past work history. The symbols and artifacts of these subcultures were visible in their workspaces, the separate work rooms for each instrument teams. While each room was similar in physical construction, the artifacts within made each distinct: Buddhist prayer flags, champagne, family photos, comic strips, pictures of members, and posters 'borrowed' from the main working area. Although the doors to these offices were almost always open, and there was no badge required to gain entry, there was a strong sense that only workgroup members, managers asking about work and invited guests were allowed to circulate freely. Eventually, with permission from Stephen Gorevan, the head of the Rock Abrasion Tool (RAT) workgroup, and his team (see image c, Figure 3), I gained access to the designated space of the RAT workgroup, a site that came to be my regular spot to hang out and work in. As it would happen, this workgroup included a number of dynamic individuals whose humor drew other mission members into their work space.

MER mission operations

The MER mission had been scheduled to operate for 90 days. The proposed timetable was a safe estimate given the expectation that the rovers could operate for three times as long (Squyres, 2005). As readers know, the nominal mission was successful and the rovers continued to operate well beyond their expected life. With additional funding, MER mission continued some four years beyond the end of the nominal mission (as of September 2008).[16]

Mission operations is a broad category that describes the multiple science, engineering, and administrative socio-technical processes that comprised the inter-planetary work system for making Martian science. Figure 4 displays a simple image of the work process for MER. [17] Science operations for MER, very simply put,

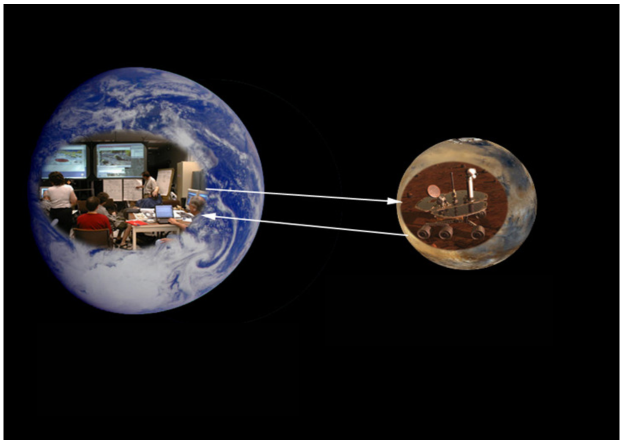

Figure 4 Inter-planetary work flow: a visual contextualization of MER mission work, sending and receiving data between Earth and Mars, between humans and robots.[18]

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[16] see Chang (2004), Martian Robots, Taking Orders From a Manhattan Walk-Up" for images and story about RAT team working on Mars while located in Manhattan.

[17] Watching the activities and communication patterns of mission operations, following scientists through meetings and conversations, it was possible to follow the production work of mission operations, even without formal training in astrogeology. Many of the technical configurations were complicated and would take time to understand but the trajectories of information, as well as the sequence of events and expectations, were not beyond comprehension. I conducted my research as I had on previous projects: observing spatial dynamics, social relations, technology infusion, communication patterns, and information trajectories. I asked questions either on the spot or at a later time, when appropriate. I read and re-read manuals, diagrams, and journalist accounts of Mars exploration and the MER mission, which often included translations of internal processes made by participating mission sciences. These sources include the Cal Tech newsletter; Pasadena Sun Times; New York Times; Space.com; the Planetary Society; and the Athena Science team webpage. Sources dated from 2001, when the mission was first announced and planning had commenced.

[18] Image credit belongs to WSD & E members C. Seah and R. Wales.

involved daily analysis of the Martian terrain – data collected by the rovers was examined and interpreted, using software and sight. There are a number of questions to be asked about training oneself "to see" on Mars, to imagine one is seeing Mars through the images taken by the rovers. The coloring of Mars requires a selection process and the positioning of camera angles and relative spatial relationships must be taken into consideration for analysis. The adjustments involve several steps of translation work and are steps in the process of knowledge production.

In order to maximize the opportunity for data collection and to meet all the mission goals, the Athena science team had decided that every day would be a full day of complete operations. Every day the rovers would send data to Earth; the scientists would analyze the images and determine the rover's next course of action; and, the engineers would send instructions back to the rovers for additional data collection. And, by the final step in the day's process, the engineering work of sending instructions to the rover, presumably the scientists would have ended their work shift. Analysis work also entailed group discussions, negotiations, voting, and reviewing, by no means simple activities (described in detail in Chapter 2).

In order to manage the work processes involved in daily science operations that were set to schedules organized around the data collection practices of the solar powered rovers, a time support technology was produced – *Mars time*. Mars time was a modified version of clock time constructed to address the temporal difference between the length of a day on Mars and Earth. The length of a day on Mars, referred to as a "sol," was approximately 24 hours and 40 minutes. As a support technology, Mars time did not present itself as a central artifact, or ritual, at the start of the mission. But as the research in this dissertation will establish, in the process of making Martian science, NASA and MER mission members constituted Mars time as though it was a natural condition. In Chapter 2, the constitution of Mars time is discussed in detail and in Chapter 4 the significance of naturalizing Mars time is discussed. Assembling mission members is only one component for the making of Mars time. The objects around which their work was organized were two rovers. Next I turn to look as these space vehicles. Although I problematize the categorization of the rovers as artifacts in Chapter 5, initially, the space vehicles appeared as the primary tools used by the community in the production of scientific knowledge.

The Rovers

No description of the MER community would be complete without a discussion of the rovers. Scientists collected data on Mars by directing the rovers' movements and the tools with which they were equipped, see Figure 5. Weighing in at 384 pounds, each six wheeled rover was equipped with a deck of solar panels and was capable of moving at up to 5 centimeters per second on flat hard ground (NASA, 2003). This mileage per second was reduced, however, due to the hazard avoidance equipment down to 1 centimeter per second. Two stereo pairs of cameras used for hazard-identification were mounted at the front of the rover and the rear. Besides supporting automated navigation, the one on the front also provides imaging of what the rover's arm was doing. Of the six science instruments packaged by the Athena Science team, the Pan Cams were two other stereo camera pairs placed at the top of a mast. The rest of the science instruments were located at the end of the "instrument deployment device," also referred to as “the arm.” The Mini-Thermal Emission Spectrometer, or Mini-TES, was an instrument used to capture infrared radiation emitted by objects. The Rock Abrasion Tool, or RAT, was used to grind the surface of rocks. The Micro Imager was used to provide an extreme close-up view of rocks and minerals. Mössbauer was used to detect iron-bearing minerals. And, the Alpha Proton X-ray Spectrometer, or APXS, was used to determine the elemental chemistry of rocks and soils.

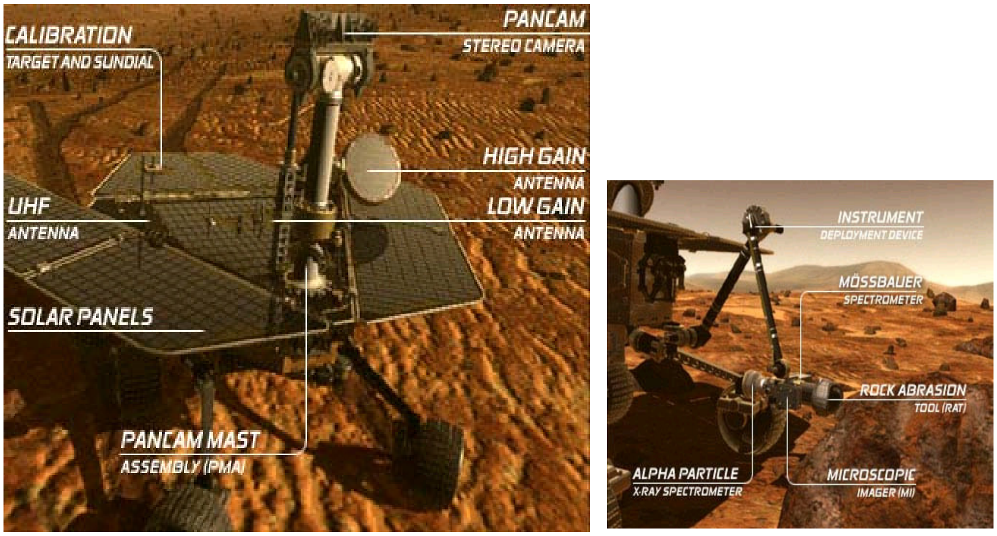

Figure 5 The remotely operated space vehicle: in the left image, the rover is viewed from a top-down shot; on the right, a close-up of the instrument deployment device, or “the arm,” on which the four in-situ instruments are located (Cornell University, 2005).

The rovers were essential constituents in and of the MER community. In Chapters 2 and 5, I describe the rovers in greater detail, locating their roles along the work process timeline of making Mars science and the interactions between the rovers and the scientists and engineers. These ensuing discussions (particularly Chapter 5), however, will challenge the notion that the rovers were *only* tools. While their participation in the MER mission can be described using terminology that excludes socio-cultural aspects, these aspects could not be ignored in situ. The work practice design for the process of making Mars science may have categorized the rovers as physical objects but in the context of daily operations the rovers can be understood as occupying the roles as mission members of MER.

To complete this mapping of the physical and social relationships that bounded the community of the MER mission, I return to the image of the mission provided earlier in Figure 3, and reprinted below in Figure 6. In the image, the black background signifies the context and the location of Mars and Earth in outer space. Space and distance overshadow the mission members and the rovers; they appear as two separate entities connected only by signals, circuits, and software. An account from within conventional organization studies would support focusing primarily on

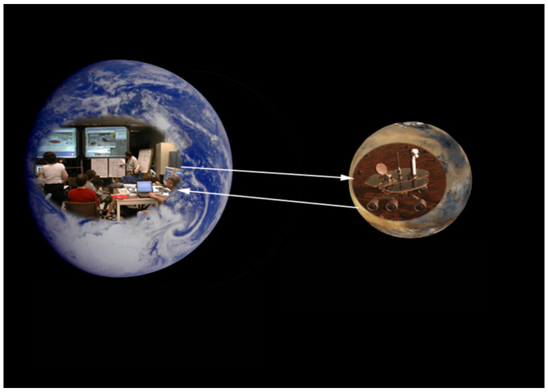

Figure 6 MER mission landscapes across which work was coordinated between scientists, engineers, administrators, and rovers.

the left side of this image – examining the terrestrial organization as the primary site of production. The rovers, communication systems, and space travel would fall under the investigation of technologies of work support (or information communication technologies). Cultural studies of science and technology, on the other hand, would lean towards privileging the rovers on Mars and the processes by which technological apparati serve as extensions of humans and conductors of life sciences within distant landscapes shaped by terrestrial political and social forces. However, the perspective of the MER mission that I am endeavoring to share with the reader is of an inter-planetary composition of the community of MER. By putting aside the act of privileging one planet over another, or of people over rovers, and by removing the emphasis on space, we have a re-presentation of the MER mission (see Figure 7). From this alternate perspective, I foreground the process of information exchange and the exchangers of information, and the organization of the MER mission is bound as an interplanetary community, comprised of people, rovers, processes, and planets. With this representation, our attention is drawn to the organization of the MER mission as an interplanetary work system. From this perspective, several assumptions from

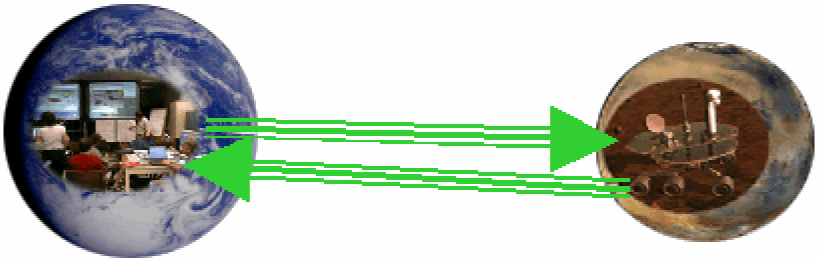

Figure 7 the inter-planetary workspace of the MER mission

which the coordination of work are based are called into question such as the importance of planetary motion with respect to the coordination of information exchange, as well the subsequent work practices built upon the framework used to connect time and space between Mars and Earth. Sharing this perspective is the first step towards understanding the socio-cultural investigation in this dissertation of the relationship between organizational infrastructure and the production of extra terrestrial scientific knowledge.

In the following chapter, I begin by foregrounding one of the essential assumptions embedded in all organizational infrastructures – time. I lay out the work schema for the daily production of Martian science among mission members at JPL, with particular attention to the technologies and social processes provided to support following the unique timetable that was set according to Mars time.

Chapter 2

Mars Exploration and the Curious Problem of Inter-planetary Time

"Wearing two watches, one for Mars time on the left wrist and one for Earth time on the right wrist, Jim Rice works in three time zones on two different planets simultaneously. 'Days of the week on Earth don't matter anymore because we are living on Mars time with the rover twins,' says Jim in his strong Alabama accent. He beams: 'Most of us are averaging about 4-5 hours of sleep a night. I don't know if it's a.m. or p.m., but I'm loving every minute of it (JPL, 2004)!'" Dr. Rice, an astrogeologist from Arizona and a member of the Athena Science team, summarizes the unprecedented work schedule required for the operations of the MER mission's inter-planetary work system – scientists on Earth worked according to the time of day on Mars. As well, Dr. Rice's zealous description of working on Mars time is an example of the enthusiasm shared by many of the mission members, an enthusiasm that masked the work of weathering the socio-technical breakdowns of time management. I present how this arrangement of time and space operated, the formal and informal technologies used to support it, and the evidence that it was not as successful as public representations convey. I lay this out in the direction of understanding how a problematic time standard, beyond the direct observation and experience of humans, came to support work and was supported by work on the MER mission.

Science-fiction rubrics of extra-terrestrial space exploration breaking pedestrian terrestrial conditions of time and space dimensions aside, the same tool that has shaped work in organizations in terrestrial space for centuries – time – was used to coordinate the co-located work processes of making Martian science. However, of the two locations, Earth and Mars, only one had time – clock time that is. Thus, Mars time was constructed. Using the standards of terrestrial clock time, a technology by which units of measurement are built around the presence and absence of sunlight on Earth (Jespersen, 1979), the MER mission produced an extra-terrestrial version of clock time around the presence and absence of sunlight on Mars. As a participant and as an observer of the inter-planetary work system of the MER mission, I experienced and examined the astounding process by which humans on Earth sent two robots to Mars and used them to gather data that was transformed into evidence that water had once been present on the surface of Mars. As a social scientist, my curiosity was drawn to the socio-technical processes of Martian science production vis-à-vis the everyday work practices of organization members and the structural provisions of the organization. In order to participate in the day to day operations of time management on the MER mission, epistemological questions concerning the socio-cultural construction of Mars time had to be muted, though not abandoned – questions like, "how could there be time on Mars if no human was there to calibrate it?" and, "how could mission members set their sleep/wake cycles, their circadian rhythms, to the presence and absence of sunlight on Mars, a sun they could neither see nor feel?" The question, however, that pushed me to stick with the theme of time was more abstract. As the success of the mission was repeatedly pronounced, each time there was a new discovery of evidence that water was once on the surface of Mars, I wondered about the ways in which the everyday practices of mission operations were implicated, sharing in the branding of success, and the ways in which public representations of mission operations, and Mars time in particular, produced a version of operability that I, having witnessed time on the inside, found very disconcerting. When time management breakdowns took place on the MER mission, although these breakdowns did not circumvent the success of the mission, the results included cognitive dissonance, stress fissures within the infrastructure, and support for inoperable assumptions about time and work. Working to Mars time required reliance on entrenched assumptions about the operability of clock time as given, universally and organizationally, coupled with the zeal of members who did not want to talk about these issues as *breakdowns*.

In this chapter, I explore the nature of this seemingly surmountable configuration of managing Mars time from Earth. Nature is not used here in the sense of an a priori state of the natural world; it is used to reference the conditions of socio-cultural and technological contexts that support making sense of what is nature. In this examination of the multiple temporalities of an inter-planetary work system, I lay out the infrastructural provisions, support technologies and social processes, used to support time management. Through ethnographic data, I examine two of the primary formal technologies provided by NASA, several of the informal technologies that emerged in response to the inadequacies of the formal tools, and the conditions of technological drift by which the formal technologies were adopted for alternate uses and of the emergence of informal work. In my analysis, I question some of the assumptions about the management of time as an activity of information processing. I consider the constitution of time through socio-technical processes, formal and informal technologies used to support science work processes, and the temporal rhythms (Zerubavel, 1981) of inter-planetary work systems.

The inter-planetary work system

Operating the rovers remotely was not analogous to operating a remote controlled car; the work of directing the rovers' movements toward a rock, grinding its surface, and taking a picture required an iterative process of hypothesis formulation and testing without the inclusion of one of the primary activities of geological work practice – in situ, direct and tactile observation. The Athena Science team had to develop new processes for dealing with the unique challenges of doing field geology on a distant planet with a robotic vehicle (Squyres, 2003) and these processes were tightly bound by several temporal limitations. In this section, I lay out the basic schema of the work processes involved in an inter-planetary production process of Martian science. Within that schema, I draw out the importance of time in supporting the coordination and operability of socio-technical work processes; and, I examine the processes through which Mars time was constituted and made to appear operable. I enter the discussion by setting up the order of work before explaining the provision of multiple temporalities. The reason for this approach is to avoid underscoring the idea that working on Mars time was required because the rovers were solar powered. Although this is the most oft made comment in public representations of the relationship between time and work on the MER mission, it is not true, or not quite the whole truth.

The primary reason for having scientists on Earth work according to Mars time was to maximize the utility time of the rovers, increasing the odds of completing all of the mission success requirements. Just as sending two rovers instead of one doubled the chances of success, the choice to run the rovers in accordance with solar time on a daily basis allowed mission operations to run through the work processes of rovers and scientists on a daily basis, creating the possibility of having 90 days of full data collection to meet the measures of mission success that had been set out in the mission plan. But the impression that the work of the MER mission had to be on Mars time in order to maintain time standards set by the solar powered rovers did a particular kind of work in fashioning Mars exploration as a human endeavor, as a collaboration between humans and anthropomorphized rovers, a consideration that I discuss in Chapter 5. Through this representation, NASA's MER mission appeared to require coordinating work between two teams of workers – the rovers and the scientists – and balancing the drive for scientific discovery with the solar-determined technological fragility of the rovers. These considerations lend themselves to demonstrating a concern for the most prominent feature for which NASA has been heavily criticized for two decades – safety. I am placing this up front rather than in the later analysis as I want to impress upon the reader the understanding that the relationship between time and work on the mission was not solely based on technological affordances and constraints. The relationship between time and work on the mission was also shaped by socio-cultural considerations.

Coordinating mission operations: the tactical timeline

Coordinating the work of the robotic geologists on Mars, mission scientists were guided by a work schedule they had developed, with engineers, during the two years preceding the rovers' landing. This work schedule, the tactical timeline, integrated the division of labor meted out among three workgroups: the rovers, the engineers, and the scientists. The tactical timeline was a linear timeline along which tasks were plotted, by order and duration, representing one complete cycle of work, see Figure 8. From the science working groups' perspective, a complete cycle of work was as follows: the cycle began with the reception of data from the rovers, and while

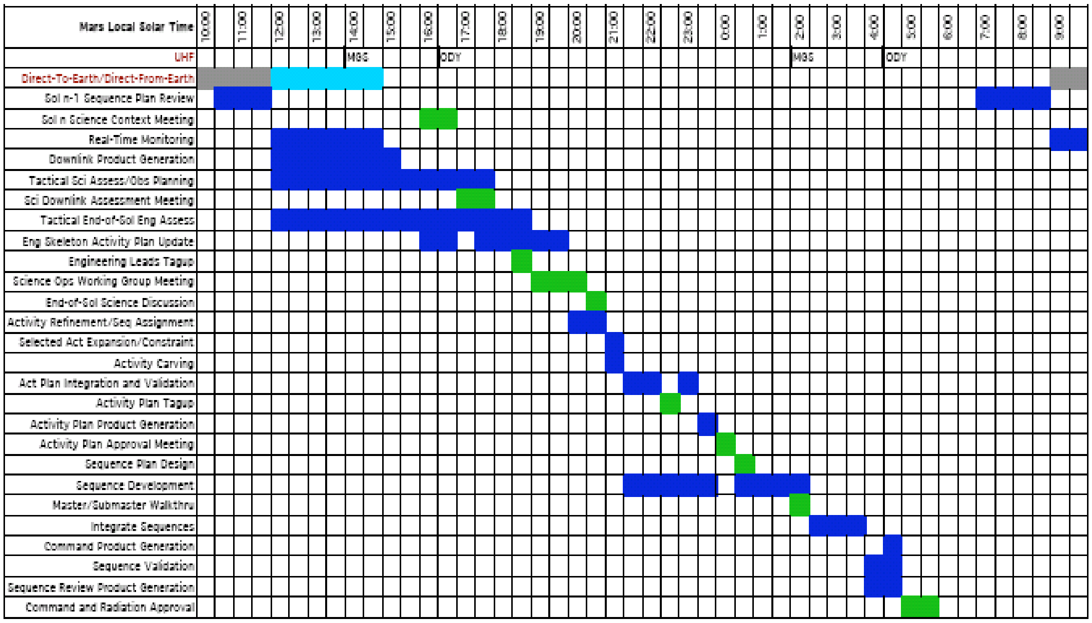

Figure 8 The tactical timeline: along the x-axis is a timeline of Mars time and along y-axis are a list of the activities and meetings that took place each day of operations. In top left corner, a grey bar indicates the reception of data from a rover, which begins the cycle of work. The blue bars indicate the progression and durations for engineering tasks and the green bars indicate the progression and durations for science tasks.

engineers were preparing the data to be handed over to the scientists, the scientists were meeting in preparation for receiving the data. Once the data was received and reviewed by the scientists, a meeting was held to discuss analysis and to propose the next set of data the rover should collect. At the same time, engineers were monitoring the rover's "health," a term used to describe the technological condition of the rover. Then, the scientists would come to a consensus on which of the multiple options of scientific data collection should be selected; then, the science workgroups responsible for the chosen plans would prepare the specifics for collecting the particular datum while designating which instruments would be used (for example, using the Rock Abrasion Tool could be necessary before taking a mineral composition read). Finally, at the science planning meeting (Science Operations Work Group Meeting or SOWG), the scientists would go through the parameters of the selected data collection plans, putting them together in a final list that would be handed over, to continue downstream as they said, to the engineers. During the series of activities wherein engineers translated the science plans into rover commands (activity refinement), one last science meeting was held, discussing the day's events and thoughts for the future. During these meetings most of the scientists were present, whether they were presenting a science plan, data analysis, or responding to the presentation of hypothesis or findings of other scientists. The aim was to analyze the latest data and, as a group, put forward a plan for the rover's next day of work. Figure 9 shows a timeline along which only the science operations work appears. Although it is not my focus in this chapter to look closely at the knowledge

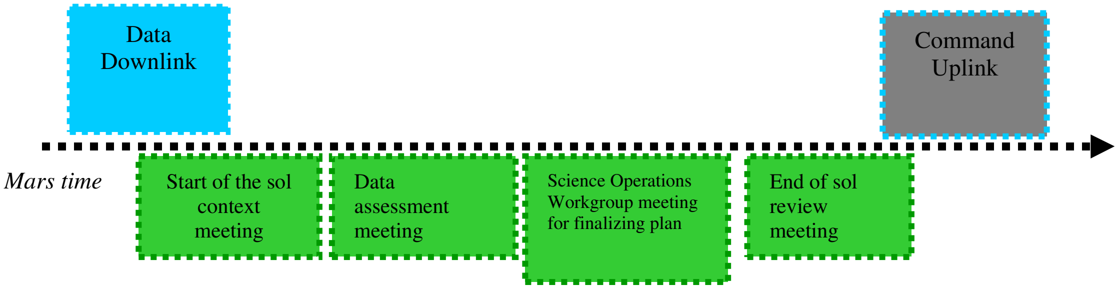

Figure 9 Science operations timeline: shown are four meetings, decision-making sessions, through which each day's scientific analysis went through. In these meetings, scientists would discuss and present interpretations of the latest data and present arguments in support of a particular plan of action for the rover's next day's work

production process, it bears mentioning that the daily process of surveying, sorting, and sifting through the many possible science data collection commands was referred to as "making sausages" and "eating at the buffet." This jargon gives some indication as to the variety of interests that constituted a science plan like the variety of meats that constitute a sausage and the range of scientific possibilities that had to be selected from while others were left behind in the same way as one encounters the food selection at a buffet.

The tactical timeline was a primary communication tool used for coordinating the activities of communication passes, data analysis, and decision-making. It also demonstrates the division of labor and the reliance on task completion of one workgroup for the next workgroups' tasks to begin, allowing us to see in the tactical timeline the production line of work processes. On a production line, set according to a time schedule, the movement of the central object, that which is being produced, is moved forward through stages bound by predetermined temporal durations. Along the production line guided by the tactical timeline, the object being produced was the rovers' commands for data collection. Understanding that the object being produced through each cycle of work was the information that was sent to the rovers on Mars, not the science data presented to the public on Earth, brings us to the reason for organizing the scientific knowledge production of Martian science around the rovers' rather than the humans' optimal hours of operation.

There was constant social pressure within the organization to complete a checklist of activities not necessarily tied to the discovery of past systems of life support (water) for the mission to be considered a success. Public representations of the MER mission depicted it as a success after both rovers landed and emerged from their shells. And this success was underscored by a presidential commitment, made a few days after the landing of the first rover, that the U.S. would return to the Moon and send humans to Mars (White House, 2004). But the criteria within JPL for determining whether or not the MER mission was a success included conducting data collection for 90 days, employing all of the in situ instruments, obtaining images, operating the rovers simultaneously for 30 days, and traversing for a minimum of 600 meters (.37 mile).[19] There were finer parameters nested within criteria that added to

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[19] The complete list of criteria: 1. Launch two identical lander/rover missions to Mars during the 2003 launch opportunity, from the Eastern Test Range aboard separate Delta II-class expendable launch vehicles; 2. The MER-2003 rovers shall each acquire science data and conduct in-situ analysis for 90 sols, and shall be designed for operations independent of the lander; 3. At each landing site, operate the Athena instrument suite (i.e. Pancam, Mini-TES, APXS, Microscopic Imager, and Mössbauer spectrometer) during the 90-sol operational phase of the rover mission; 4. At each landing site, acquire at least one full-color and at least one stereo

the number of considerations that had to be kept in sight during the production process – parameters such as whether the rover had moved a prescribed distance between two points and using a particular instrument at each of the two points.

The pressure to complete mission success criteria brings up the presence of several sociotemporal rhythms, rigid patterns of time related to social activities and events (Zerubavel, 1981), external to the production processes of MER. This would include, for example, the funding timeline or the deadlines for proposing future projects and justifying present projects. President Bush's mandate, announced mid-January 2004, included the creation of an Office for Mission to the Moon, which introduced new funding requirements with which even the MER mission members had to comply despite the fact that they were more immediately engaged in a successful MER mission.[20] Mission members with other home institutions (university

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360° panoramic image of the landing site with the Pancam, with a resolution of less than 0.3 mrad per pixel. Acquire at least one image of a freshly exposed Mars rock that is also analyzed by another Athena instrument (i.e., Microscopic Imager, Mini-TES, APXS, or Mössbauer spectrometer); 5. Drive the rovers to a total of at least eight separate locations and use the instrument suite to investigate the context and diversity of the Mars geologic environment. Every reasonable effort shall be made to maximize the separation between investigation locations to increase site diversity, without compromising overall mission safety or probability of success; 6. To investigate complex science operations on remote planetary surfaces, the MER-A and MER-B missions shall operate simultaneously on the surface of Mars for a period of at least 30 sols; 7. At least one of the rovers shall demonstrate a total traverse path length of at least 600 meters, with a goal of 1000 meters.

[20] It was at this point that mission members from NASA Ames had to put time into writing up justifications of their current projects and proposing new projects. The latter proposals were only proposals to propose – they would be reviewed at NASA Headquarters and only a portion of them would receive an invitation to submit a proposal, which was again subject to the competitive process for resources. By the fall of 2004, many people began leaving NASA Ames, some had not received an invite to propose and some had tired of the never ending proposal process that had funding deadlines subject to change at the promote of political changes in the administration. The exodus could be seen through the daily emails, sent by departing members saying their goodbyes and leaving forwarding information. Leaving without obligation to finish reports, I considered this situation to be one that had its advantages, organizationally speaking. In that, without record of what had been achieved, or understood, the next

affiliations) had similar considerations to keep in mind, such as academic publication deadlines.

In addition, the work required of the rovers, the same work that the scientists imagined they would conduct were they exploring the Martian terrain, had to be implemented especially slowly. The phrase that was used to compare the time it took for a rover to complete the same action as that of a human was "1 day to 30 seconds," meaning that it took the rover one work day to complete the same activity that a human could do in thirty seconds. The rovers' top speed on flat hard ground was 5 centimeters per second. This was including stops for negotiating hazard avoidance: controlled by preloaded software, the rover was required to stop and reassess its location every few seconds. So, over time, the rover was really traveling at a speed of 1 centimeter per second (JPL, 2007). These differences, the temporal duration of the kinetics of field geology, were negotiated by the scientists during meetings even as they supported scientific plans with rationale that included, "if I was the rover, this is how I would do it," and "in coming up with this plan, I moved myself as the rover has to move."

Given the drive to make Martian science and render the mission a success, the tactical timeline was laid out to maximize the rovers' life span, or maximize the time that the rovers had to operate while taking care not to damage them in the process. While the rovers were stronger than humans and by physical composition able to travel millions of outer-space miles to work on inhuman terrain, they were also more

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generation could claim new discoveries, of considerations that may have already been understood but without record "do not count." I thought that this might be one way of constructing a standard for invention and innovation.

fragile and constantly at-risk of failing without warning, or as they said on the mission – of dying or getting sick. Their temporal fragility was personified by the terms in which mission members referred to them as "terminal patients," a status that came up frequently when a workgroup team leader was attempting to push a particular data collection request. This reasoning was a bit hyperbolic but it was based on the expectation that the rovers' power source would eventually burn out from exposure to conditions on Mars. Each rover had a large solar panel deck that produced nearly 900 watt-hours of energy per day to repeatedly recharge two batteries inside the body of the rover (JPL, 2007). Over time, the rovers' batteries would slowly lose their capacity to store charges, analogous to the process that takes place with cell or cordless phone batteries. And, the exposure to Martian elements that would eventually fell the rovers was the presence of dust in the Martian atmosphere. The dust, it was imagined, would accumulate on the solar panels, eventually blocking the reception of sunlight.

Thus, the tactical timeline for the MER mission's inter-planetary work system was designed around the best hours of operation for the rovers – sunlight hours on Mars. And in order to maximize data collection each day, the inter-planetary work system ran one complete cycle of work every day. This was known as sol-to-sol planning, a phrase that encapsulates the temporal strategy employed to support the infrastructure for the inter-planetary work system of the MER mission – Mars time.

All in a sol's work

Coordinating activities using time between two points required time to exist at both points. For that, Mars time was invented. During the planning stages of MER, there were no words for a Martian hour or minute, the concept of Martian time had to be produced (Bridges, 1999). Since the work of the rovers was scheduled according to the presence and absence of sunlight in the duration of an axial rotation, in other words — a day – a term for a day on Mars was needed for the narrative of coordinating time between two points. Mission members chose to use the term sol to describe a Martian day, as it had been used on two previous NASA Mars missions (Squyres, 2005). Minutes and hours were discursively modified using Martian as a pre-fix, although these increments of time were rarely used.

This seemingly innocuous three letter word that aided in linking inter-planetary work can also be understood as discursively planting an American flag on Mars; aside from NASA missions to Mars, Viking and Pathfinder, no formal construction of a day on Mars had been agreed upon by scientists, nationally or internationally. There has been a long tradition, at least one hundred years, of planning by Mars enthusiasts on the arrangement of a calendar for Mars, a framework that would allow humans to begin locating an attachment to Mars. One of the most relevant (to this discussion) schemas is the suggestion that the years on Mars should be counted beginning with the first NASA Mars mission, Viking (Gangale, 1986). This underscores the attempt to claim Mars through the naming process and reflects the degree to which space exploration and extra-terrestrial science are nation-building activities.

Of course, the foremost reason for giving a day on Mars a different name is because a day *is* different on Mars than on Earth; the temporal rhythm of the presence and absence of sunlight, what sociology of time scholar Eviatar Zerubavel (1981) calls a physiotemporal rhythm, on Mars is about forty minutes longer than on Earth. On Earth, a day is 24 hours long; on Mars, a sol is 24 hours and 39.6 minutes.[21] Although this measurement provides a reasonable assessment of the planetary differences, it also reproduces the terrestrial ontology of clock time, which does not exist on Mars. One solar day is 2.75 percent longer than a day. And, due to Mars' greater distance from the sun, a Mars year is comprised of 668.6 sols while a year on Earth is comprised of 365 days. Other than the term sol, no alternate naming schema for Martian minutes, hours, or years was used. The first day that the first rover landed on Mars, sol one began. When the second rover landed on Mars, seventeen days later, on Mars it was sol 18. Located on opposite sides of Mars, thus subject to alternate experiences of solar exposure, the rovers did not operate on the same sol, or occupy the same sol – they were (are) separated by about half a sol.

These temporal differences, between days and sols, were flattened by the tactical timeline making the conduct of inter-planetary work appear as a simple coordination between two different time zones, like New York and Los Angeles or Tehran and Oakland. Terrestrially, this coordination requires simple math performed once – once the time difference is established, three hours behind or twelve hours ahead, it is constant. But inter-planetary time difference cannot be managed as such. Synchronization of this sort required a constant (daily) *re-set* of a terrestrial standard clock by forty minutes forward – a configuration that one Mars enthusiast wrote, twenty years earlier, would be too clumsy to ever be used (Gangale, 1986). To make

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[21] One study (Gangale & Dudley-Rowley, 2003) describes the lack of agreement on the accuracy of Mars time representation provided by some of biggest contributors to Mars exploration such as Cornell, Harvard, NASA/JPL, NASA Ames, Space.com, James Lovelock of the Royal Society, Robert Zubrin of the National Space Society.

Mars time, clock time on Earth had to be stretched, slowed down, and forced to include an additional forty minutes each day. As Principal Investigator for MER Professor Steve Squyres (2005) described the situation, if the planning process started at 8:00 a.m. Pacific Standard Time today then tomorrow it would have to start at 8:39 a.m., slipping thirty-nine minutes later to account for the longer duration of a sol. The next day it would be 9:18 a.m. Then 9:57 a.m. Then 10:36. Three weeks later, it would be the middle of the night, slipping inexorably inward around the dial of the Earth-time clock, see Figure 10. And, as Professor Squyres put it, it would get worse still when the second rover landed on Mars.[22]

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Mon	Tues	Wed	Thurs	Fri
Mars	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am	8:00 am
Earth	8:00 am	8:39 am	9:18 am	9:57 am	10:36 am	11:15 am	11:54 pm	12:33 pm	1:12 pm	1:51 pm	2:30 pm	3:09 pm

Figure 10 Translating Mars time to Earth time: this table assumes an 8:00 a.m. start time for the science work processes, for example the first meeting that established what transpired during the time that the scientists were supposed to be asleep. Each day, local pacific standard time, represented here as Earth, would have to move forward by forty minutes from the previous day's adjusted time.

Looking back at the tactical timeline in Figure 7 (page 29), the time shown across the y-axis is Mars time. The hour blocks are not sixty minutes long but

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[22] In addition, communication between the humans and the rovers was affected by time shifting. During the course of the 90-day Spirit mission, Earth and Mars moved steadily apart. As they separated, the time it took for light to travel from Mars to Earth steadily increased. When Spirit first landed, the neighboring planets were about 106 million miles apart, which translates to about a 10-minute lag. By the end of the Spirit mission, Earth and Mars became separated by more than 180 million miles, resulting in a time lag of more than 16 minutes. By the end of the Opportunity mission, 20 days later, the delay increased to more than 17 minutes (Bortman, 2003).

somewhere between one and two minutes longer. Note that in the schedule representation alone there is a built in disregard for temporal dissonance, which is to say that the presentation of a different standard of time, Mars time, is identical to representations of standard clock time. This reading of the schedule's failure to make explicit a time management issue is not something that can be remedied by simply adding an asterisk or another row of information indicating that each Mars hour is about 2 minutes longer than an Earth hour. Not only does this reading of the technology foreshadow the problems of the temporal support technologies to be discussed, it also demonstrates the attempt to use a standard representation, like a time schedule, to condense multiplicity; a process that only appears to make managing multiple times easier. This last point will be discussed further in Chapter 4.

The fact that there were two rovers on Mars, one on each side of the planet, translated to around the sol operations: when one rover was in darkness and powered down (asleep), the other rover would be in sunlight (awake) and collecting data. Thus, after the second rover arrived on Mars, each rover's dedicated team of scientists, teams which were determined before the start of the mission, worked according to a different schedule, see Figure 11. I am intentionally using the anthropomorphizing language, and image depictions, used by mission members and media in discussing the rovers and various aspects of conducting science on Mars. While tables alone could provide the numeric information, the anthropomorphized images and language texture the

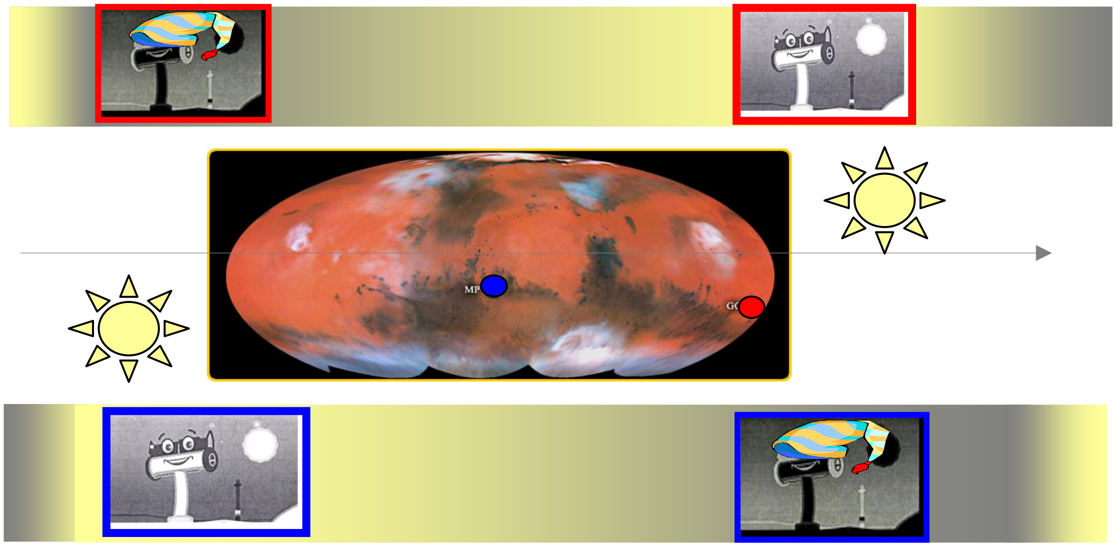

Figure 11 Mars time for the rovers: the top rover, outlined in red, was landed at the Gusev Crater (GC) and the rover outlined in blue was landed at Meridiani Planum (MP). These two sites were on opposite sides of Mars. Temporally, this means that when it's noon at MP, it's midnight at GC.

time management processes with the biotemporal rhythm of sleep cycles and social processes present. The compositions of images and shading are intended to convey some of the tactile and kinetic senses involved in working on MER's inter-planetary work system according to the presence and absence of sunlight on Mars.

Once the second rover landed on Mars, two tactical timelines were needed and two teams of scientists, one dedicated to each rover. It was interesting that the rationale of redundancy used so explicitly to explain the benefit of two rovers rather than one rover did not seem to guide the preparations for the science teams. The work schedule depicted earlier in Figure 7 represents the work schedule used by mission members for each of the rovers. However, it does not represent the unsteady vacillations of scientists between rover missions. Some scientists had particular interests in one landing site more than the other. As a result, self-selection was a primary method by which scientists were assigned to rover teams. Given the numerous responsibilities outside of the MER mission – the temporal rhythms of family life, single life, health care, other organizational work processes including funding and publication deadlines – all scientists were not always present to participate in situ on their rover team. Scientists would cover shifts for one another, or a scientist's expertise or experience with certain mission related processes was needed for discussions on the rover operations to which they were not at the moment assigned. In addition, scientists had established ahead of time a rotation of work between the two tactical timelines. Interestingly, it is only in this temporal movement, working from one rover to another, that Professor Squyres (2005) located the potential for jet lag:

> All of us who wanted to work flight operations would have to shift our sleep schedules constantly, keeping pace with the planet where we worked instead of the planet where we lived [sic]. And it got worse…We would have two rovers, each landing on a different place on Mars. So we'd split the team in half, one for each rover. All of us would live and work on Mars time, but in two different Martian time zones. And if you were working on one rover and you had to switch to the other, you'd get Martian jet lag. It was going to be confusing and exhausting at best, and maybe dangerous. Would sleep deprivation affect our judgment, leading us to fatal mistake at some critical juncture?

As the experience of Mars time would play out, Martian jet lag was a daily experience and predictably so. Terrestrial time adjustments can take between one and three days, up to a week, to adjust to. Inter-planetary time adjustments required a daily time adjustment each day to a different time! Normally, you wake up about the same time every day to prepare for work. Now imagine waking up one hour later every day for the same routine. Then, about every two weeks, you would need to adjust that time as though you were moving from day shift to the graveyard shift, for moving from operations for one rover to another was a movement from opposite sides of the day and night cycle on Mars. The cognitive confusion that this scenario invokes cannot be overstated, especially since part of the work of being a successful mission member was demonstrating that these stresses were not unbearable, as demonstrated in the public accounts of mission members as well as the conversations inside the mission space (discussed in Chapter 3).

The physical space of the mission operations did not support the separation of time into distinct physical states. Mission operations for both rovers took place in the same building: each rover had one floor with a third floor of shared space. The science working space for each rover was *identical*, in room layout, tables, MERBoards, hallways, and bathrooms, except for the color of the chairs and an identification horizontal stripe. Upon entering the floor for each rover, MER A, Spirit, was announced with a red stripe, and MER B, Opportunity, was announced with a blue stripe. And, the color of the chairs for each floor corresponded accordingly, except that there was a chair shortage. This shortage caused a mix up in the color schema and some difficulties in relying on this code to locate oneself within the mission space. In other words, the color coding that was intended to support the distinction between floors became muddled with the mixture of red and blue chairs. The proximity of the science operations work spaces was very important to the sharing of information and exchange of expertise (always two flights of stairs away). Ostensibly, the work schedules separated the scientists between rovers' operations but these schedules did not prevent the curiosity of Martian scientists, a curiosity that is arguably a common if not expected character trait of scientists, from hurtling themselves up and down the stairs after completing a sol of work. Figure 12 depicts the trajectory a scientist following curiosity around the sol, by ending one set of science operations and then moving to the start of science operations for the other rover. Some of the cognitive dissonance that created was found in question, "what floor am I on?" asked by mission members as they walked through the door from the stairwell.

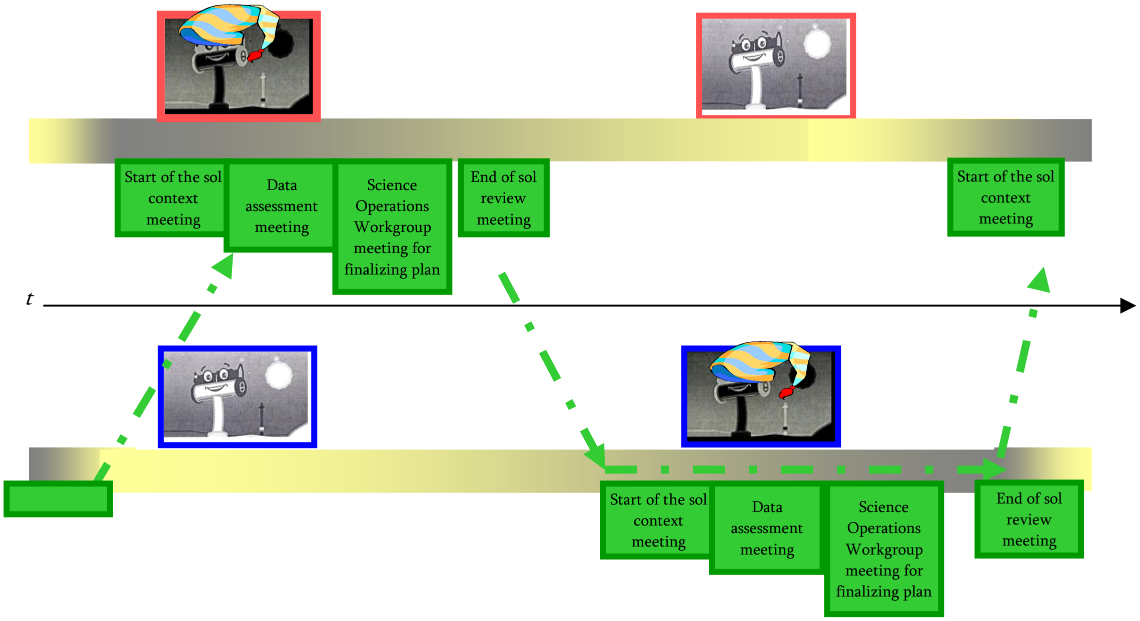

Figure 12 Mission scientists following Mars time: the trajectory of a curious scientist moving between rover operations.

Athena scientist Dr. Matt Golombek provides a description of the time management experience thus far described:

> I would arrive at JPL 38 minutes later each day to synch up with daylight time on Mars for the solar powered rover I was working on. In 6 weeks, our schedule moved forward by 24 hours, so we were coming and going at all sorts of bizarre hours and we were always jet (er Mars) lagged and some of us moved back and forth between rovers, which were separated by twelve hours…even though we were all in southern California, we were all really living on Mars with rovers. [Atkinson, 2004]

Dr. Golombek's statement, made after several weeks into the mission, slightly varies from Professor Squyres' predication. Dr. Golombek notes that the experience of Martian lag took place on a daily basis; and he also identifies a different number of minutes for the daily adjustment to keep up with Mars time (an interesting phenomena that quietly points out the absence of "real" time on Mars). Like Dr. Rice, Dr. Golombek does not complain about the experience; rather, he highlights the unique arduousness of time management. What is noticeable is that time management is being described as difficult but in a manner that does not allow one to suspect that there were any breakdowns that resulted from having to live on Mars time. Consider again the question that Professor Squyres posed at the end of his statement about conducting the mission according to Mars time: "*would sleep deprivation affect our judgment*, leading us to fatal mistake at some *critical juncture*?" This is a rhetorical question posed primarily to confirm that Mars time management was operational. The question appears in his account of the mission published in 2005, one year after the landing of the rovers. And a more recent, though much more subtly made, affirmation that Mars time works can be seen in the decision to return operations for one rover to

Mars time (JPL, 2007).[23] However, these public representations aside, ethnographic data from inside the mission demonstrated that managing the multiple temporalities of inter-planetary work was highly problematic, and probably not reproducible. The point of reproduction, as a condition of determining operational success, will be considered in my analysis, following the next section in which I present various support technologies, breakdowns, and drifts of technological support for time management. Instances of members' expressions that contradict the notion that managing Mars time was fluid are described further on; but, I would like to share one humorous example found in a cartoon hung on a wall in the mission operations space, see Figure 13.

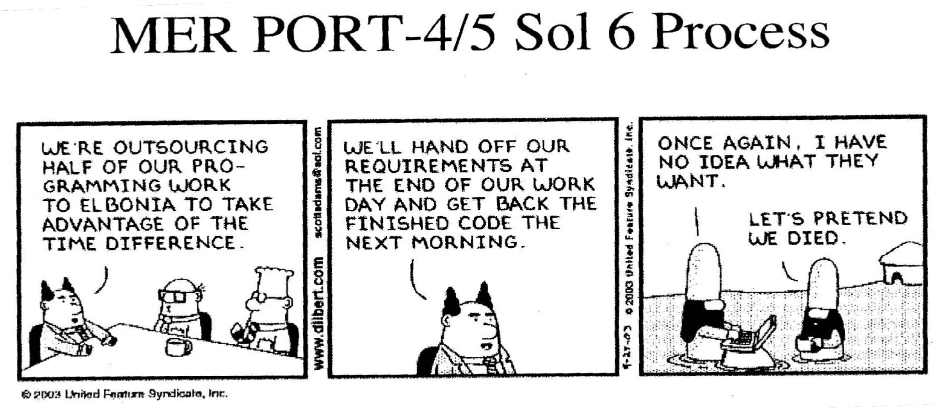

Figure 13 An expression of frustration and humor regarding the procedure of coordinating work between rovers, scientists, and engineers; this comic was hanging in a workspace where engineers worked on the rover science commands. One interpretation is that the "Elbonians" were the engineers, but they also could have been depicting the rovers. A few organization studies scholars maintain that Dilbert comics do the work of placating the frustrations of organization members, salving them with humor in lieu of taking action or having frustrations formally addressed.

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[23] From sol 1398-1403, December 17, 2007, *Final Winter Haven Selection Near:* to make the most of waning sunlight during the approach of Martian winter, Spirit's handlers have returned to "Mars time." This means their working hours coincide with the Martian day, as they did for the first three months after the rover landed on the red planet.

Mission manager Dr. John Callas, a physicist by training, had a lead role in managing the outfitting of mission operations work space. Dr. Callas had a significant role in determining the set-up of infrastructural support for the MER mission, though his decisions were still subject to hierarchical decision-making processes. In an interview during the pre-operation readiness trainings, he described the various support processes that would make working on Mars manageable. These processes included a van service with blacked out windows so mission members on a Mars time schedule that had them leaving JPL while the sun was out could leave the building wearing dark shades and ride home maintaining a sense that their day was coming to an end; special meal services to make up for the lack of access to the JPL cafeteria (which was operated between 6:00a.m. and 2:00p.m. PST); and, nap rooms with cots for those who needed to sleep without going home. Although Callas' list was more like a wish-list than a to-do list, it does serve as evidence that issues of transportation and food were not always considered solely the responsibility of the mission members. Though a lack of budget may have explained why all of these support processes did not materialize, it did not explain why mission members did not insist or make public pronouncements about the absence of support for the difficulties they encountered. One mission member who was not shy about pointing to some of the gaps in work support relayed to me the idea that the mission budget should have earmarked one million dollars to feed mission members in the same manner as actors and crews are fed on movie sets. He also described having to use overturned garbage cans to make up for the lack of chairs.

The description of Callas' intentions calls attention to some of the physical considerations of what it meant to live on Mars time. The physical space of mission operations at the JPL in Pasadena, California was a total of three floors in an eight story building. The three floors were modified to prevent the mission members from the disorientation of seeing out of the windows. At all times the three primary floors of mission operations were tightly sealed with black-out shades that covered every inch of every window, preventing daylight or moonlight from entering the building. Seeing the terrestrial world associated with the 24-hour temporality of Earth clock time would cause cognitive confusion for mission members living, sleeping, and working according to solar time on Mars. But while mission operations provided total immersion for scientists from the physical world's terrestrial sunlight, other conditions such as phone conversations with non-mission members, newspapers, computers, internet, and food services kept the terrestrial world always present. And, of course, the moment that a member left the mission space, the outside world was Earth, where members were subject to terrestrial sunlight conditions and the physiotemporal rhythm of Pacific Standard Time.[24] Usually, the issue of whether and to what extent an organization's infrastructure should or should not provide for the transition between

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[24] Circadian rhythms are an important factor in establishing regular sociotemporal patterns, for work shifts and for personal life (Lavie, 2001). Circadian rhythms on MER, as I was told, fell in the jurisdiction of the Human Factors workgroup. This workgroup was present before the nominal mission began, leaving behind the special watches for a sleep study, posted flyers that reminded mission members of the warning signs of fatigue and how to promote proper sleep, and a ten page resource guide "for managing fatigue and sleepiness for team members and their families." When I raised questions about their practices and lack of presence in human centered computing conversations, I was informed of the jurisdiction divides. This is not the main reason that I do not address circadian rhythms though. The reason is that in this particular kind of work, as I describe in Chapter 3, the goal is to resist the logic of circadian rhythms. To be a hero, a daring explorer, one must rise above the human need for sleep. From this view, circadian rhythms were something that each member of the mission was to manage in their "own time," putting it outside of organizational responsibility.

the work site and home, or public and private, raises fairly conventional questions of corporate and individual responsibility. But, the issue has a different, stronger, traction in the case of MER because of the asynchronous relationship of a day and sol.[25] Moreover, the expectation that time management outside of the organization was something for members to handle "on their own time," so to speak, built an even stronger expectation for the operability of the time support technologies provided by the mission. What then were the formal support technologies that were intended for time management?

The idea of coordinating work processes between two planets relied on the notion that mission members would be able to abandon a local experience of clock time in favor of a distant, abstract experience of clock time, much in the same way that humans manage time differences around the world. Nevertheless, the formal technologies that were designed to support the management of such time differences did not perform as expected. What I want to foreground is not the failure of technological components but the failure of assumptions at play that were relied upon (and typically relied upon) to manage time and work in the organization. First, though, I will present some of the technological drifts and breakdowns that brought the problem to my attention.

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[25] Logically, one response is to try to locate this issue relative to shift work, the grave yard in particular. Experientially, I do not respect this comparison because for shift work is terrestrial bound and all movement is regulated by the same clock. Having the benefit of past work experience in a field that required some shift work, I am familiar with the adjustment that can take place, with activities getting schedules racially opposite to the normative work/leisure week. Again, the difference with MER is that time shifted forward every day, so no two days were the same.

Working time with support technologies

The tactical timeline was but one of the technologies designed and approved for use on the MER mission. In addition, the MER board and the Collaborative Information Portal, CIP, which were intended to support the management of scientific data but drifted into use as time management tools. Through the experience of observing and participating in the management of multiple temporalities, I collected over sixty days of data in which Mars time management was a central theme (mission operations were only set to Mars time for the first 90 sols). And it is from within this data that the emergence of informal technologies – tools that were developed by mission members in response to breakdowns or the absence and/or inadequacies of the formal tools for time management – is examined. And I argue that these workarounds highlight the failure of the organization infrastructure provided for Mars time management.

The MERBoard and CIP were designed to assist mission members with managing, displaying, and distributing information such as the tactical timeline, images received from the rovers, and the analysis of data. Used together and separately, they were developed independent of one another. The design of the MERBoard was partly informed by work practice research conducted among mission scientists during the planning phase of the mission (Trimble, 2004), when scientists had been observed huddling and jockeying around a single laptop computer. When the audience grew to a size larger than ten, an attempt would be made to connect the laptop to a projector screen – a process which inevitably took five to ten minutes and was not always successful. In the interest of work support, the MERBoard was to provide scientists with the ability to (1) display an image to a larger group of scientists, (2) make line drawings on the image for emphasis, and (3) even e-mail the image, modified or not, to any or all of the scientists (Tollinger, 2004). The MERBoard, a large, 50-inch plasma screen sitting atop a metal frame, stood about 6 feet tall, see Figure 14.

Figure 14 The MERBoard is displaying an image of the Martian terrain, colored for analysis.

Each science working group (there were five for each rover) had their own MERBoard, positioned against a wall flush with their workspace. And the idea, again, was that group analysis and discussion would take place in front of the large plasma screen, see Figure 15, rather than around a seventeen inch monitor. Significantly, however, there were two things that the designers of the MERBoard had not designed for: the phenomenology of exploration work and of the process of telling Mars time.

sequences of commands.

The MERBoard design is intended to address direct user needs of the mission operations team. These include the need to display, annotate and share information in a natural way, the need for a medium such as an electronic whiteboard that allows for brainstorming, sketching ideas, compositing, and lists that can then be captured and shared easily, and the capability to easily save, recall and distribute the data.

MERBoard Core Applications:

Figure 15 MERboard in situ: about twenty-four Athena scientists look on as one scientist describes an image displayed on a MERBoard. This image was taken during the field testing stage of the mission and appeared in an informational flyer for the MERBoard.

Certain phenomenological considerations of exploration work did not appear to be considered in the work set-up for space exploration. While terrestrial expeditions like Shackleton's Antarctic exploration, sea-faring discoveries, and the land-based exploration of the "new frontier" were used discursively among mission members, these "templates" of exploration work also served to inform phenomenology of space exploration. Although the MER mission was taking place in a post-industrial organization space where the possibilities for new information communication technologies (ICTs) were limitless, linking the work of Mars exploration to terrestrial explorations connected some mission members to the physical experience of exploration taking place pre-ICTs. Watching the scientists standing over maps splayed out on tables too small to hold them (see Figure 16), I was reminded of the images of explorers pouring over maps by candlelight, or while standing at tall tables.

Figure 16 Scientists discuss the Martian terrain image on a print out while a MERBoard is unused in the background to the right;

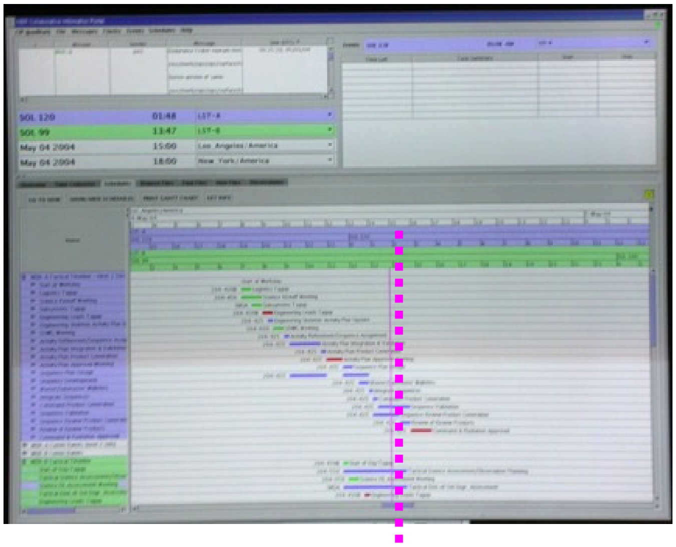
The rovers' PanCams provided panoramic images of Mars, which could be viewed on the MERBoard and were printed and posted on the walls of the main science working room. These images would not stay up for long, as mission members took them down and hung them in the work rooms or took them back to their corporate housing to be used as wall hangings. A reprimand was issued, chastising members who took images out of the main working room, which included the statement that the budget for printing out images was nearly exhausted (and it was still the first month of the mission). And yet, printed images continued to be more popular than images displayed on the MERBoard. This can be partially explained by phenomenology of the work of terrestrial exploration. Although the work of data collection was taking place millions of miles away, the scientists were engaged in the process as though they were conducting geological work in the field. The work of map reading most often entails a top-down perspective, a lean over, and sometimes a standing in front of. The mission scientists enacted these physical gestures over their objects, the maps. So, between their personal computers for small group discussions, the large projector screen for whole team discussions, the MERBoard were rarely used to display images for small group discussions, see Figure 17.

Figure 17 Scientists collaborate around a piece of paper while three MERBoards in the background are used as time displays.

Instead, the MERBoard was primarily used to display time, the multiple temporalities of the inter-planetary work systems, which included Mars time at two different locations on Mars, Pacific Standard Time, Eastern Standard Time, and various other local terrestrial time zones associated with scientists' different home institutions, from Germany to Arizona. At the outset of the mission, there were no Mars watches, no Mars time alarm clocks and no personal support technology for time management. During the first PORT (several months prior to the rovers' landing), Professor Squyres walked by a group of scientists I was observing. While in conversation with him, someone noticed a pocket watch chain dangling from his jeans. Professor Squyres had a uniform that was like a cowboy's set of clothing: cowboy boots, worn out blue jeans, a belt, and a tucked-in, button-up, long sleeve, fitted shirt. This clothing ensemble rarely, if ever, varied. For this reason, any adornment was quite noticeable. Professor Squyres pulled out the watch, flashed it briefly, looked up and said that it had been given to him in Florida (at Kennedy Space Center) following the launch of the second Delta rocket. The scientists cooed as Squyres pocketed the watch and walked off. As the door to the science working room closed behind him, one scientist jibed, "Well, at least *he'll* know what time it is."

Within mission operations, it seemed to be taken for granted that people would be able to tell Mars time. The standard distributor of time, a clock face, was present in the form of a digital clock on the MERboards. There were at least six MERBoards on each of the two floors of rover operations and the CIP software had been installed on each computer and laptop, allowing time displays to be accessed anywhere that one was at a computer or by a MERboard. And, providing context for the Mars time display, the tactical timeline and work schedules ordered each person's experience of task completion and information handoffs. There was no visual reason why a person would be unable to answer the question, "What time is it?" But producing the temporal rhythm of a physically removed time required more than a clock face and one way that we can know this is because often the MER time display was absent or wrong and yet the temporal rhythm could be picked up or realigned in correspondence with the social processes of other mission members. It was primarily through the situational awareness provided by the community moving through the sol-to-sol production line that the sense of Mars time was made present. And here we can locate one of the operating assumptions about the relationship between time and work in organizations: the assumption that clock time is an immutable mobile, an unchanging object that operates independent of human engagement. As such, the phenomenology of keeping time, or keeping to time, is an activity that is completed by the human processing of the numerical metric of sunlight in a twenty four hour period. Seen through this assumption, replacing clock time with Mars time needed only to be supported by technologies analogous to those that support clock time – timepieces, or information technologies that present the answer to the question, "What time is it?" In Chapter 4, I take a closer look at the permutation of this assumption, of the relationship between time and work in the constitution of time in organizations in the United States; and, I explore some of the ways in which considering the phenomenology of work, and respective literatures, pulls on the role of the community in constructing temporality.

While the MERBoard served as a time display, CIP provided the version of Mars time according to which the tactical timeline was set. The CIP designers intended for CIP to facilitate quick and easy management of the thousands of images returned from the rovers. It also featured a tactical timeline that moved according to Mars time, permitting a scientist to know at any moment the current location of work in the production process. CIP's display options of the tactical timelines provided for easy configurations so that the user could select only those activities, meetings and the corresponding start and stop times, for example, that were critical to their position, to the rover to which they were primarily committed for the duration of their shift. Figure 18 shows a CIP display of the tactical timeline and a CIP clock.



SOL 120	01:48	LST-A
SOL 99	13:47	LST-B
May 04 2004	15:00	Los Angeles/America
May 04 2004	18:00	New York/America

Figure 18 CIP display of the tactical timeline for one sol. A pink vertical bar, highlighted in bold pink, moves through the staggered start and end bars indicating the current time. The CIP clock is in the upper left corner.

The user friendly feature of the time display component of CIP allowed scientists to display the specific time zones relevant to their work with a particular rover, their home institutions, and their personal life. However, at the same time that it accommodated the numerous shifting configurations and importance of different time zones, this feature disrupted the stability of the activity of keeping time, as described above. Unlike the face of a terrestrial timepiece that has become so mundane that we can tell time on a clock that has no numbers, the face of time on CIP was almost always different depending on the location and position of the workgroup and the MERBoard. Each MERBoard could have different selections of time on display as determined by the individual user who walked over to the MERBoard and called up the application, see Figure 19. The most frequently occurring display, during the nominal mission, was of two planets and three time zones: Pacific Standard Time, Mars time at Gusev Crater, and Mars time at Meridiani Planum. But a MERBoard in another room, or even 20 feet away in the same room, might display the time on one planet and three time zones: Earth-UTC, Earth-PST, Earth-EST, or two planets and two time zones: Mars time at Gusev and Earth-UTC. Figure 20 demonstrates one such occasion.

Feb 22 2004 21:03 Phoenix/America
Feb 22 2004 20:03 Los_Angeles/A...
SOL 29 17:55 LST-B
Feb 22 2004 23:03 Indianapolis/A...

Figure 19 CIP on a MERBoard. The CIP clock is being used to display time for four different locations: from top to bottom, Arizona (21:03), Los Angeles (20:03), MER B landing site (17:55), and Indianapolis (23:03).

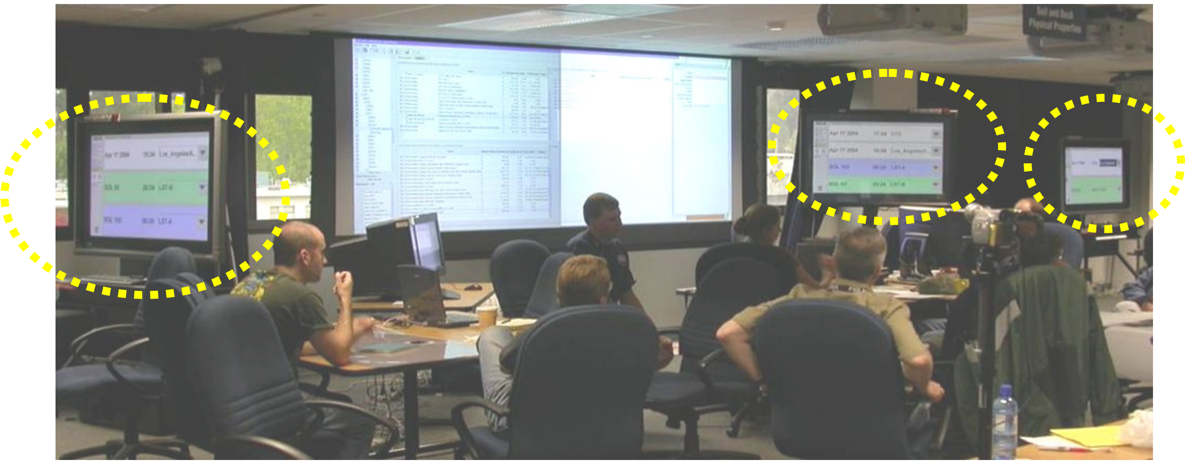


Figure 20 Three MER boards are circled in yellow, each display a different set of Mars and Earth times, and a different display order of time. Mars time for Gusev is colored green, and the Mars time for the landing site of Meridiani Planum is in purple.

To the disappointment of its designer, CIP was not used primarily as a data management tool. In an interview during a PORT, the designer proffered a few reasons for this turn of events speculating that it occurred because of the scientists' lack of familiarity with the software, not enough time spent in training (or allotted for training), and the need for one feature for which the scientists had no alternative – the time function. There were several user design issues that can be summed up in the criticism that users could not find where the data was, or keep track of what they had looked at, or where they had put it.

The MERBoard and CIP were gradually recast by scientists and engineers from tools for data management to tools for managing time, an activity referred to in organization studies as technological drift (Ciborra, 2000). The technological drifting of these two tools was fairly rapid once the nominal mission began and the scientists were living full-time on Mars time. Although there were indications of drift during the mission operations simulations stage, PORT, these indications were considered as possibly a result of the incomplete set-up of the mission operations space and the absences of the rovers on Mars, considerations which I take up from another perspective in Chapter 5, Membering the Rover. The MERBoard and CIP were designed to support collaborative processes in data analysis among the scientists; instead, the scientists used the two technologies to make up for unsupported considerations of time management. Furthermore, scientists' developed several workarounds and informal technologies to deal with the limitations of these technologies in adequately supporting time management.[26]

Standing out on the list of informal technologies employed by mission members to make-up for the inadequacies of the formal technology, paper proved to be a quick fix-it. Slipping schedules, meeting duration fluctuations meant a different pacing on subsequent processes downstream, further along the production line. As the tactical timeline could not be formally adjusted, and the CIP software could not be manipulated by anyone other than its designer, scientists resorted to paper – paper easels, post-it notes, and notebook paper. In some instances, updates to the schedule were posted on a large pad of paper attached to an easel propped in front of a MERBoard. This paper workaround, however, would not be replicated in front of all MERboards; typically, it was just in front of the one MERBoard located at the front of

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[26] Distributed among each of the five groups of scientists per rover and engineer groups, all in shared work spaces, there were about twenty MERboards in total. The CIP program, accessible on the MER board, was also accessible on personal laptops that met the criteria for secured access. I am clarifying that only secured laptops were equipped to access CIP because all mission participants did not have secured access due to conditions such as foreign national status or human error. And while the image of three floors with twenty MERboards and three times as many laptops may give a sense of a space fairly well-stocked with displays and programs, this image does not account for need to access information when one was not at or around a computer, when mobile, when at home, when in transit, when circling for parking, when eating off-site, when in a press conference, etc.

the science room, near the spot where speakers would stand to address the group, presumably positioning this MERBoard as higher on the hierarchy of information displays. Also, time changes could be found posted on $8^{1/2}$ x 11 sheet of paper that would be stuck to a wall directly in front of the elevators, a wall that members would encounter immediately upon walking out of the elevator. These pieces of paper sometime fell on the ground, where they remained unnoticed.

In addition, the list of informal workarounds to support sharing time management up-dates that could not be made to CIP's tactical timeline included e-mails, word of mouth, and cell phones. Each had its own familiar limitations. Individuals did not always check their email when off site and thus missed mission updates. Word of mouth required staying in close contact with people, but if one did not reside in the mission relocation housing this was not always possible. What these workarounds had in common was the reliance on human interaction and a process of communication taken up with personal technologies (cell phones and laptops). Also, since there was no assigned role for a person to keep everyone current with updates, these workarounds were undertaken at each person's own behest. It was also the case though that sometimes the announcement of something changing in the work scheduled would be followed by the direction "to let people know." It became habit as well to call other mission members just to see if anything had changed while one was off-shift.

Two informal technologies that emerged in the attempt to support managing Mars time outside of the mission space were the Callas Rainbow and the Mars time watch.[27] Both were developed by mission members' who took it upon themselves to solve the problem of knowing what time it was on Mars while located off lab, each day. One was free and the other cost between $120 and $250 (plus the priceless conversations with the watchmaker who operated with the "charm" of an old world watchmaker). Ultimately, neither sustained consistent use.

The Callas Rainbow, named by the designer Dr. John Callas, the mission science operations manager, was a simple, single-page, double-sided, spreadsheet on which the tactical timeline was laid out in a rainbow of colors, see Figure 21. Vertically, there were three sections: from the top, the first section depicted the tactical timeline, the second section showed the work shifts for certain mission members, and the third section provided time conversions of PST to Mars time in increments of 39.6 minutes.

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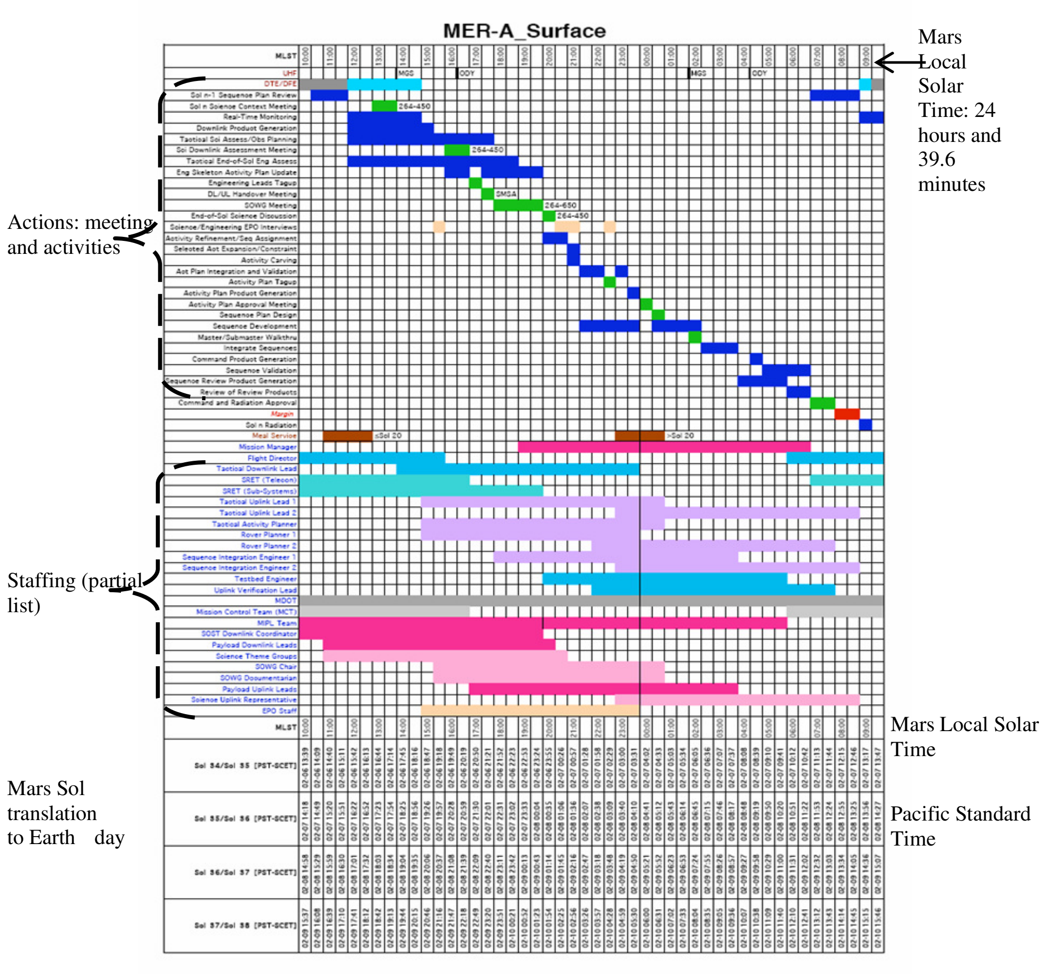
[27] This order of presenting the informal technologies does not indicate that the subsequent technology emerged in response to aforementioned problems. Rather, as one technology brings up for us a problem with time management, another technology is presented showing the attempt to deal with the limitation.



Mars Local Solar Time: 24 hours and 39.6 minutes

Actions: meetings and activities

Staffing (partial list)

Mars Local Solar Time

Mars Sol translation to Earth day

Pacific Standard Time

Figure 21 Callas Rainbow: the tactical timeline should be apparent in the first section

The Callas Rainbow was especially popular but short-lived. When both rovers began operating on Mars, its production ceased. There may have been several reasons for this. Dr. Callas' position on the mission required him to be present for both mission operations as well as at JPL and NASA management meetings. It was not possible for him to produce these time management tools due to time constraints as well as official obligations. Also, the tool was not officially approved for use – as all tools on the mission had to be recognized formally by a review board. However, the Callas

Rainbow did provide a template that was used subsequently and informally by individuals who reproduced them and tailored them to their role on the mission.

The most public (and yet) informal technology was the Mars watch (see Figure 22), which received a good deal of media attention with hardly any mention that it had not been formally provided for in the organizational infrastructure for MER mission ops. Two mission members took their interest in a watch that ran according to Mars time, forty minutes slower than a regular watch, to a local watchmaker, Garo Anserlian at Executive Jewelers, Inc. Taking a regular watch, and adjusting the coil, Mr. Anserlian produced the so-called Mars watches, one by one, in his store in Montrose, California, but there were a few stipulations that had to be agreed upon before Mr. Anserlian would make the watches: he needed a minimum order, all watches had to be purchased from him (he would not adjust a watch that you brought to him), orders had to be placed six to eight weeks in advance, and there was no money back guarantee. The cost for each watch was $125.00 to $275.00 and for an additional $50.00,

Figure 22 Mars watches were regular watches that were adjusted to run slower. They were requested and purchased by individuals looking to make up for the lack of mobile Mars timepieces.

he would put a sticker of Mars on the face of the watch, beneath the glass, and provide a certificate of authenticity.[28]

Initially, mission members were awed by the possibility of being able to know what time it was on Mars regardless of where they were – at home, at the movies, when waking up, or when traveling on their days off. Once the watches were in use, however, problems appeared that halted several purchase orders. Some members discovered that after removing their Mars time watch on their days off, it had stopped running. Taking off the watch had given the self-winding mechanism a chance to stop running. Although it could be re-started and adjusted, the minutes began to slip. And, even while regularly wearing the watch the accuracy of keeping time would slip, an event that might only get noticed after arriving to a meeting late. Mr. Anserlian would fix these watches, but that required driving to his shop and leaving one's watch there for days or weeks.

Not everyone purchased a Mars watch because they were expensive, kept time poorly, and would be useless after the mission (one scientist referred to it as an expensive piece of junk). There were several mission members who bought them for the attention they anticipated receiving, as one scientist put it, "When someone asks me if I have the time, I can say 'Sorry I only have Mars time.'" But for those who did rely on the Mars watch, one was not enough. Figure 23 is the display of watches for

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[28] At the time of writing, 2008, these watches are still for sale. The prices range from $250 to $695. For $95 you can buy a regular Earth time watch that has a Mars face sticker on it, which were not available at the time of the mission. But maybe these are the Mars watches that did not stay on Mars time and were re-categorized as regular watches. Another timepiece that was created was a digital alarm clock reconfigured to run according to Mars Local Solar Time, and the creator was a Mars enthusiast from a NASA center. He created about ten of these clocks and gave them as gifts to the lead scientists. He also posted the process of production on the internet for free.

one mission member whose role on the mission required her to keep track of all mission critical time.

Figure 22 From left to right, the first watch is for Mars time at Gusev; the second watch is a dual faced Earth watch; the third watch is a fatigue measure watch – this was the most visible contribution made by the Human Factors scientists to the MER mission. It was used to record the duration of time that scientists slept. When they were going to sleep they pressed a button. When they woke, they pressed it again. I never saw anyone press their watch before they fell asleep during a meeting. The fourth watch is for the second landing site, Mars time at Meridiani Planum.

No matter what timepiece mission members relied on, the work of keeping up with Mars time was confusing, exhausting, and disconcerting. One scientist admitted to a near disaster while driving tired after work when he turned the wrong way into a freeway off ramp (Bass, Wales, & Shalin, 2005). I do not mean to challenge the performance of members making Martian science under these conditions. Instead, I wish merely to highlight the various ways in which time management problems appeared to stress the organizational infrastructure for MER. I am referring to the activities of the mission members as the organizational infrastructure for MER, as without their socio-technical processes the mission could not operate. The work of space exploration is about discovery, and as there was always a rover at work, the possibility of discovery was always present. Mission members pursuing these discoveries wanted to be present all the time, around the sol. And, as explained, keeping this sort of time could only make some sense if one opted to never leave the mission space. In the debate between being present at JPL to participate in scientific discovery and leaving JPL in order to maintain a regular temporal rhythm, the former almost always won. And, supporting this condition were the problems that arose from taking time away from the mission.

Work schedules had been arranged so that mission members would be on site four days and off site for three. But for some scientists who traveled from out of state, going home became more of a chore than a break, due to their inability to be in sync with their family's temporal rhythms and adherence to terrestrial time. Some of these scientists ceased traveling home because, as one scientist stated, "what good is it being with my family when I am awake while they sleep and I sleep while they are awake." In addition, going home also involved falling out of whatever pattern had thus far been established in keeping Mars time. Personally, I found that one day off every six to seven days was the best way to stay in rhythm with mission operations. This one day off would be spent sleeping, running errands, and maybe catching a movie. Otherwise, it was most comfortable to work around the clock, to move between rover operations; by sticking with one of the instrument teams, the RAT workgroup, I would take breaks as they did between their tasks.

Mission members with offices took to napping in their offices and/or sleeping on the mission provided army cots. Rather than take on the time consuming task of leaving the mission space or JPL for food, the vending machines were regularly emptied and the free ice cream freezer was depleted at such a rate that a sign was posted admonishing the scientists to reduce their consumption. Dr. Charlotte Linde, another Human Centered Computing research scientist, and I noted the absence of complaints about fatigue made in the shared spaces of science operations. It was common for scientists to explain an act of confusion, like forgetting how to use the projector or being unable to locate their data during a presentation, with a statement to the effect of “sorry, I’ve been up way too long.” This would be received with smiles and nods and then the work would continue. But it was mainly in the private spaces, the workrooms for the instrument teams and in conversations that took place in the cafeteria or in restaurants, that mission members talked about the time confusion as openly as the decision on what to order to eat.

It was curious that what I considered to be non-harmful considerations critical to providing work support were taboo subjects unless raised in closed conversations. One event that highlights the effects of fatigue but for which there appeared to be no complaint, or remedy for that matter, took place while I was hanging out with several mission members in a private workroom. A scientist came in with an image and asked for help in seeing, that is, in locating a particular feature of a Martian rock. The scientist told the group to come and find him when and if they were successful; he would be in the main room. As the members huddled around the image, one member pulled the image up on the computer and began manipulating it to try and discern the feature being sought. That everyone’s eyes were tired was as much a part of the conversation as the various technical strategies they discussed. After being unsuccessful in finding the feature, I stepped away from the screen to consider the event with respect to the bigger picture of how one of the primary activities for doing good work, seeing, was not the main feature around which work was scheduled. Had it been so, we would have seen work scheduled around human biotemporal rhythms, circadian, nutrition, and ergonomics of sensory work support. As my input was not critical in solving the problem put to the workgroup, I had the time to consider what else was going on during this event. Eventually, one member located the feature, circled it, and took off to the find the scientist.

These events speak to commonly overlooked considerations of work arrangements, considerations of biotemporal rhythms, sociotemporal rhythms, and work culture. Before explicating these categories to demonstrate the embedded incongruity of the temporal rhythms within the organizational infrastructure of MER mission operations, I present a few considerations of the expansion and compression of the socio-technical processes in the making of Martian science. These fluctuations remain obscured by the bigger picture of the success of the mission and the seeming operability of Mars time.

During the simulation exercises in the months prior to the landing of the first rover, keeping science operations synchronized with Mars time and in step with the durations allotted for tasks on the tactical timeline was difficult. The duration of time that it took to complete activities or make determinations in meetings as scheduled fluctuated. To account for this several explanations were proposed. It was suggested that the conditions of simulation did not mirror the conditions that would be present during the nominal mission. It was also suggested that some of the tools and workspaces that would be used for science operations were not yet ready, and would not be ready for operation until the rovers actually landed on Mars.

When the first rover landed on Mars, the Mars clock started running during its egress, the process of unfolding and moving off the lander took several days. And the first sol of science operations went well. Simulation trainings had taken everyone through the sequence of meetings and development processes for the science plans. Scientists kept in step with Mars time in that they met their deadlines, but the expansion and compression of the durations of activity times continued even as they gained experience using software and cultivated habits to deal with the incongruity of working on Earth according to Mars time.

The duration time of activities on the tactical timeline fluctuated as a result of the unpredictable nature of data return interpretation. No one could ever be certain what the data return would be like – some sols were more about driving the rovers to cover distance (an activity that engineers seemed to prefer, "put the pedal to the metal") than plotting out a few sols to check out a rock from several angles. The interpretation of data required a whole set of visual practices that entailed the translation of images by some mission members, before other mission members could work on analyzing the data for Martian science.[29] Based on their translations, the various science working groups would present options for further investigations and the group, or the PI, would decide which of the options would be prepared for the

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[29] Claims by other social scientists were made to this territory of the scientific knowledge production processes. Unlike the Athena scientists, working according a set of "Rules of the Road" that arranged up front the order of authorship, the social scientists were not organized as such.

rover's next sol of work. Interpretation and decision-making for some sols were quick; and other times certain conversations took the entire allotted duration and then some.[30]

Mission members would informally negotiate amongst themselves and with the engineers for more or less time to complete activities. When activity completion was running behind its scheduled completion time on the tactical timeline, and there was no time to negotiate an extension, the scientists would put analysis to the side for later, after the production cycle for the sol had ended (or "after-sol"). The scientists would remain to discuss data analysis in the hours between the end and start of their 10-12 hour shifts. For the next sol, the data analysis that had been put aside would then be ready for presentation to the other scientists for possible integration into the plans for the rover's data collection. This is an example of maintenance work conducted by mission members in order to give cohesion to the considerations of work not accounted for in the formal system but required for effective operation of the formal system (Star, 1991). When there wasn't enough time to complete data analysis for consideration of the next sol of data collection, the scientists' workarounds or the informal work performed to address the breakdowns in work systems, included remaining at JPL past their 12 hour shift, returning to JPL a few hours prior to the next shift, skipping the trip home to sleep, and/or continuing data analysis past the deadline and arranging to have a command "slipped in" (after the formal approval

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[30] The communication processes during these meetings was a significant theme in my research, a topic too large to broach here. Several considerations contributed to the duration of decision-making, from the particular domain of a workgroup (atmosphere science was the quickest and the briefest in presentation) to the translations required between scientists and engineers (there were mission members whose tasks included acting as these translators).

meetings). These workarounds allowed the scientists to prepare, if indicated, for the next sol of data collection.

These fluctuations and amendments to meetings were largely handled through the informal technologies that I mentioned earlier – word of mouth, emails, phone calls, and paper signage. These sorts of updates did not appear to be captured through a formal accounting process of the events that took place on the MER mission. Even notes delivered via email that notified members of a decision to delay a meeting, or a task for a particular meeting, were not necessarily going to be recalled as a part of the information distribution process that needed to be improved. And as it was, email messages frequently failed to reach all mission members. The absence of a formal report that captured these instances of work slippage appeared to me to be one way to imagine how it is that breakdowns are built into organizational infrastructure – that is produced by drawing from successful models of work operations. If planning for a coordination of work led people to consult the mission ops of the successful Mars mission, for example, then we might imagine that the reproduction would include some of the same conditions that had fostered breakdowns and were managed by workarounds.

Maintaining time through work

During the nominal mission, coordinating work according to Mars time was a mission critical practice and by public accounts it was a successful practice. In the every-sol activities of mission ops, however, ethnographic data indicate that operating Mars time was not the same as operating clock time and the provisioned formal time support technologies were inadequate. In addition to the technological workarounds created to make-up for the lack of mobile Mars time information displays, mission members used various social practices to make-up for the inadequacies of information technologies, formal and informal, for managing Mars time. However, the inability for either formal or informal technologies to support time management indicated that there had to be an unsupported consideration in the operation of Mars time. I believe this to be the human element of time enactment, the consideration that the motion of the human body requires more than an information display to establish a rhythm of work and time.

I know these sentences may appear laden with time-speak but this comes from the effort to build a case for the complexity of time that seeks to set it out rather than only gesture to it. The problems of relying on time displays for temporal information were found in the technological drifting of the MERBoard and CIP, and they were also found in the various ways that mission members boot-strapped part of their way through work processes. Through an analysis that centralizes the processes of time enactment, however, we may be able to articulate some of the assumptions that have led or contributed to planning the relationship between time and work for an inter-planetary work system as though the extra-terrestrial time zone could be treated as just another terrestrial time zone. The three categories of temporal rhythms that I have been using to discuss time are drawn from Zerubavel's (1979) identification of temporal patterns that distinguish three kinds of temporal motion: nature, biology, and human interactions. According to Zerubavel, (1) reoccurring movements in nature define the first kind of temporal motions, physiotemporal patterns occur in relation to the movement of planetary bodies such as the axial rotation of the Earth; (2) biotemporal patterns occur in relation to the functioning of biological life, such as the stages of larva or pregnancy; and (3) sociotemporal patterns occur in relation to social situations, activities, and events. These patterns were identified primarily to provide a way of distinguishing the location of social processes of ordering that are not necessarily reliant on physiotemporal or biotemporal patterns. Typically, time studies and organization studies that seek to distinguish the presence of multiple temporalities do so mainly by focusing on sociotemporal patterns (Adam, 1990; Bucciarelli, 1988; Dubinskas, 1988; Gurvitch, 1964; Lefebvre, 2004; Orlikowski & Yates, 2002; Roy, 1959; Traweek, 1988), though the language with which these patterns are investigated varies from one scholar to the next. Without doubt, taking up the confluence of multiple sociotemporalities present on MER would yield some interesting considerations but the presence of another planet drew my focus in another direction.

What is distinctive about investigating time on the Mars mission is that the inter-planetary work system requires that we pay attention to two asynchronous physiotemporal patterns – the axial rotations of Mars and Earth – and two asynchronous biotemporal patterns – the life functions of the rovers and the life functions of the humans. These temporal patterns involve motion that operates with or without clock time, and are motions around which time itself has been formed. The temporal rhythms of these patterns are defined by reoccurring engagement with motion, which may be set in nature or in a human-built environment, with the kinetics of particular kinds of work, and the enactments of cultural practices. Here, I am thinking only of the relationship between humans and motion in the conduct of work.

I take up the constitution of the biotemporal patterns or the necessity of linking the rovers' operable hours with solar time and the anthropomorphization of the rovers, in Chapters 4 and 5 respectively.

The phenomenological considerations of temporal rhythms that construct notions of time and that help to elucidate the underlying issues of time management breakdowns can be harder to perceive than rocket science, especially among communities who practice knowing through technology, like rocket scientists and space explorers. This limitation pushes me to find another way of presenting the problem of expecting humans to enact the motions of multiple temporal rhythms of inter-planetary work systems solely with the assistance of time displays. As I said, managing multiple temporalities on the Mars mission required members to combine one to three standards of clock time (time based on one physiotemporal pattern) and one or two standards of Mars time (time based on two physiotemporal patterns). Rather than fashioning socio-technical tools to support these heterogeneous temporalities, support was provided for by organizational infrastructure that had been constructed to support only homogeneity, through particular social and cultural practices (Star, 1991). By assuming that there was only one significant time, Mars time, and organizing work around that single notion of time, work support was structured in the same way it might be for managing a single standard of clock time. And, when the infrastructure failed to support the work system, mission members driven to succeed at any cost and with little formal complaint, bootstrapped their coordination of multiplicity. A white board, hanging in a less conspicuous space than in front of the mission managers' offices, kept a list of "Overheard Remarks:" "If I am working Mars hours, and Mars hours are 2.5%more than Earth hours, shouldn't I get an extra 2.5% pay raise?" and, "Excel is not a substitute for scheduling, communication, or management." These remarks illustrate what I have tried to explain throughout this chapter: the gap between Mars and Earth time was not accounted for in the arrangement of work and information technologies were not sufficient for time management practices. By using the term bootstrapping, I am foregrounding the physical conditions of time management as well as the cognitive processes. To give this process a more contextually appropriate term, I consider the efforts of mission members to manage the breakdowns of support technologies as infrastructure maintenance work (IMW) – work that is conducted in order to support the very infrastructure provided by the organization and needed to carry out a production process. Looking at these activities as IMW offers a way of understanding the organizational implications of relying on human ingenuity and heroism to address and compensate for time management problems. An organization which depends on IMW may not be an organization that can reproduce the successes that it claims.

With respect to the organization of NASA, and of space exploration, the ability to replicate is critical to constituting science and technological operability. Replication is an aspect used to evaluate the success of a scientific experiment – can the conditions proving a hypothesis be repeated with the same outcome – and engineering systems, where casual models are used to test repeatability. Considering the conditions that allow for replication of a set of work practices, conditions such as a record of the work that was conducted, how it was conducted, what worked and what did not work, illuminates the problems of relying on IMW.

Let us return to Professor Squyres' (2005) construction of a metric by which to determine the success of Mars time management, "*would sleep deprivation affect our judgment, leading us to fatal mistake at some critical juncture*?" Clearly, producing Martian science according to a schedule set and run to Mars time did not contribute to a fatal error. Although this metric serves a purpose, it obscures the problems of Mars time; it directs attention to a single criterion by which to evaluate an entire inter-planetary framework of time and work. Even without a formal metric to highlight them, we know that there were problems with the management of Mars time and there were various social and technical workarounds employed by mission members. However, without a formal metric or some other form of explicit acknowledgement the problems operating Mars time remain out of sight, increasing the likelihood that organizations will reproduce, rather than address, the conditions leading to time problems.

Why did individuals assume the responsibility for Mars time management breakdowns? It is to this question that I turn in Chapter 3. The culture of NASA and popular culture about NASA are closely linked and the ways in which this link mattered within the workspace of the MER mission offers one response to this question. In popular culture and consciousness, NASA has stood for an iconic organization carrying humans into outer space one step at a time. As an organization, it offers a material site where people can go to realize their dreams of space exploration. Thus, prior to arriving at NASA, people's conceptions of what it means to work at NASA have already been partially shaped by representations of the work of space exploration at NASA and dramatic stories of unparalleled activities of material construction and recovery.

Chapter 3

Dreaming of Space, Imagining Membership

> The carpenter's apprentice must learn how to handle his saws and hammers. The college engineering student learns how to operate his slide rule long before he graduates. But how on earth do you train people for unearthly jobs; jobs that never before existed, in an environment that man has never known? [Grissom, 1968]

Virgil "Gus" Grissom was one of the seven Mercury astronauts, the first men selected by NASA to experience space flight, and he was the first American to fly in space twice. His personal account of these events is found in Gemini (1968), a book that reads more like a socio-cultural manual for understanding human space exploration than a personal memoir. In one chapter titled *How to Make a Gemini Astronaut*, Grissom describes the training processes invented to prepare the astronauts to go where no one had ever gone before. Not only had no person ever orbited the Earth, but no person had been trained to perform such an activity. His account of participating in the various process of simulating the work of space travel joins those of many others who have similarly participated in or observed the processes by which astronauts learn to be astronauts (Burrough, 1998; Carpenter & Stoever, 2004; O'Leary, 1970; Santy, 1994; Weitekamp, 2004; Wolfe, 1979). These discussions are predicated by our understanding that training is the informative activity that provides the "right way of knowing and doing," work. But, this is not to say that people begin without any sense of how to conduct the work; rather, when people enter an organization and receive job training they bring with them prior conceptualizations and expectations of what it will be like to engage in the socio-technical processes of work. This is the relationship that I am interested in – the relationship between the conceptualizations of work that precede joining an organization and the actual experience of work after joining an organization. Once a person joins the organization to which they may have long sought membership, how do their imagined versions of work and identity come to bear on their actual work practices? And, how do members respond in situ to discrepancies between imagined and actual experiences of work?

These questions emerged for me as I observed scientists and engineers on NASA's Mars Exploration Rovers mission (MER). As I mention in Chapter 1, these scientists and engineers underwent a four month preparation and simulation of the *unprecedented* work of remotely operating two space vehicles on Mars for a minimum of ninety days scheduled according to Mars solar time. The production process for this work, which no human had ever done before, was organized around the work schedule of the rovers on Mars (which was unprecedented work for the rovers as well). Because the rovers were solar powered, their work schedules were set in accordance with the rise and setting of the sun on Mars. Concurrently, work schedules on Earth were set according to the time of day on Mars. As I've noted, the problematics of this inter-planetary time management equation were borne from the fact that the Mars day is 40 minutes longer than an Earth day; as such, Earth time had to be moved forward by 40 minutes each day for people to synch their work on Earth with the rovers' work on Mars. In Chapter 2, I outlined some of the ways in which the time support technologies that were provided were inadequate and I described some of the technologies that mission members created in order to compensate for this. In this chapter, I will be shifting my perspective to examine another dimension in the socio-technical processes that constituted Mars time focusing specifically on the mission members. In what follows, I investigate how, and I suggest why, mission members acquiesced to time management breakdowns which were necessarily a result of the organization's infrastructure. In an organization heralded for its technological prowess, why did members refrain from insisting upon operational socio-technical work support?

While there are many ways we might answer this question, in this chapter I propose that scientists opted to deal with breakdowns without notifying the organization in an effort to maintain a particular identity, one that had long been dreamed of and imagined through media representations of the work of space exploration and of NASA. In situ, when faced with a discrepancy between a preconceived notion and the actual experience of work practices, scientists' responses could be seen as attempts to prevent displaying character stigmas that threatened to reduce their member status and life chances. Stigma management, as explored by Erving Goffman (1963), involves the work of refraining from a demonstration of attributes that deviate from the norm, that is, from the culturally established category of normal. And, I contend that this category of normal, in the case of the scientists on NASA's Mars mission, was informed by preconceptions of idealized membership and work practices constituted through media representations of organization membership.

I begin by laying out the dynamic relationship between organizations, members, and media and discussing this dynamic relationship in general terms across professional sites before looking specifically at its possible effects in the context of the MER mission. I adopt this approach because the relationship is not unique to MER or space exploration even while the work of being a member of an organization that conducts space exploration (still) occupies a unique place in popular culture and consciousness. In the first section of this chapter, therefore, I take up a variety of organizational accounts presented by media in order to illustrate how these accounts shape preconceptions of membership identity and work. In the second section, using empirical data from the MER mission, I look at the convergence of popular preconceptions of work practices with actual experiences through mission members' responses to breakdowns of support technologies for time management. Pointing to the lack of formal reconciliations of infrastructural breakdowns with workarounds, I argue that the responses of members are acts of stigma management. Finally, I discuss some of the possible implications of stigma management for the development of organizational infrastructure.

Organizations, membership, and media representations

Joining an organization, gaining employment, is an act of "membering," or membership. Underscoring this standpoint, etymologically, is the Greek definition of organos which translates to "*body member*." Body refers to an assembly of humans ordered by self-imposed rules of social order (Keeley, 1988). From this perspective, I seek to emphasize the processes of social ordering, power relationships and decision-making, and work roles that constitute an organization.

Joining a professional organization is not an accidental act; it is a conscious act, possibly shaped, in addition to interest, by necessity, scarcity, access, or proximity. You may choose to join an organization because of where you live, what jobs are available in your field, or how much you need to earn to meet financial demands, as well as for socio-cultural considerations of family relationships and psychological rewards. In the most basic terms, it can be said that organizations serve two primary functions – economic and social (professional) – for people who join them. In order to receive the economic or social gains of a particular organization, one must first join, which is a granting of passage from being an outsider to being an insider of the organization. In my examination of organizations and the people who inhabit them, I identify people who work for an organization as members of the organization, rather than employees or workers because I want to foreground the social over the economic.

Media representations of organizations and membership

The argument that media representations of organizations shape people's perceptions of work has been advanced by individuals across disciplinary domains that include communication, organization studies, sociology, and cultural studies. For example, Hubert Blumer (1933) posited that people become acquainted with aspects of life and develop schemas of conduct with regard to perceptions of work through media accounts.[31] Blumer's qualitative research was conducted among high school students, from whom he elicited information regarding their post-high school job directions and the reasons motivating their choices. More recently, work in sociology has focused on the concept of anticipatory socialization, the process of gaining knowledge about work that begins in early childhood and continues until entering the workforce full-time (Levine & Hoffner, 2006). And, in organizations studies, scholars who focus on organizational culture (Van Mannen & Schein, 1979) have considered the development of a person's work identity as one aspect of organizational socialization. There are a fair number of scholars who take up these perspectives; however, a longer consideration at this point would re-direct this investigation. Instead, I carry these points forward with Blumer's established notion that people form preconceptions about particular kinds of work from sources other than the organizations wherein the work is conducted.

Providing depictions of work settings, activities, rewards, and breakdowns, media accounts are often the primary resources that give people a sense of the events taking place inside an organization. Potential organization members, outsiders to the organization or "the public" are exposed through media of film, television, and literature, to accounts of organizations that are illustrative of the cultural values associated with organization membership (Hassard & Holliday, 1998; Vande Berg &

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[31] Consider for example, in this regard, the impact of various iterations of the crime-solving television series *CSI* in shaping popular representation of forensic work in determining how and by whom crimes are committed (Cole & Dioso, 2005; Lovgren, 2004; Rincon, 2005). And there are other examples as well: from an early historical moment in television history, we have, for example, Dr. Kildare, Ben Casey, Perry Mason, Combat, Star Trek, and later, L.A. Law and E.R.

Trujillo, 1989). In these accounts of organizations, audiences receive representations of an organization's who, what, where, when, and how – who works in the organization, what kind of work is conducted there, and the where, when and how of the production process. Cultural values depicted in media accounts of organizational membership can serve to inspire the imaginations of non-members by encouraging expectations of social relationships, material rewards, public approval, or group status that members enjoy in varying degrees.[32] In these accounts, typically, the protagonists negotiate a myriad of trials and tribulations encountered in organization life – hierarchical management relationships, personal relationships, workarounds, moral tensions, financial or social remuneration, or a view from the other side of the service counter – which are then most often resolved. While happy endings allow us to understand (generally) how problems are resolved, they do not necessarily include all the details of how things work out – in other words, they rarely detail the myriad of tasks, relationships, and temporal aspects entailed in getting everything "to work out right."

To repeat this last point, most sources of professional inspiration tend not to depict the daily work processes in "real-time." This point is taken up by Hassard & Holiday (1998) in a discussion of realism and representation in popular culture. Representing the minutia of a particular worksite is typically about foregrounding the drudgery of particular kinds of work that are considered boring, but even in such cases it is but a small moment used didactically. For example, the boredom of particular

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[32] A familiar trope used in television shows about office life depicts the familial aspects of organization life, where bosses act as parents and co-workers as siblings, spouses, and lovers (Taylor, 1989). While this depiction may be at odds with the human resource policies of many organizations, it is often the case that these relationships are fostered in the workplace and possibly informed by these media representations.

kinds of work will be highlighted by representations of the work in real-time, such as watching temporary office workers sitting at their desks with nothing to do in Clockwatchers (Flock, 1997) or canning factory workers immobilized by positions on the factory floor as in the opening sequence in Clash by Night (Krasna, Parsons, & Wald, 1952).[33] While these media accounts may only be intended for entertainment and make no claim to being anything more than fictious, I want to point out the public's limited abilities to gauge the extent to which these representations are exaggerated – and this, by virtue of their status as non-members and the limits of their organizational knowledge. It is not my intention to question the accuracy of these representations of organizations; rather, I seek only to emphasize the lack of depictions of *actual* work practices taking place in "real-time" in organizational accounts that instigate preconceptions of membership. Real-time has come to denote time being experienced in the moment, or the Now. It is a useful phrase for discussing how long it actually takes to complete a task vs. how long one can make it appear for a task to be completed. For example, in real-time a cake takes 30 minutes to bake but on a cooking show baking time is condensed so that it appears to have been baked in a short 60 seconds. At the same time, a notion of (a) "real-time" discursively suggests that there is a standard or transparent version for reality, when in fact "real-time" is but one version of reality specifically contextualized: in other words, 30 minutes @ 350 degrees is the suggested time that it takes to bake a cake *in a particular set of circumstances*.

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[33] Hassard's (1998) work on cinéma vérté provides a point of contrast in that he presents the work of ethnographic documentaries which attempt to represent reality, 'the real world.' This point of contrast though sits to the side of this discussion because cinéma vérté is not necessarily as widely received as popular culture.

Nevertheless, it is useful for the purposes of this investigation to note simply that I am pointing to the absence of depictions of work as it happens in *real-time*.

Representations of rewards

Media representations of organizations and membership frequently highlight those organizations that bestow significant rewards either in terms of social status or wealth (or both). But even when material rewards may appear only to serve as contextualizing information, they provide an indelible association of particular organizational identities.[34] One of the most effective disseminations of material rewards gained by members of financial organizations comes from the film Wall Street, a film that brought the phrase "greed is good" into common parlance (Pressman, 1987). The film is a Faustian tale of a young stockbroker's pursuit of power, wealth, and respect. A twenty-something male, the film's protagonist, pursues a Wall Street titan in his mid-forties, Gekko, who possesses the material and social attributes the young stockbroker dreams of attaining. He is willing to go to any lengths, lying and stealing, to work for Gekko in order to learn the one key knowledge about time and work that Gekko has – how to accomplish the most amount of profitable work within the shortest amount of time. This time/work equation, in effect, frees up more time in which to conduct profitable work.

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[34] Lawyers, for example, as seen on television shows such as Ally McBeal (Kelley, 1997) and L.A. Law (Bochco, 1986) working for private companies are depicted as well, demonstrated by the ownership of prime real estate, the designer clothes, and the leisure time spent at upscale bars with equally affluent professionals.

In an organization devoted to producing an ebb and flow of currency, affected by the fluctuation of the national and global stock markets, time is central. With no indication of having read Bruno Latour, Gekko's key is to follow the object: money never sleeps so neither should its pursuers.[35] A temporal comparative is provided by the presence of the young stockbroker's father, an airplane mechanic to whom the audience is first introduced knocking back a few beers with other mechanics after work. Gekko, on the other hand, first appears only in name. Following a long chase scene the audience learns that Gekko is always so busy working that it is difficult to get into his office to see him. When he finally appears on screen, still, the audience is kept waiting while he finishes making a business deal on the phone; and, in the course of the film, the only time Gekko is seen meeting with people over drinks is when business is being conducted. The contrast of time relations in the two kinds of work underscores a critical point: for one kind of work, as with the airplane mechanics, there is a start and end to the work day, while for another kind of work, work performance has no end. The stockbroker never sleeps and must always be at the ready to turn information into money. This depiction of time and work makes obvious another interesting dimension of the time/work relationship: in a setting where information is the product there is no end to the production process; in a setting designed to produce a material object the end point is more easily choreographed.

I chose to use the film Wall Street for its representations of work because in the two decades following the film's release there have been several noteworthy accounts

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[35] Taxonomically, some geckos are diurnal, engaging in activity both during the day and the night, and they eat other geckos.

of the effects that these representations have had upon audiences. The actor who played Gekko, Michael Douglas, was surprised to find that many people found his successful, greedy, and immoral character to be an inspirational role model (Kiselyak, 2000). Contrary to his expectations, fans have thanked him for inspiring them to become stockbrokers on Wall Street.[36] "I wouldn't mind if I never had one more drunken Wall Street broker come up and say, 'You're the man!' (guardian.uk, 2007)." And although the film ends with the aspiring young stockbroker turning Gekko over to Federal investigators, and himself being driven to court in preparation for a short jail term (shortcutting time to make a lot of money lands them both in a place where the only currency is time), for some, the primary message was still the conferment of material rewards – high-rise apartments, private jets, gold cufflinks, and Darryl Hannah.[37] Douglas Jordan "the Wolf of Wall Street" Belfort, a 26-year old multimillionaire convicted of money laundering and securities fraud, appears proud that his two role models were Gekko of Wall Street and another corporate raider portrayed in the film Pretty Woman. For Belfort, these men's work accomplishments allowed them 'the best of everything - the presidential hotel suite, the Ferrari, the house on the beach, the gorgeous blonde, the expensive wine, the art auctions, the yacht - the ultimate Wall Street rich guy (telegraph.co.uk, 2008).'

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[36] Robert Downey Sr. talks about the same irony – being thanked by people who were inspired to work in advertising after they watched his movie Putney Swope (1969), in which he satirizes the ruthless and immoral marketing practices of the advertising industry.

[37] A few other media representations of specific industry and organization practices: The China Syndrome (1979), depicts the internal operations of a nuclear plants; The Sweet Smell of Success (1957), depicts the social relations of gaining access to information for newspaper columnists; The Paper (1994), depicts the operations of printing newspapers; and Nine-to-five (1980) depicts office power struggles.

The point that people may be drawn to particular kinds of work, or organizations, for financial rewards hardly needs to be emphasized. Nevertheless, the example of Wall Street and its social impact nicely demonstrates the relationship between preconception and enactment by bringing together media representations of work and rewards with actual accounts of individuals who have sought to inhabit those media representations in their everyday lives. And in this way we can also think about the social rewards that draw people to particular kinds of work. One distinction between material and social rewards is that the former appears more obvious, subject to less interpretation, than the latter. Towards identifying and interpreting material rewards, it appears self-evident that making a million dollars a year is something to which most people might aspire. But with social rewards, matters are less self-evident and appear more subjective.

Social rewards are defined here as attributes, qualities, or character traits granted to an individual for the particular work in which they are engaged. Examples of social rewards include ways in which an individual might be described (e.g. intelligent, courageous, heroic, brave, powerful, nerdy, or overbearing) or the manner in which they might be treated (e.g. with respect, reverence, or deference).

For some types of work, social rewards seem to be second-order consequences. The young stockbroker in Wall Street demonstrates his financial rewards through the purchase of a penthouse. The second-order consequence of his success is the admiration and deference he receives from the real estate agent, his girlfriend, and guests. Work like space exploration flips the reward order. Media representations of such work – in terms of teaching, scientific discovery, or inventing – tend to foreground character traits of being perceived as intelligent, selfless, heroic, or independent. Material rewards are hardly ever represented as even a second-order consequence for such work. In fact, films about space exploration tend to include morality tales about scientists who in seeking to commercialize their discoveries reap only disaster. Taking this a step further, media representations often show that people in science related work are successful only if they *are* selfless and heroic. Consider in this regard the film Battle beyond the Sun (1975), in which a race to Mars ensues between two nations that appear to be representative of the Soviet Union and the United States. The "American" characters acknowledged that the race itself was not good for the environment even while they were compelled to persist for the selfless reason of scientific discovery. By contrast, the Soviet Union's stated aim was planetary domination (the Americans win).

Material and social rewards can be acquired by individuals as well as organizations, something that we see especially clearly in the case of NASA. The space agency and the individuals affiliated with it can each acquire social capital in the same sense of reputation – both can and have come to be seen as heroic, selfless, and intelligent. But before moving into the next section to specifically detail the connection between media representations and organization membership in NASA's case through the social reward of hero identification, there is one a important commonality between media representations of social and material rewards that I want to remind the reader: that media representations of either social or material rewards most often fail to depict work processes in the real-time that it takes to attain them.

Drawing from dreams of space exploration

References to motion pictures and literature, fiction and non-fiction, were common place in conversations and comments made by the MER mission members. Dreams of space exploration authored by Jules Verne and H.G. Wells were practically required reading, a source of cultural knowledge that presented itself both in casual conversation, in the form of jokes, and in more formal capacities, in the form of passwords and Mars terrain identification naming schemas. In conversations – where fantastical technologies were accepted as being just one good design away – imaginative and sometimes unrestrained possibilities similar to those found in science fiction were offered in consideration of phenomena discovered on Mars. These references led me to reflect on the ways in which popular depictions of space exploration had shaped scientists' expectations in terms of social rewards and guiding work practices. In Figure 24, three images depict the works of three of the most influential figures on conceptualizations of space exploration. There is Jules Verne's novel From the Earth to the Moon, H.G. Wells' The First Men in the Moon, and Wernher von Braun. Although I have not yet mentioned him, von Braun is an iconic figure who shaped the discourse of space exploration in the United States not only for his work as head of NASA's Marshall Space Center, where they designed the Saturn rockets used to land Americans on the Moon, but also for the communication strategies

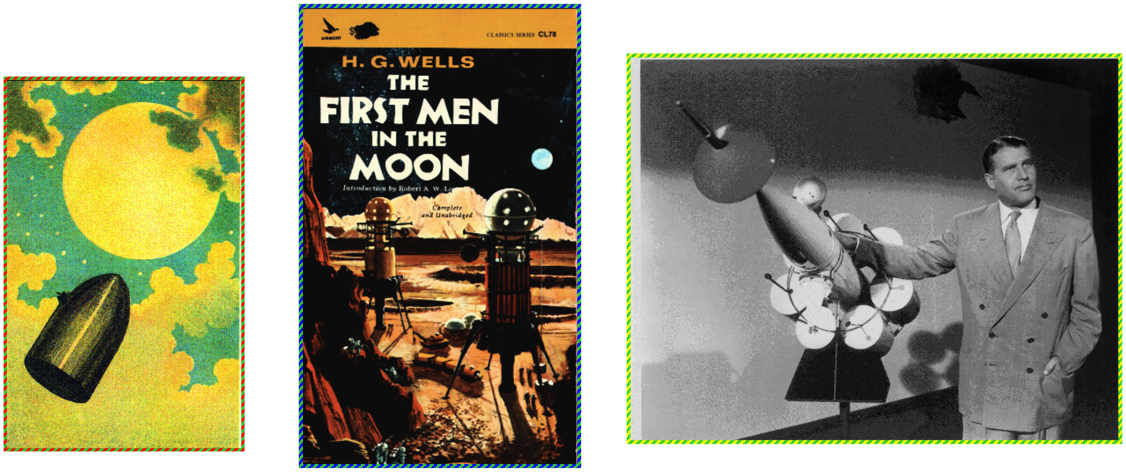

Figure 24 Conceptualizations of space exploration: from left to right: the front plate for Jules Verne's (1860) novel From the Earth to the Moon; cover art for H.G. Wells' (1901) The First Men in the Moon; and, a still image of Wernher von Braun in Disney's (1955) Man and the Moon.

he employed to generate public support for space exploration (Telotte, 2005; Wright, 1993).[38] His relationship with Walt Disney involved the production of three space-related television films (Man in Space (1955), Man and the Moon (1955), and Mars and Beyond (1957)) and is but one example of a long relationship between Hollywood (the center of media production) and NASA. Another example of the relationship is found in the frequent visits of directors and producers to JPL, under the auspices of discussing films that might feature NASA activities or depict "NASA-like" organizations. But suggesting that these references serve as explanatory devices for work practice choices necessitates drawing out the relationship between media representations of NASA and work practices at NASA. And to do this I want to take a closer look at some media representations of NASA, its members, and work practices,

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[38] Without these successes we can only speculate how von Braun's background as a German scientist designing rockets for Hitler at Peenemünde might have received greater public scrutiny. Though for many his past organizational relationships were not forgotten, and were committed to public memory in a song performed by Tom Lehrer in 1965.

in order to consider how these representations (may) serve to constitute a category of "normal," of normative work practice and membership identity.

NASA's presentations of itself and outside media representations of NASA are tightly coupled. NASA promotes particular images of itself and its members through press releases, websites, and relationships with the film industry; and public accounts of organizational activities at NASA, most often mirror these accounts. This has to do, in part, with NASA's status as a public government organization. It is an international symbol of the United States' superiority in science and technology and a symbol of government competence (McCurdy, 1997).[39] Public accounts of NASA, for the most part, serve to protect that image in the service of maintaining a national symbol of excellence. The result is a fairly consistent singular narrative of NASA and membership roles across popular and professional discursive arenas. From both sources, depictions of NASA feed a public narrative constituted by values of personal sacrifice for technical progress and of competition for setting standards for technological innovation: indeed, in the popular imagery NASA is an indefatigable organization that does not cease work until success has been achieved.[40] It competes to be proprietor of space and supports members who work to claim it and name it, in the name of the United States of America. These attributes construct NASA as heroic at home and abroad, outperforming rivals seeking similar discoveries and thus second to none. In foregrounding these depictions my intention is not as much to criticize as to

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[39] Some people may be inclined to recall the latest space shuttle disasters at NASA. However, the claim made here is grounded in the decades of successful manned and unmanned space exploration accomplished through coordination of distributed technological and social resources.

[40] Even satirical accounts of space exploration include these notions; for example in the film Galaxy Quest (Cantillon, 1999) the members' mantra is "never give up, never surrender."

underscore the ways in which such visions of the organization work to promote particular notions of work while obscuring others.

Drawing from the dreams of space exploration promoted through media (film, television, news stories, and science-fiction literature), the organization of NASA has been constituted as a domain for heroes or people whose work defies nature and is accomplished in spite of nature (Benjamin, 2003; Kilgore, 2003; McCurdy, 1997). Many media accounts have depicted NASA's organization members as unwaveringly committed to the ideal of technological progress and personal sacrifice (which might include relinquishing personal relationships with family and friends, and neglecting to maintain personal infrastructure involving food, sleep, and repose). These images of NASA have imbued the cultural consciousness with a standard of excellence known as "the right stuff" – qualities that demonstrate one's ability to overcome any obstacle be it human, machine, or nature – in achieving superiority over nature, other humans, and even one's own human-ness.

I want to offer a few of these media representations or some of the public narratives of organization membership at NASA, which inspire the imaginations of membership. In this sketch, I will locate some of the perspectives that serve to foster preconceptions of work practices at NASA and that later serve to inform schemas of normal identity. Specifically, what I want to point to, though it may seem obvious, is the representations of normative work practice that are present in the accounts of space exploration.

Organization heroes

Both individuals and organizations can be identified as heroes. The status of hero is typically conferred for spontaneous acts of courage, kindness, or generosity that may compromise your own well-being, acts which require doing something that tests you against what is conventionally said to constitute human nature (or the instinct for survival). For an individual, this might include running into a burning building unprotected to save someone trapped inside; or sitting inside a small container positioned atop tons of explosive rocket fuel that is catapulted skyward at 17,000 miles per hour, leaving behind the comforts of gravity, and reaching into space in a demonstration of human ingenuity besting nature. While space exploration seems to be the topic of the second example, it also involves the first one as well. The work of space exploration, whether or not one leaves Earth, can be dangerous and harmful to the human body. Furthermore, harm to the human body can be considered both physical and emotional, affecting the individual and their social group (family, co-workers, the public). Explorers, across the globe, into the Antarctic, beneath the seas, and into outer space (each of whom faces encounters with the unknown) have long been called heroes. For an organization, hero status may be conferred for "sacrificing" profit by donating money to aid other organizations (such as Bill and Melinda Gates Foundation) or donating time to aid individuals (such as doctors who perform services for a considerable amount less than their services normally earn). Comparable acts of spontaneous contribution to the public good may seem less likely for organizations but, as in the case of NASA, they can be depicted as having accomplished exactly that. In this regard, we have for example the manner in which NASA has been depicted as springing up in full maturity in response to Sputnik and America's defense against communism. Activity that counters the standard notion of the goal of the organizational production process – namely profit – is another way that grants organizations shades of heroism. And, this is but one of the ways that organizations like NASA with the production goal of pursuing knowledge are cast as society's heroes (Bromberg, 1997; McCurdy, 1997; Tompkins, 2004; Wolfe, 1979).

Accounts of the harrowing and complicated feats of space exploration are promoted by NASA public relations and in popular culture. In these accounts technology is often a silent lead and it is not required to speak or to produce arguments for its primary status. Rather, it is a basic assumption turned truth: progress, happiness, and even freedom are made available through a progressive technological future. This is reinforced by depictions of the personal sacrifices of organization members and their obedient elevation of technological considerations over their personal lives. Organizations as main character is not an uncommon casting in films (Hassard & Holliday, 1998; Parker & Cooper, 1998);[41] and, in early films such as Frau un Mond (Lang, 1929), in which rocket scientist Hermann Oberth imagines landing humans on the Moon, the space vehicle itself clearly occupies top billing over the humans. Another example preceding the advent of NASA but contributing to the discourse of space exploration heroism is Rocketship X-M (Lerner, 1950). In this film, a crew is sent on a mission to Mars and on the return trip to Earth all five members of

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[41] Sometimes organizations serve as figures in the background and sometimes they figure as prominently as any of the other protagonists, e.g. in the film Waydowntown (Gliserman & Pigott, 2000), a company, its members, and the office building that they occupy are the main protagonists.

the crew (four men and one woman), both scientists and engineers, perish. However, their rocketship outlives them as does the organization's mission. Upon receiving the news that the crew had perished, the grave mission manager declares the mission *a success* and orders the next mission to commence. The valor of the organization thus survives and is enabled through the hardship of its members and carries on with the mission of space exploration. Foregrounding the hardship of these members – that is, their deaths – touches on a significant trope of human sacrifice that has been used to construe astronauts as heroes.

Organizations can also be realized as heroic by supporting the work of heroes. And this brings us to media representations of NASA's most famous organization members: the astronauts. To this point, Howard E. McCurdy (1997) has described NASA's cultivation of a "culture of competency" specifically by using astronauts, the organization's most magnetic members, as representative of the organization's own attributes.[42] Most accounts of the early days of the space race and the first astronauts hardly ever fail to mention NASA's arrangement with Life that granted the magazine exclusive access to the Mercury astronauts and their families (Wolfe, 1979). Hard-working, self-sacrificing, dare-devil, "golden-boys" were (and are) promoted to inspire

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[42] The development of an organization's image, or brand, is often explicitly produced by organizations seeking to attract consumers and new members (Schultz, Hatch, & Larsen, 2000). A present example is found in the cultivation of an organization where work appears as "fun" rather than tasking. Google is one example. Google's public representation is of an organization that gives comfort to its members by providing a fun atmosphere and amenities to make life easier, such as wearing causal clothing, leisure activities in the work place, dry cleaning services, barbers, and massage therapists. Looking through public representations of Google, information about its atmosphere overshadows information about the actual work practices (Google, http://www.google.com/support/jobs).

public support for the organization.[43] While carrying out their normative work, these members are constantly engaged with one particular standard of heroism – the willingness to put oneself in harms way, to potentially sacrifice one's own life. One example of human sacrifice with respect to space exploration was recently depicted in the film Space Cowboys (Rooker, 2000). In this film, when a shuttle crew encounters conditions that may prevent them from returning to Earth, one astronaut volunteers to take on the task that will ensure the crew's safety at the cost of his own life. This act of sacrifice is accepted, with some protest initially, as an acceptable option. It is an example of an act of heroism in which an individual has chosen to go against what is considered to be a natural human instinct, the instinct of survival. This existential moment, when the astronaut chooses death, imbues his work with a certain value, one that is created by the possibility always present of choosing death on behalf of preserving the lives of others. And, this preservation of life can be either in the form of immediate preservation, as in the example given above, or in the form of long-term preservation – sacrificing one's life in the pursuit of knowledge about outer space in order to preserve and enhance the human species.

Prior to NASA's first catastrophe in 1967, the notion that the work of space exploration potentially involved the loss of human life had only been depicted in fictional accounts or accounts of Soviet space exploration activities. This changed with

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[43] This two-way flow of the relationship between media representation of space exploration and NASA is documents in the case of Nichelle Nichols, an African American actress who portrayed Lieutenant Uhuru on Star Trek. In 1977, NASA hired Ms. Nichols as an astronaut recruiter. The first African American astronaut in space (1992) Dr. Mae C. Jemison recognizes Ms. Nichols, as Lt. Uhuru, as the inspiration for her career. Dr. Jemison went on to appear in an episode of Star Trek: the Next Generation (Kilgore, 2003).

the Apollo accident, in which three astronauts were burned alive when their command module caught fire on the launch pad during a simulation exercise (Bergaust, 1968; Kennan & Harvey, 1969).[44] In the initial official version of the accident, it was not revealed that the astronauts had been burned alive. Accounts of the fire insisted that the astronauts had lost consciousness first and had thus died painlessly. Relatively quickly, however, opposing accounts surfaced, including stories in the New York Times and the Washington Star, that indicated that tapes existed of the astronauts' final minutes and on these tapes they could be heard screaming (Kauffman, 1999).[45] Although interpreted by some as a cover-up, and by others as an indication of an organization taken by surprise, the manner in which NASA went about keeping silent on the cause of the accident (there was a media blackout issued immediately after the fire) and the horrific details of the astronauts demise may also be read as an interest in keeping aspects of the human costs of work breakdowns out of public sight. In the death of these astronauts the sacrificial aspect of space exploration had been realized.

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[44] January 27, 1967 Apollo (204) caught fire on the launch pad and the three astronauts inside, Virgil "Gus" Grissom, Edward White, II, and Roger Chaffee, died.

[45] The Apollo fire was the public's first exposure to the fallibility of NASA as an organization. The technical failures that caused the fire and the inability of the astronauts to escape could have been avoided (the design of the escape hatch and the use of highly flammable materials). Informing the debate over whether or not NASA's actions following the fire constituted a cover-up is the issue that NASA chose to protect its image rather than act in the role as a public organization that must provide transparency to the public. By keeping the tapes of the astronauts screaming out of public earshot, NASA was able to minimize the sense that the astronauts had suffered a painful and gruesome death in the course of a workday. Following the fire, the public's attention was directed away from the organization's capacity to make mistakes and mismanage breakdowns and directed towards members of the organization. Emphasizing the astronauts as individuals who were physical embodiments of NASA mythology allowed NASA to reclaim its earlier image through the carefully groomed identities of the self-less, infallible, and unbreakable male astronauts. The successful recovery from breakdowns aboard Apollo 13 demonstrated to the public the close relationship between the astronauts and other members of NASA (the engineers working in mission control who came up with solutions "by the seat of their pants") and their shared characteristics of intelligence, ingenuity, and determination to succeed.

But their deaths did not deter people from pursuing the work of space exploration or the role of astronaut. And, underscoring my earlier point, one of the astronauts who perished, Gus Grissom (1968), in a book published a month before the Apollo accident, observed that death was probably inevitable. In his words, his death, "…we are going to lose somebody … if it does [happen] I hope that Americans won't feel it's too high a price to pay for our space program."

In addition to human bodies, another form of human sacrifice in the name of science and technological progress plays out in the everyday activities of space exploration with sacrifices of time, psychological well-being, financial rewards, and relationships. These sacrifices do not garner the same kind of attention that a life or death situation garners, but they are present to an even greater degree considering the amount of work processes that are enacted for each space flight. Subtle or dramatic, acts of sacrifice make their way into representations of normative work practices, demonstrations which employ the familiar frame of sacrifice as a condition of great achievement. Consider two recent media headlines that capture this work ethic: "Sleepless Nights Pay Off in Giddy Joy at Stardust's Success" (Leary, 2006), an article about the scientific rewards received in exchange for suspending sleep; and "Halfway to Mars: How a hardy band of researchers braved freezing nights, bad food, and high winds in the Chilean desert to test the next generation of planetary rovers" (Kumangi, 2006).

A film favorite among mission members, Apollo 13 (Hallowell, 1995), precisely characterizes the message of the heroism of sacrifice. The film is based on the actual events of the 1971 Apollo 13 mission. On this lunar mission, oxygen tank failures forced the astronauts to circle the moon and return to Earth. The mission was not called a failure in part because the astronauts survived and because their survival was the result of what was a miraculous engineering feat. However, in the first fifteen minutes of the film, before any of the dramatic events unfold aboard the shuttle, we are presented with acts of familial sacrifice – not only do the astronauts miss out on family events, they allow family members to live in fear of abandonment (if the astronauts do not return safely then their wives will be left alone to deal with children and the press). But there are many small heroic feats nested in this larger story and they unfold almost immediately from the training stage of mission preparations. In one scene, following many hours of flight simulations, the three astronauts climb out of the shuttle after learning that had their simulated operations been real then they would not be alive. The commander, played by Tom Hanks, directs the simulator controllers to reset the controls and orders the other astronauts back into the shuttle to commence operations until they get it right. The members around him glance at one another, look strained, and then silently follow his commands: after all, failure is not an option. Meanwhile, the members down in mission control, aside from the managers who are allowed to be volatile and express emotions, are shown to be obediently and silently working at their consoles. The film provides a demonstration of the freedom to be innovative, to act informally by-the-seat of your pants, and to create unapproved workarounds *only if* proven successful (otherwise, such actions are considered a violation of work practice). Through the accounts of these individuals, their creativity, drive, and ambition, NASA is personified as a hero – a hero that saved the United States from second place in the

Space Race by getting “us” to the moon (Holmes, 1962; McCurdy, 1997; McDougall, 1985).

Turning now to the experiences of members on NASA’s MER mission, I observed recurring instances when members intertwined references to motion pictures, literature, previous NASA missions, and feats of terrestrial exploration (in casual conversations) with each other and with me in conversations about their work. These references were treated as valid conceptual resources. In a conversation, where fantasy is understood as one good design away, unlimited imaginative and sometimes hysterical possibilities were posed to offer explanation of phenomena discovered on Mars or in seeking further data. The community of temporarily relocated scientists and engineers, who had moved to Pasadena, California for the mission, resided within ten minutes of one another, of JPL, and of the downtown area; and invariably they would come together several nights a week to eat, drink, or watch movies. Movie nights were held at apartments and group outings were informally organized to view films about space exploration and action heroes. Following the films, discussions would take place mocking or praising the film’s special effects. T-shirts, screen-savers, closing quotes on e-mails, were some of the ways in which members would mark the blurred line between accounts of fictitious and actual space exploration as sources of inspiration. Demonstrating NASA’s support of the blurring of fiction and reality is demonstrated by one of the posters hung in the hallways at JPL: the title of the poster was “From myth to reality” and the text that followed described the connections between science-fiction stories of the past and space exploration in the present. Yet, how one actually goes about turning myth to reality is not presented. It is left unsaid that it is up to each individual and their imagination. However, imaginations do not necessarily spring from a void and this returns us to media representations as a source for conceptualizing work goals, practices, and identities.

While I have an abundance of additional data points of ways in which mission members drew from popular culture media focusing on Mars, space exploration, and robots, these events do not demonstrate the reaction of mission members to the difference between preconceptions of particular work practices and actual work practices. Through the data of mission members for whom preconceptions of membership may have been used to inform responses to work system breakdowns like time management, I present an organizational account of the MER mission and the breakdown of time management. In Chapters 2 and 4, I discuss the issue of time management with respect to socio-technical processes, organizational infrastructure, and socio-cultural history. In this chapter, I am concerned with members' responses to expectations of time management. To make sense of the mission members' responses to the convergence of preconceptions and actual experience of work practices at NASA, I turn to Goffman's theory of stigma management and draw on his insights to tease out some possible implications of stigmatization for mission members. Finally, I will present an analysis of this configuration in which the maintenance of particular membership identities is demonstrative of invisible work, work that is imperative to operations but not formally recognized in preparation, support, evaluation, or funding (Nardi & Engeström, 1999; Star & Strauss, 1999). Understanding members' experience and responses to discrepancies as stigma management sheds some light on the way in which social issues are marginalized in NASA; and, how these conditions point to a process by which breakdowns that emerge from the infrastructure are returned to the infrastructure as problems of greater complexity.

Organizing NASA's Mars Exploration Rovers mission, 2003

Five months prior to January, 2004, the expected landing date for both rovers and start of the "nominal mission,"[46] MER mission members were engaged in Project Operation Readiness Trainings (PORT). The PORT phase involved a series of simulations of the work systems for the remote operations of the rovers on Mars and for the stages of science data collection and analysis. The duration of each PORT was about seven days. At the end of each phase, a meeting of all members took place, during which workgroup leads would give ten to twenty minute presentations detailing work practices that were successful and those that needed improvement.

These meetings were attended by a majority of mission members, lead science investigators, and engineering leads. The meetings were scheduled for the duration of four hours, and it was only at the behest of members that the presentations were pushed through to keep the meeting from running over. The presentations were followed by a discussion concerning possible ways to address the various issues workgroup leads had raised. Some of the issues generated discussions in which members agreed on, sympathized, rejected, or offered ideas with respect to causes or solutions. If an issue could not be resolved or explained by such reasons as insufficient

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[46] The nominal mission is the length of the mission that constituted the mission success criteria of operating two rovers at two sites for a period of 90 sols (1 sol [24 hours and 39.6 minutes] = 1 day [24 hours]).

preparations, human error, or the environment of simulation, it would be taken "off-line," which means taken out of the public forum and into conversation among selected interlocutors, for further discussion. It might then be entered onto the formal list of mission operations issues pending resolution. Once an issue was taken off-line, updates were rarely given unless the issue surfaced again on a subsequent PORT.

MER work systems involved human coordination of co-operations between technologies (such as the rovers and the visual imaging software) and humans (such as the scientists and the engineers). Some tasks were reliant upon technology for completion, others upon humans, and still others an iterative process between the two. To delineate between the human and technological, complexity was reduced to the simple categories of "social" and "technical."[47] Although there was no official edict proclaiming the importance of one over the other, *technical issues were discursively constituted as being of far greater importance than social issues*. Rather than insist on the organization's responsibility to resolve any issues related to work problematics, mission members appeared to treat social issues as personal issues. Which came first is a matter for debate, but that debate does not preclude the conditions as they occurred. Because social issues were not treated as significant causes for concern, members may have understood that contradicting this norm would undermine their credibility. And, likewise, for members not to demonstrate the same level of concern for social issues

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[47] Within an organization the categories of "social" and "technical" separate the humans from the technology. Social also refers to the interactions between humans. Technology covers hardware solutions and objects or processes that have been fabricated or fashioned by humans (Kling & Star, 1998).

that they demonstrated for technical issues may have prevented social issues from receiving the same attention as technical issues.

Among the matters that arose as social issues during PORT were the allotments of time (duration) for work practices, the cycles for work schedules (shift lengths), the physical challenges of insufficient work spaces, and the usability of computer technologies. In tracking the social issues brought up in presentations given by members, I found that members were suppressing negative comments in the collaborative forum. *The number of members who spoke up, during formal meetings, to account for experiencing particular social issues, was greater than the number of times that an issue was formally recorded in presentations.* In other words, there were more people verbally complaining than went on record. If an issue does not appear as a part of the written record then it remains in the category of the anecdotal. It did not appear that any of the social issues were assigned to the formal list of mission operations issues to be resolved, posted after the meetings. Rather, it would be taken on the word of the mission operations manager that the matter would be resolved. Thus, members' treatment of social issues was distinctly different from technical issues in that there was no formal process for recording and addressing social issues. This activity or lack thereof, contributed to an organizational culture in where social issues were *not* seen to be as important as technical issues.

Time management

Beyond the mundane problematics of time management issues that exist in all organizations, specific to the MER mission was the mission requirement to simultaneously operate using interplanetary temporalities, Earth time and Mars time. This condition was chosen to maximize data collection during the period of the nominal mission, ensuring mission success. Although it was known that the nominal mission would operate on Mars time, during PORT only one simulation was conducted using multiple temporalities. Hence, *members were required to live and to work according to multiple temporalities of Mars and Earth times with very limited phenomenological experience, the underpinning of work systems simulation*. Simulation exercises support kinetic human learning not just in terms of body movement but also with the sense of pace and time, or temporal rhythms. The time management issues that arose during PORT included problems with the durations allotted for task completion and information distribution, as well as "just knowing what time it was." Some members used the whole duration to conduct meetings while others insisted that they could "move more quickly" through the discussions and analysis. Even the act of knowing what time it was did not have full support and could not be simulated. A typical response to these problems was to simply postpone them: "once the actual mission commenced" it was said, "things will be different." Mission members with prior mission experience were certain that once the actual mission commenced, the pressures from dealing with the rovers would be intense enough to drive members through their work systems. In other words, they were suggesting that the mission would run itself, that adrenaline from pressure and stress would allow them to do things with their bodies and senses they were unable to do in less critical circumstances. In this respect, therefore, it seemed generally assumed that they did not have to worry about familiarity with on site demands or prior knowledge of these demands. One might (as some did) call this approach "flying by the seat of your pants."

Time management issues were explained by mission managers (most of whom did not participate in daily mission operations) as a condition specific to the environment of mission simulations. It was expected that once the nominal mission began, all workspace construction would be completed: supporting technologies would be operational and the work schedules set. At that juncture, time management issues would not contribute to breakdowns: work-shifts would be set so that no member was working for more than fours days on Mars time, giving them three days on Earth time to be with family, to complete other organizational work, and to rest. Moreover, all the windows in the mission operations work spaces would be covered with blackout shades (each member was also told to mimic this at home) to prevent terrestrial sunlight from confusing members' work synchronization with Mars time. And, temporal support technologies would be present in the operations space, as I discussed in Chapter 2, to alleviate the need to do the math of coordinating time between Mars time and Earth,

Among mission members, approximately twenty-five percent listed difficulties associated with time management in their post-PORT presentations. But when discussed, the issue brought comments and agreements from members as well who *had not* listed it in their presentations. From the member responses given, more than *three* *times as many members experienced a problem with time management than formally reported this problem* in their presentation. At this stage, it was too early for me to posit more than a cursory analysis of the incongruous reporting. Why did members who experienced time management issues opt not to list them in their presentation but, nevertheless, vocally state them? There are a number of explanations: they may have trusted the mission managers who insisted that things would be different when the mission began; they may have not minded the issues; they may have been reluctant to report time management as an issue but, upon seeing others do so, spoke up in agreement.

Breaking down time

Once the nominal mission commenced and contrary to organizational expectations, several of the social issues had remained unresolved, including time management issues. Although the organization fostered the expectation that temporal support technologies would remedy time management issues, once the mission began these issues not only remained, but proliferated. The preconception regarding their reconciliation was grounded in the not unreasonable belief that in a technologically sophisticated organization like NASA, temporal support technologies would solve all problems. However, once members began experiencing the discrepancies between the expectations and actual experiences of time management, they refrained from raising the issue publicly because *the standard of normal behavior to which they were holding themselves, and one another, was grounded in ideal membership identity of the silent, sacrificial, and indefatigable member*.

The experience of time management in the context of the MER mission demonstrated that time was not entirely a technical matter. The technology of time may provide clock time, but it does not address the phenomenological experience of constantly adjusting human temporal rhythms between Earth and Mars time – going from circadian (24 hours) to infradian (24-plus hours) cycles – on a weekly or a daily basis; or, the daily rhythms of jet-lag (shifting the terrestrial time clock back 40 minutes each day to maintain synchronous with Mars time) and shift-work (day-shift, night-shift, graveyard shift). The information technologies were not mobile and thus were inadequate for keeping track of time while members were at home, in transport to the organization, or located in various spaces inside the mission operations floors. A numerical source of information fails to adequately support managing the complexity of temporal relationships like navigating between home and work life rhythms, between simultaneous member identities within NASA and other organizations, between present performance and future performance, and between present difficulties and future life chances (Bowker, 2005; Egger & Wagner, 1992; Zerubavel, 1979).

The stigma of being human

Goffman defines stigma as *an attribute that is deeply discrediting* (1963). When a person is present and evidence arises that she possesses an attribute that makes her different and "worse" than others, she is thus reduced in our minds from a whole, usual person to an unusual, discredited one. The attribute is the stigma and the use of it as discrediting evidence is the process of stigmatization. Goffman traces three types of stigmas – physical, character, and tribal – along a historical timeline. Beginning with the Greeks, physical stigmas were identified as bodily signs that were placed (burned or cut) onto a person's body to designate low moral status. In Christian times, this category was broadened to include bodily signs that marked people born of low moral order as well as those imbued with holy grace. Character and tribal stigmas are visually less apparent. Tribal stigmas are characterized as stigma that can be transmitted through lineage such as religion, race, and nationality. Character stigma, the stigma of my focus, is described as a blemish of individual character perceived as a weak will, domineering or unnatural passions, treacherous or rigid beliefs, and dishonesty. Character stigmas are not apparent in the same manner that physical or even some tribal stigmas can be. Instead, they are inferred from current behavior (Goffman's example is radical political behavior) or a record of past behavior, such as imprisonment or unemployment (or, in the case of NASA, having worked on a failed project). A wide range of imperfections can be imputed on the basis of the perceived original one and this increases the discrediting characteristics of the stigmatized.

The deleterious effects of stigmatization are found in the varieties of discrimination that people exercise to effectively, if often unthinkingly, reduce the stigmatized person's life chances (Davis, 1961). In any organization, the reduction of life chances can be understood as a reduction of opportunities for financial advancement, position promotion, community inclusion, or intellectual respect. In an exclusive organization like NASA, one of only a few sites worldwide where a very particular kind of work can be pursued, the limitations to professional mobility are dramatically consequential and underscore the importance that members place in successful stigma management. One MER mission member described the competition among scientists for inclusion on the MER mission: "after all, how many times does NASA land remote-operated scientific data collection vehicles on Mars?" He described the process by which selected scientists received phone calls asking them to join the mission – all of whom had about twenty-five years experience and membership in the community of extra-terrestrial exploration – and the dismay of those who were not selected. Scientists who received a call, the mission member recounted, to participate were overjoyed and grateful, possibly to the point of feeling indebted. In contrast, their fellow scientists who were excluded from the mission had to wait with the rest of the public for scientific data, were bewildered and even bitter, over the selection process.

Considering then how one's performance or perceptions of one's performance are valued both for the task at hand and potentially for future tasks as well, the importance of the practices involved in stigma management cannot be overemphasized. At NASA, performance on a successful mission is evaluative of the performance of individual members. There is still the need, however, to distinguish oneself from other mission members, as not everyone can move on to the next mission at the same time. For mission members, once a mission has achieved a certain level of success, the goal is to secure a position in the design stage of the next mission. In fact, one can read the membership status of those who leave a mission early as the most successful while the members who remain are, to some extent, classified as less successful. This reward structure, the organization's standards for membership success, works to inhibit members from formally articulating problems, as it can stigmatize them as uncooperative. Former NASA astronaut, Colonel Mike Mullane, has recently given organizational accounts in which he describes the pressure to perform and the potential effects of displaying discrediting behavior (Schwartz, 2006). Accounting for why astronauts refrain from speaking up about known safety risks, Mullane writes, “The line into space was long and nobody wanted to be at its end, or worse, be banished from it altogether."

Preconditions to stigmatization

Cultural norms within an organization, schemas of normal and complementary attributes are formally set discursively and materially through communication and the negotiation of objects, objectives, and expectations found in training regimes, performance reviews, physical structures, and reward structures (to name a few). The material and discursive acts help to shape, explicitly and tacitly, the formal organizational culture(s).[48] The organization and its members co-construct schemas of normal used to evaluate what are or are not discrediting behaviors. I am restating some of the influences as a reminder that the representations of work found in these accounts is substantively and substantially under- representative of actual experiences of timing, motion, coordination, and communication of work at NASA. Recall that in the depictions of NASA’s most successful members, the astronauts, men are indefatigable, insatiably curious, sacrificial of families and personal time, silent and obedient, tall, driven, willing to give their lives, and prioritize the needs of the

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[48] The processes of organizational culture have been discussed in great and interesting length (Engeström & Middleton, 1996; Frost, 1985; Hutchins & Klausen, 1996; Morgan, 1986; Schein, 1985; Smircich, 1983; Star, 1995; Traweek, 1988; Van Maanen, 1998; Vaughan, 1996; Weick, 1995)

organization over personal needs. Man in pursuit of space exploration is a machine, a machine that supports the operations of the organization.

For character stigmatization to take place, Goffman describes the primary structural precondition as an established category of "normal" against which discrediting behavior is assessed. What is normal and what are the attributes of normal are determined by "ordinary" and "natural" society. Specifically, it is the social setting that determines the categories of normal persons one can expect to encounter. In Goffman's example of physical stigmas, informing the category of discrediting physical attributes is the standard set by society that "normal" people have all senses and limbs intact and operational. Any person with physical attributes that show them to deviate from the norm is stigmatized. Although Goffman's discussion of stigma management was defined in terms of individual and society, the preconditions and effects of stigmatization address actions and relationships in an organization between it and its members.

As described earlier, these preconceptions of identity can be shaped from a lifetime of gazing upward; from the desire to experience space exploration, scientific discovery, and technological innovation. Many MER mission members expressed having inclinations towards membership with an organization such as NASA since first "looking up at the sky and dreaming of space exploration" as a child. Without fail, this origin story has been used to introduce what appears to be a necessity, or a destiny, for particular individuals to pursue space exploration.[49] In this narrative, the

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[49] Almost without fail, rocket scientists, astronauts, space explorers, and journalists ground their investigation of space exploration, as a participant or as an observer, in their youthful gaze, this

author is telling of a suspension of belief in that they did not know how they were going to get to the stars (after all, they were but children) but through hopes and dreams they surely would. In this narrative, there is another origin story: one affirms the work practice of setting a goal without full knowledge of the system by which one will need to carry it out. By their own accounts, many of the mission members were greatly influenced by popular culture, literature and films, as well as oceanic and interplanetary explorations. A few members even said that it was specifically the organization of NASA that they wished to join, because it represented the highest achievement of intellectual exclusivity. Some also referred to the socio-cultural contexts of their lifetime as many of them were born about a decade before the birth of NASA (1958), and in their lifetime had experienced the Cold War, Sputnik, and/or NASA's lunar landings. Literary influences were significant as well and included Jules Verne and H.G. Wells, Isaac Asimov and Arthur C. Clarke. Moreover, there were more than a few scientists who were science fiction authors – one scientist had published what was considered by other members to be the best science fiction book about Mars exploration (Landis, 2000). And, films that were most often quoted included Apollo 13, Ghostbusters (Brillstein, 1984), a film about scientists as heroes, The X-files (Carter, 1993), a television detective series about the search for supernatural life, and Star Wars (Lucas, 1977).[50]

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includes: Wernher von Braun, Donna Shirley (mission manager on Mars Pathfinder mission), astronaut Scott Carpenter, journalist Marina Benjamin, and the first female space tourist Anousheh Ansari.

[50] Among the representations of ideal membership identities found in popular, there are demographics that depict the parameters of the physical identifiers for belonging: white, male, lean, "conservative" in dress (i.e. no visible piercing or jewelry), and dare-devils (mavericks, cowboys) in attitude. NASA psychologist Patricia Santy (1994) refers to an attitude of

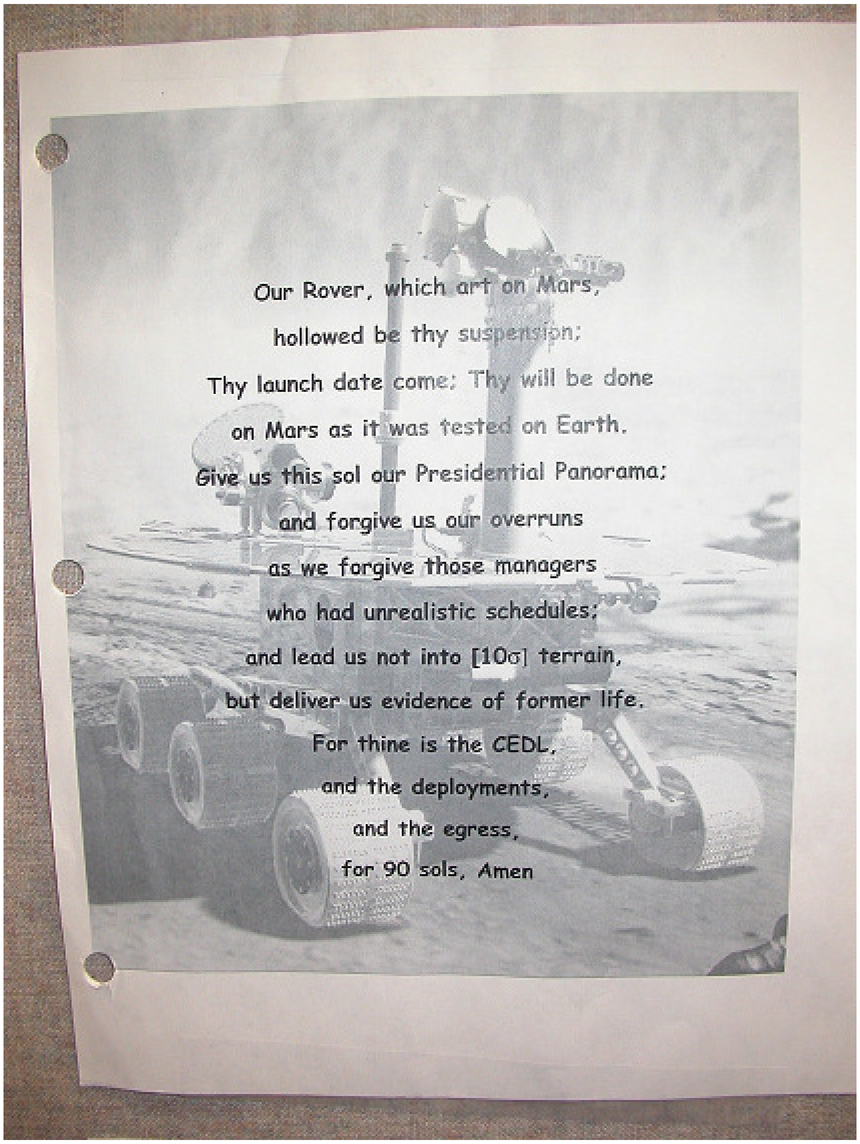
Stigma and identity on MER

It took less than three weeks for the effects of temporal confusion to emerge in mission operations. It appeared that for most members one week of constant jet lag was manageable. However, after three weeks, there were physical signs of weariness and disorientation (see Figure 25). Late arrivals to meetings, missed meetings, dozing during meetings, walking into walls, driving the wrong way on one way streets after leaving the lab, all were observed effects of time mismanagement, which I discussed in Chapter 2. Members went outside of NASA to purchase wristwatches from a local jeweler who claimed that he was able to adjust the coil of the watch so that it ran

Figure 25 a scientist falls asleep during a planning meeting. His seat location, however, indicates that he was not present in a mission critical capacity.

"maleness" among astronauts. It should be noted that the demographic composition on NASA's MER mission did favor the above demographics with some "exceptions." Using gender as an example of "exception," the number of men on the MER mission greatly out numbered the women. I hesitate to provide a ratio as I would fail to accurately account for the women who performed in roles that I was aware of but not in touch with, like the administrative assistants. It is interesting to note that in film depictions of women in NASA-like operations, a common characteristic is their (requisite) position as the "love" interest of another member. In three significant films of space exploration, <u>Frau im Mond</u> (Lang, 1929), <u>First Spaceship to Venus</u> (Mahlich, & Zajicek, 1959), and <u>Rocketship X-M</u> (Lerner, 1950), a single woman is a member of the crew but is first introduced as the love interest to another (or several of the other) male crew members. In each depiction, the female's role as an object of desire precedes any of her other qualities.

according to Mars time. And, even this device failed to support time, as the coil needed constant readjustment by the jeweler. One strategy that members developed to mitigate temporal confusion was *not to leave* the site of mission operations. Members would abstain from leaving the building, opting to nourish themselves from the unlimited supply of ice cream and “food” from the vending machines. And yet, despite these struggles of time management and breakdowns, fatigue and temporal confusion were not discussed, not during the PORT meetings or in the formal meetings during the mission. While frustration with time management did occur, it was primarily masked as jest. Adding to the numerous examples given throughout this dissertation I offer Figure 26, a rescripting of the Lord’s Prayer.



Our Rover, which art on Mars,
hollowed be thy suspension;
Thy launch date come; Thy will be done
on Mars as it was tested on Earth.
Give us this sol our Presidential Panorama;
and forgive us our overruns
as we forgive those managers
who had unrealistic schedules;
and lead us not into [10σ] terrain,
but deliver us evidence of former life.
For thine is the CEDL,
and the deployments,
and the egress,
for 90 sols, Amen

Figure 26 Rover's prayer: a depiction of a rover is in the background to a prayer, which includes a line (line 8) that ties work breakdowns to unrealistic expectations of time and work coordination.

Mission members appeared to take it upon themselves to work out the struggle of living on Earth and working on Mars without the aid of robust infrastructural support. Members avoided displaying their *very human* responses to a problematic work environment by keeping their stigmatizing behavior in the backstage area of mission operations (Goffman, 1973). Rather than make explicit the various ways in which the mission infrastructure was inadequate for supporting work systems, members turned to innovations of individual technologies and social relations. Members relied on their personal technologies, cell phones and laptops, to share information about changing schedules by emailing or calling other members to retrieve or remind them about time/schedule change information.[51] In these acts, we can locate the invisible work performed by members in order to maintain the organization's problematic infrastructure, which was failing to adequately support work practices carried out to complete organizational goals.

As I noted, to announce that there were time management breakdowns resulting from inadequate organizational infrastructure meant announcing one's own incapacity for heroic action like working without sleep. Recall that at this time in NASA's history, the Columbia Accident Investigation Board (United States, 2003) report had formally asked members to make explicit any conditions that could contribute to mission failure. Instead of adhering to this pronouncement, it appeared that mission members continued to adhere to the norms set by the maxims "sleepless nights are worth the data" and "failure is not an option." The sleepless and the tired were the brave. Being too tired or confused was not an option. Indeed, even Henry Cooper's (1976) otherwise sympathetic account of the revolt aboard Skylab (America's

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[51] Within the collaborative meeting spaces, fatigue and temporal confusion were observable but not discussed. Rather, such discussions occurred within back stage areas where responses to time management issues were seriously engaged and addressed by individuals (as individuals). These areas were "safe" spaces for conversation as access was very limited. Unlike the frontstage area, it was not special badge access that kept members away; rather, it was through a silent understanding that only members of these workgroups and their intimates could enter these rooms. When other members entered for official reasons, conversations would come to a dead stop until the "other" left the room.

first space station[52] in which the crew appeared justified in their unauthorized work stoppage) characterizes the astronauts' attitude as unpleasant and their complaints as bitchy.

In keeping with Goffman's trajectory of stigma transmutation, whereby normative expectations finally transmute into demands, dealing with the issue of time management became a *mark of valor*. To demonstrate "real" membership, one needed to bear the scars of carrying out maintenance work. Comparing the number of consecutive days spent inside the windowless workrooms, sleeping on a cot in the workspace, or receiving sole nourishment from the vending machine earned boasting rights. After the nominal mission ended, new members brought in for the next phase sought to learn if one had "really" participated in the nominal mission through the question, "*but* did you live on Mars time?" Newspaper articles and NASA press releases through PORT and the nominal mission recreated the valorization of this aspect of membership as well. For time management to go from a "problem" to a "demand" on the MER mission further warrants understanding member responses as attempts to manage stigmatization. The composition of the ideal identity on MER required members to dismiss particular infrastructural breakdowns. Thus, the members were performing another kind of maintenance work, identity maintenance work, which was necessary to functioning operations.

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[52] Skylab, a science and engineering laboratory, was launched into Earth orbit in May, 1973. Three crews of 3 astronauts lived on the station, their missions lasting 28, 59, and 84 days. The final mission took place in 1974, and five years later Skylab fell from orbit.

Conclusion

Once a person joins the organization to which they have long sought membership, how do their imagined versions of work and identity come to bear on their actual work practices? That is, how do members respond in situ to discrepancies between imagined and actual experiences of work? And through their responses, are issues characterized as structural (responsibilities of the organizational infrastructure) or individual (personal responsibilities)? In this chapter, I have examined how this configuration helps to make visible the work practices that emerged in response to work system breakdowns of time management, which had been inadequately provided for in the organizational infrastructure. And, I have tried to suggest why members constituted these breakdowns as individual rather than structural responsibilities.

Aspects of carrying out the work once one has gained organization membership are hardly present in media representations. And this is especially the case with the temporal rhythms of work life in real-time that are different from depictions of the relationship between time and work that have been abbreviated or condensed to fit into the standard running time of a film. Work practices in real time might not make for captivating content for motion pictures. A step-by-step depiction of work that includes the pauses, silences, workarounds, successful and failed negotiated actions, and interruptions is usually compressed using time-lapse. These compressed timelines foster impressions of shorter temporal trajectories for communication processes such as information flow, decision-making, negotiations, or travel. This compression of time provides an interpretation of events, an abstraction of moments, being received by audiences alongside images of rewards that are understood to be concrete and *not* symbolic. This leads to my conjecture that the impressions of compressed time, which dictates the pace of work, can lead to expectations of work practices that are not representative of work practice in real-time in an organization.

By constituting the infrastructural breakdowns of time management as an individual matter rather than structural matter in order to prevent a display of stigmatizing behavior, members refrained from formally integrating workaround work practices that may have in fact been beneficial to the organization of NASA. If technological development is dependent (and it is) on human innovation, then coordination and support of work practices is critical. The preconception of rocket science as the litmus of greatest degree of difficulty works against the very organization that sold the adage to us. A brilliant group of NASA members faced with social issues of work practice contributed to making invisible these issues because, as they say, time management has never been considered rocket science. By implicating themselves in these failures of the organizational infrastructure, members were essentially letting NASA off the hook and contributing to the maintenance of unrealistic standards of ideal membership identities.

As a participant, my expectation of NASA was that it could provide all necessary infrastructure for managing the complexity of multiple temporalities, even if that meant inventing a new timepiece for a new temporal rhythm. I was inclined to believe this, in part, from having been influenced by the public lore of NASA and from having witnessed amazing technological and software development while working inside of NASA. What I was not expecting was the way in which problematic technologies were accepted, especially such a mundane (so I thought at first) technology as time. In the next chapter, I return to the relationship between time and work on MER in order to investigate some of the assumptions about the socio-technical operations of time in organizations. Succinctly put, I was not (am not) convinced that time management breakdowns resulted from poorly designed technology and human failure. A better explanation for these breakdowns, or so I argue, can be found in the underlying assumptions that operate within organizations to naturalize the relationship of time and work.

Chapter 4

The Sound of No Clock Ticking: Mars mission ops in an agrarian era

The adoption of atomic time in 1967, almost ten years before NASA's first spacecraft landing on Mars,[53] mandated the calibration of standard clock time to the vibrations of a cesium atom. Up to then, the units of standard clock time were based on the Earth's rotation, the irregularity of which required timekeepers to manage changes to the length of a second. These "rubber seconds" vacillated each year with the Earth's rotation and defied standardization (Jespersen, 1979). For this reason, the cesium atom appeared to provide a stable and consistent metric upon which to base the unit of time, the atomic second; and, as the international standard for time measurement, it seemed the best measure of time by which to coordinate scientific practices in physics, chemistry, and engineering (Lyons, 1950). Encouraging the adoption of atomic time as the international time standard, Harold Lyons, the chief of the Microwave Standards Section of the National Bureau of Standards who oversaw the invention of the first atomic clock, offered an appeal using our planet of interest, Mars. In addition to the aforementioned reasons, Lyon's argued that atomic time was *universally* applicable, defining "the universe" as all sites where the rotation of the Earth had significance; and,

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[53] Viking 1 and 2, respectively, landed on Mars in July and September of 1976. It was NASA's first successful landing of spacecrafts on another planet, since the lunar landing in 1969. And, according to NASA's media office: "…when humans finally arrive on Mars, they'll find a pair of dusty pioneers already there – the Viking landers that blazed the trail for all to follow (Webster & NASA, 2008)."

addressing a potential contradiction to this claim of universality, he explained that the planet Mars "should not prevent the assessment of universal applicability given that one was not very much interested in the rotation of the Earth for timekeeping when living on Mars." Why Lyons and other advocates did not foresee an occasion when an extra-terrestrial relationship to clock time would become an issue is a matter of conjecture. It could be that among this community space exploration was a non-issue, especially the idea of coordinating an inter-planetary work system between Mars and Earth. While the specificities of the MER mission, from the development of Mars time to the importance of the life (power) cycle of the rovers on Mars, do not undermine the rationalization for the adoption of atomic time, they do provide an empirical position from which to question the momentum of constructing temporality in organizations along a progressive continuum of distancing time and human motion. While most people in the United States probably did not even notice it in their daily lives, from a socio-cultural standpoint the adoption of atomic time marked a significant shift, a final disconnection between the relationship of human sense perception and the environment (Adams, 1995; Anderson, 1964).

In Chapter 2, I discussed the construction of Mars time through technologies and work practices, laying out the MER inter-planetary work processes and the instantiation of Mars time used to arrange the coordination of scientific knowledge production. In my examination of the breakdowns and drift of time management support technologies, I raised the consideration that managing Mars time did not yield itself to the practices of standard time management. With over ninety sols of ethnographic data on the interactions between scientists and their tools while moving through the scientific knowledge production process, coupled with my interest in the socio-technical arrangements of everyday work, I considered exploring what kinds of tools or social processes would better support the complexity of inter-planetary time management. I think this is an interesting question but it can also lead to a position that merely repeats a technological determinist argument – if the tool was better then all would have been right in the world. But that issue is to the side of the concerns of this inquiry. Rather than consider how Mars time might otherwise have been rendered operable, I want instead to move "under" the phenomena to ask, what assumptions gird the promulgation of the relationship between time and work in organizations that operate as though clock time was a force of nature? Another way of stating this question, following Zerubavel's (1981) temporal ontology described in Chapter 2, is to ask how sociotemporal rhythms of work in an organization engage clock time as though it was a physiotemporal rhythm. Asking this question, and guided by the search for comparative case studies, in the following chapter I foreground two incongruous notions supporting the breakdowns in the time/work relationship that appear, on the surface, as individual human failures or technological design flaws in time management.[54] And, through these underlying assumptions, I offer one possible explanation for how a post-industrial organization at the forefront of technological ingenuity conducted space exploration according to the temporal rhythm of agrarian work.

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[54] I am making a distinction between a critic of NASA and taking a critical approach directed at the arrangement of socio-technical processes constituting an organization as an object of study. I think it would be worthwhile to consider what sorts of technologies and social practices could lead to a steady enactment of an inter-planetary temporal rhythm.

In the endeavor to understand socio-cultural processes used to render time operational inside organizations, scholarship in organization studies provides a good deal of comparative research. Case studies in factory settings have provided data and analysis on the cultural practices used by employees to manage and to subvert the conditions of time and motion working on a traditional production line (Roy, 1959; Thompson, 1967; Young, 1989). Case studies in office settings draw attention to similar cultural practices developed by employees processing information and the conditions of time/space compression precipitated by the sheer number of employees in an organization, new technologies such as video conferencing, mobile phones, and emails, and transnational operations (Barley, 1986; Dubinskas, 1988; Kunda, 1992; Orlikowski & Yates, 2002; Whipp, Adam, & Sabelis, 2002). While these worksites are made distinctive by the qualitative differences, factory vs. corporation or the production of concrete materials vs. abstract knowledge, they share a reliance on quantitative measurements for evaluating work processes. Often, the qualitative aspects of time are sidelined into a discussion of the demarcation between the experience of work and of leisure (Sorokin & Merton, 1937). What these literatures cannot or at least do not address is the socio-cultural condition of an organization dealing with temporal rhythms set by inter-planetary work systems. Even while many of the organizations studied have involved work coordinated across multiple time zones, they are all terrestrially based, intra-planetary. Typically, such analysis is grounded in the assumption that an organization's primary site of decision-making, its headquarters, determines the primary temporality according to which the other work times zones must be coordinated. Furthermore, although the prioritization of one time zone has logical advantages for managing multiple time zones, it fosters prioritizing the socio-cultural time management practices of one site to the detriment of ignoring others. As such, I was drawn outside of the time management literature in organization studies in order to locate research that foregrounds multiple cultural considerations of time within an organizational domain, with respect to scientific knowledge production. On this point, scholars in science and technology studies have paid particular attention to the social construction of time among scientists and engineers and the cultural practices through which time is enacted to structure standards for work performance and membership identity (Dubinskas, 1988; Marcson, 1960; Traweek, 1988). Still, the limit of sorting through comparable considerations of the relationship between time and work in scientific knowledge production within a large-scale organization was inevitably reached – particularly since no other study dealt with more than one physiotemporal rhythm, the order of time set by the patterns of a planet.

In seeking to understand some of the assumptions about the relationship between time and work within an organization housing an inter-planetary production of science and technology, I set aside the consideration that a comparable study would serve as an explanatory device. Instead, I turned to scholarship that focuses in the relationship between work and technological progress within a socio-historical landscape particular to the United States (Anderson, 1964; de Grazia, 1964; Dreyfus, 1992; Marx, 1964; Mumford, 1963; Nye, 1994; Smith, 1997). And I took cues from two works in particular at some remove from the work of rocket science. The first is a socio-cultural history that disrupts the popular idea that production work in the antebellum South did not meet the criteria of modernity due to the perception that agrarian work did not incorporate clock time (Smith, 1997). The second work is a critique of artificial intelligence and the notion that the physical environment can be represented without a physical relationship with the environment (Dreyfus, 1992). These two studies that focus on work in the agrarian era and in the post-industrial era, together, help to identify some of the underlying assumptions that were operating on the MER mission. I bring the case of the MER mission, Mars time, and inter-planetary work system management into conversation with time studies in organizations and scientific knowledge production, and I raise the possibility that these works broaden the approach that we can take in our interdisciplinary standpoints are heavily weighed down as they are by the necessity of our terrestrial locations.

Admittedly, I am making a complicated picture more complicated by calling attention to recessed assumptions and cultural practices that, while currently operating in the domain of interest, are not necessarily present in obvious material form. The added complexity, however, enables a more nuanced view. In lieu of presenting a diagram of the historical landscape, crossed with temporal dimensions, and multi-cultural aspects, I will begin this inquiry into the assumptions that naturalize the relationship between time and work in organizations by reminding the reader of the boundaries of the domain – large-scale organization of inter-planetary knowledge production – and the conditions of time as a social process and a technology that regulates the motions of work.

Simply defined, an organization is an arrangement of two or more people engaged in the production of goods or service through division of labor and hierarchy. The human-built organization is a large-scale technology, a set of processes organized to facilitate the accomplishment of an activity, made operational through material technologies and social processes. Its structure is not necessarily permanent; it is subject to changing shape in response to any number of externalities, social forces such as political, social, and economic climates, and internal activities such as everyday decision-making, culture, and demographics. Time is one of the essential technologies used by almost all organizations, as it provides a common point, a shared piece of information subject to little or none misinterpretation. Time's constancy as a global feature embedded in organizational infrastructures has supported its acceptance as a natural representation of nature. That is, clock time is a given, matter-of-fact, representation of the duration and motion of sunlight on Earth. And, curiously, this natural conductor of duration and motion retains its image as a natural element even when set within the domain of the non-natural, human-built organization, where anything technological is subject to innovation (material intervention).

Tracing organizational temporality through the changing relationship between time and work

This brings us to the first assumption about time and work that I will discuss, located in the idea that organizations develop along a Newtonian timeline (partially demonstrated in the above definitions) in the same fashion that technology develops – a Darwinian process of the survival of the fittest. The presence or absence of particular technologies, such as writing, print, math, plumbing, religion, and, of course, time and rockets have been used to categorize communities along a timeline of social progress, primitive, traditional, and modern (Latour, 1993; Redfield, 2000; Verran, 2001; Wynne, 1989). Despite the fact that not all technological development fits within this ontology of social progress, demarcations of technological development along the Newtonian timeline of social progress have remained firmly fixed. However, if we reject the idea that not all technology in use maintains its position because "it works the best," a rejection that is grounded in technology studies (Bijker & Law, 1992; Hughes, 1989b; Latour & Porter, 1996; Law, 1992; Turkle, 1984; Winner, 1986), then we can interrogate the status of clock time in organizations by seeking to understand the cultural and historical forces that have supported maintaining the technology of standard clock time as though "it works the best." Such an investigation would allow us to foreground temporal relations within organizations and disrupt what may appear to be irrefutable cultural histories of the relationship between time and work in organizations.

The possibility of refocusing a popular perception of a particular organization's, or a community's, location along the timelines of social and technical progress presented itself in the work of Mark Smith (1997). Smith's work is an example of a cultural history of the relationship between time and work that disrupts the timeline of social and technical progress used to historically locate communities within particular production eras. In Mastered by the Clock, Smith uses archival records to demonstrate that the adoption of clock time among slaves and plantation owners preceded the Civil War. He presents evidence that the technology of timepieces was employed by some slave masters and slaves (although only the former were allowed to own timepieces) to manage temporal rhythms of work in agricultural society. Smith's thesis subverts the dominant discourse that the antebellum South was a society lagging behind the modern, progressive North, a framing of the South that made the work activities of agrarian work and slavery appear to be only located in pre-modern societies. And his research significantly blurs the popular timeline that links particular technologies as demarcations for social progress, opening up the possibility that with comparable studies a more discernable uncoupling could be achieved.

Taking a cue from Smith, in the following discussion the time and work relationship on MER is considered such that the cultural historical context of relationship between time and work is brought to bear on understanding the assumptions about time management in organizations and, in particular, the achievement of Mars time.

The official year on record for the MER mission is 2003, the year that the rovers were launched, categorizing the MER mission firmly as a project carried out by a post-industrial organization. The coordination of rockets, rovers, and ICTs enabled humans on Earth to send and receive information to space vehicles millions of miles away on Mars; all of which together constituted a successful production of technological capability and scientific knowledge. However, the work practices on the mission demonstrated that the production process was not entirely a post-industrial affair. By looking at the temporal rhythms of the participants, the MER mission was an operation representing three eras, (1) agrarian (2) industrial and (3) post-industrial, in the guise of one, post-industrial. To explain the significance of this, I layout the three eras of production organized according to changing arrangements within the relationship between time and work. Looking at the transitions that demarcate these eras will offer insight into the process by which the relationship between time and work: time goes from being understood as a direct experience between humans and nature to being a direct experience between humans and a mechanical representation of nature. Then, I explore what it means to situate the work of MER mission operations along this time line.

The three eras of production, of the organization of work, are pre-industrial, industrial, and post-industrial, typically distinguished by paradigmatic shifts in the conduct of work, the socio-technical modes of production, and the political economy of consumption although I do not address this latter point (Bell, 1999; de Grazia, 1964; Ellul, 1964; Mumford, 1963; Thompson, 1967). But there are another set of categories used to frame the same time periods that give more presence to human factors: the agrarian era, the industrial era, and the knowledge economy. Across these three eras we can see changes in the phenomenology of work, in the process of how work is carried out and where it is situated, and in the ways in which time is defined (Anderson, 1964; Bell, 1999; Bluedorn, 2002).

The shift from the agrarian era to the industrial era (mid-1800s) was a shift from agricultural work to factory work as the primary mode of production. Nels Anderson, an urban sociologist,[55] marked this shift as a move from the cultivation of nature to the operation of machines (1964). Of the many work processes which constituted work in the agrarian era, the temporally distinct process was the coordination of work according to solar time or the relationship between the position of the sun relative to the location of work (or the workspace). The physiotemporal rhythm of solar time provided a framework to which was set the production process of agricultural growth (as seasons

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[55] Anderson's research on the socio-technical processes of work includes seminal research on hoboism (1974). His ethnographic research among hobo communities is an example of an urban community that operates with distinct sociotemporal rhythms that are functional despite existing on the outside of mainstream society's normative temporalities.

and sunlight are needed for growing) and the sociotemporal rhythms of work practices and habits.[56] Clock time was present but it was not the primary temporality affecting agricultural growth (Landes, 2000; Prerau, 2005; Smith, 1997). With the growth of the industrial era, fueled by the adoption of inventions such as steam engines, railroads, and electricity (Cooper, 1998; Hughes, 1989; Marx, 1964), solar time was displaced by clock time as the prime time by which to coordinate work.

The new workspace, factories instead of fields, no longer relied on solar time for the production process as electricity lit up factories and powered the processes by which goods were produced (Anderson, 1964; de Grazia, 1964). Clock time replaced the physiotemporal rhythm set by the sun with a rhythm set by the mechanical representation of solar time. Here is the point at which clock time as synonymous with time begins to take shape, a collapse of one system of representations with the other. For, without a rival temporal framework or reason to keep present the fact that clock time was a support technology for ordering or managing everyday life, clock time slipped from standing in lieu of solar time to being granted the status of a producer of physiotemporal rhythms. I locate the process by which time has been naturalized in two specific activities that have shaped industrial organizations: the adoption of standard clock time and Taylorism.

The adoption of standard time in the United States, on November 18, 1883, was predicated by the work interests of scientists and the railroad industry. Until 1883, time

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[56] This category clearly draws on Zerubavel's (1981) use of the term temporal pattern to denote reoccurring three particular rhythms: physiotemporal, biotemporal, and sociotemporal (discussed in Chapter 2); and, Lefebvre uses the term temporal rhythms to refer to the process of time and motion that is enacted through humans carrying out everyday life (Lefebvre & Elden, 2004).

was multiple in that there was no formal order to the setting of clock time. Every town, state, company, household, and train depot, could and did run according to their setting of clock time (Abbe, 1955; Bartky, 1989; Jespersen & Fitz-Randolph, 1979; Prerau, 2005). Some count over six hundred settings of clock time. For scientists, this posed a problem in the knowledge production process as demonstrated in the case of Cleveland Abbe's (American's first weatherman) research problem.[57] Abbe had instructed some eighty meteorological observers to gather observations of the aurora borealis from locations across the United States. Upon reviewing the data, Abbe had difficulty comparing the observations due to "the errors of the observers' clocks and watches and even the standards of time used by them." Many of his observers had obtained their location's time from the railroad's clock, railroad time, which while "accurate" varied by location. The railway station clock had replaced the church bell tower as the arbiter of segmenting the day; rail time, enforced by the regular arrival and departure of trains, provided a technological source for setting daily production activities. Abbe's solution to his work process problem was for temporal synchronicity to be distributed through the coordination of standardized railroad time.

Scientists eventually succeeded in convincing railroad companies to impose a uniform standard time, without federal mandate. Before pointing out the assumptions about time found in the initial oppositions of the railway industry and of the public, it is interesting to note that initially it was the work of scientific knowledge production rather than the work of transporting people or products that spurred the momentum to

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[57] On the other hand, this time period has been brought up as evidence that multiple time is possible, sociologist of time and temporality, Georges Gurvitch (1964) has a thought-provoking interrogation into the loss of time that takes place in the unification of multiple temporalities needed for ordering the social world.

standardize clock time. The two main groups advocating standard time were the American Meteorological Society and its Committee on Standard Time; and, only eventually, the General Time Convention, a group comprised of railroad representatives (Abbe, 1955; Bartky, 1989). For the railroad managers, the initial appeal by scientists that uniform time would ease railroad scheduling work was surprisingly not heartily embraced: they were satisfied with the use of individual timetables for managing train lines and the relationships to the multiple times. Managers argued that the problem itself was not a major one, even for the traveling public:

> ...for the great body [customers] travel only short distances, and to them the proposed uniformity is of little or no importance. Indeed, multiple times affected a minority of the public: No problem existed for those travelers residing in the large cities – New York, Chicago, Boston, and so on-whose local times were being used by the regions' roads. Yet, for a traveler whose home city might use either a particular railroad's time or its own local time, there was some confusion. The solution was simple, however: *Ask…* [my italics] the solution became habit: One knew the problem existed, so one always asked. [Bartky, 1989][58]

This rationalization, that the customer need only ask what time it is in order to sync up with local time replicates the assumption about time on the MER mission, that scientist need only ask what time it was on Mars to adjust their work rhythm to it. This way of knowing time assumes that numerical representation is a sign system sufficient for ordering the rhythm of the activity/work/travel that the person is in the midst of negotiating. This is an epistemological problem of knowing time that I focus on in the

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[58] This description of railroad managers' response to time management issues could be considered as a precursor to infrastructure maintenance work, that I discuss in Chapter 2; wherein, work necessary to the organization's (the railway) production process (travel of goods and passengers) is borne by individuals without compensation. The passenger, the customer, is relied upon to figure out how to participate in the organizational process and their willingness is relied upon by the organization.

second section of this chapter –that knowing time through information technology is comparable to, compatible with, or exactly the same as, knowing time through nature.

Public opposition to the adoption of uniform standard time demonstrated a resistance to enacting a relationship between clock time and work, in particular where work relied on solar time (Riegel, 1927).[59] Dissenting farmers were, in part, giving protest to the establishment of a standard that ignored their use requirements for time. Like members of the communities in Smith's (1997) study of antebellum South, farmers were imbued with the characterization of not being able to be entirely modern – slow and incapable of enacting work according to the regular pace of mechanical time. This characterization could serve to explain a stigmatization that might occur in 2003 if one were to point out the arduousness of enacting Mars time as interchangeable to clock time. But it was certainly not this erroneous stereotype of farmers that underscored their opposition. Rather, we can imagine that in their opposition was the physical resistance experienced in the attempt to decouple rhythms of work and leisure from solar to mechanical time. Recall that this change to temporality involves reorienting to a new temporal rhythm while discarding one already established and experienced since birth (Zerubavel, 1981).[60]

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[59] Also known as God's time – another group of dissenters were priests who decried the move as a rejection of God (Riegel, 1927). Riegel notes that an ordinance in favor of the new time was vetoed by the mayor of Bangor, Maine on the grounds that it was unconstitutional, being an attempt to change the immutable law of God, not desired by the people, and hard on the workingman by changing day into night.

[60] The resistance to clock time by the farmers could be seen as a struggle of labor, a resistance to centralizing the kind of work that manufactured alienated organization members. It could also be considered a resistance to industrialization, to the machine, a form of Luddite-ism. Or, resistance to standard time may have been a resistance to the collectivization of temporality – the construction of a homogenous temporal rhythm.

The adoption of standard clock time set the stage for coordinating with time precision the movement of people, technology, and information (Anderson, 1964), prefiguring **the socio-technical process of Taylorism**, which would assist in shifting time from a technology that you worked with to a technology that you worked to. This brings us to the second of the two processes that have served to fashion clock time as synonymous with time through a collapse of one system of representations with the other. Within the new primary workspaces of factories, Frederick Taylor (1911) introduced scientific management – the use of standard clock time metrics to break work processes into standard measurable and interchangeable units. Organizing humans and production processes became a numbers game, where the humans were responsible for keeping up with particular units of time for task completion. Taylor's achievements would set a course for organizational arrangements of time/work that have yet to be adjusted or corrected.

Taylor used a stop-watch to collect data on the length of time it took for a man to complete his work tasks. The average of these time-motion studies set a metric against which employees had to set their production rates.[61] And, no longer measured by whole increments of hours, the compensation for production was broken down to individual piece rates. The time-work metric of scientific management came to define the very

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[61] An important part of Taylorism that has been left off out of the discussion of time and work in organizations is that he stated a two year study period was necessary for understanding the relationship between time and work and setting the metric for production. The duration of study was important for ascertaining the multiple ways in which work was done, that is the same job by different kinds of people, during different periods of time, and using different tools. Hughes (1989) suggests that the qualitative aspect of Taylorism was prompted by Taylor's wife who had a PhD in psychology. Taylorism and scientific management bear no mark of this aspect of Taylor's research; instead, they have a dirty cast to them of time technicians with disdain for human factors.

relationship of time and work in organizations. Enacted by management of the largest factories, e.g. the Ford factory, the practice was diffused throughout organizations, establishing scientific management as the primary method by which to set up and to evaluate the relationship between time and work in organizations (Alvesson, 2003; Hughes, 1989; Jun, 1994; Morgan, 1986; Thompson, 1967). How this practice becomes embraced as the primary tool for evaluation is another story about numbers, objectivity, and the Enlightenment (Porter, 1995). But without taking up that story, we can note that forms of Taylorism abound across public and private organizations, both small and large-scale organizations, and regardless even at times of its only marginal fit (Bowker & Star, 1999).

With the adoption of standard time and the practice of evaluating time and motion through Taylorism, the relationship between time and work came to be defined as a measurable relationship between clock time and work that was uniform across space. From this standpoint of understanding time at work, I turn to look back at the last major shift in production eras. Unlike the transition between the first two eras, the on-set of the post-industrial era was not marked by a change in the technology of time. The years following WW II mark the onset of the post-industrial era, a period characterized by the technological diffusion of information communication technologies (ICTs) invented for military operations (Bell, 1999). The additional moniker for the latest era was the knowledge economy, denoting that information was the central object of production and consumption. Clock time had become so embedded in the organizational infrastructure that most people assumed it was an element of the natural world as opposed to a construction of the human-built environment (de Grazia, 1964;

Ellul, 1964; Marx, 1964; Thompson, 1967; Toffler, 1971). Time management took on a different cast in organizations where members sat at desks in their production process rather than standing on a production line. But knowledge production work was shaped by the same temporal constraints that shaped factory work. The same subordination of task completion to a predetermined sociotemporal rhythms set to mechanical clock time existed in office work as it did in factories. While there is a multitude of legal and literary activities expressing human resistance to work metrics dictated by clock time, the resistance to the rhythms of clock time among organization members of post-industrial organizations is not necessarily comparable to the farmers' resistance to clock time. Unlike for members of post-industrial organizations, the resistance of agrarian and industrial era organization members may be located in the physicality of the requirement to shift their sense of time from solar time to clock time.

This schematic outline provides a frame for locating the relationship of time and work on NASA's MER mission. The date of NASA's birth, 1957, locates our organization in the post-industrial cold war era: it is a knowledge producing organization founded to produce extra-terrestrial scientific knowledge and technological apparatus. As an organization that was created in (political) response to the technological achievements of the Soviet Union, NASA was also responsible for producing an international discourse on the state of modernity and technological prowess of United States.[62] Forty-six years later, still operating in the post-industrial era,

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[62] Although the Soviet Union irrefutably came in first on several counts – sending the first dog (Laika), the first man (Yuri Gagarin), and the first woman (Valentina Tereshkova) into orbit and the first nation to attempt to land a spacecraft on Mars – much of the literature on the space race minimizes this list, primarily acknowledging the launch of Sputnik the status of a first great achievement. Gagarin receives the most mention, Laika the second most, and Tereshkova only

NASA's MER mission was undertaken in pursuit of similar themes. MER served not only as a transnational announcement of technological accomplishments in outer-space but as evidence of NASA's recovery as an organization after two catastrophic shuttle failures and an unsuccessful Mars missions. But the use by the organization of Mars time in the time/work relationship, as I stated earlier, demonstrates that the production processes at NASA were not entirely a post-industrial affair. By looking at the temporal rhythms of the participants, the MER mission was an operation representing three eras, agrarian, industrial, and post-industrial, in the guise of one (post-industrial).

Operating on Mars according to solar time locates the rovers in an agrarian era production process. The rovers' production process of data collection was coordinated to solar time on Mars: beginning work each sol (a Mars day) when the sun was up and ending work when the sun had receded. Although for the MER mission scientists the final object of production was not the raw data, for the rovers' it was. It was the rovers' physical relationship to solar time, to the natural world of Mars, that determined the temporal rhythm of data collection. The rovers' physical abilities were entirely driven by solar powered batteries – they needed sunlight to obtain the battery power needed for conducting data collection. So if we perceive of these batteries as the necessary

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occasionally. When Laika is referred to, it is usually to subtly point out the inhumane treatment of animals (Laika died in orbit) and the records of public outrage (in the United States) over the brutality of sacrificing a dog's life. Tereshkova's space flight preceded Sally Ride by twenty years and yet, in the United States very little popular history of space flight calls attention to this point. In a recent account of the role of female of astronauts (or the attempt made by a group of women to become astronauts during the space race), Margaret Weitekamp (2004) puts her finger on the subtext of President Kennedy's 1961 (May 25) declaration that America would reach the moon before the end of the decade: it was a move to re-define the metric by which a winner of being first in space would be judged. Following each of the Soviet's firsts, the US could only respond in kind. However, by declaring that reaching the moon was the ultimate test of space dominance and technological superiority, the US had a chance at setting a first.

element that induces the rover to power on in the morning, carry out work, and power down for the night, then we can allow this space vehicle's activity to be construed as an operator carrying out work dependent on coordinating with the experience of solar time.

Understanding the rovers' work as agrarian era solar dependent work foregrounds time as a physical experience. This point, however, seems to have gotten lost in the move from considering the rovers' work on Mars to considering the humans carrying out their work in a post-industrial organization on Earth. The rovers' operators, mission members located millions of miles away, were divorced from the physical experience of the natural world of Mars. Instead, their conceptualizations of the natural world on Mars were constructed through representations of that world received through data downlinks and the expectation of pacing work according to clock representations of solar time, Mars time. The data downlinks were sources of images of the Martian terrain, the rocks, the dirt, and the sunsets but these images were not intended to provide a source for terrestrial mission members to tell solar time on Mars. Rather, the process of sending commands to obtain images and receiving images were points along a timeline of conducting mission ops that served to provide the perception of working according to solar time on Mars.

What does it mean that scientists were coordinating their work according to a temporal rhythm that was set to a version of time constituted by a temporal relationship for which physical experience was essential? I argue that by extension the scientists' work was located in an agrarian era of production – the scientists' relationship between time and work was set to the motions of the sun. But, unlike the rovers, the scientists received *no* physical experience of agrarian temporality. In other words, the scientists were required to manage a relationship between solar time and work without the experience of solar time. The mission ops environment was not constructed to simulate the experience of sunlight on Mars. In fact, the environment was constructed countering this experience – florescent lighting, black-out curtains, and the ICT displays of numerical representations of solar time on Mars; indeed, support technologies often added to time management confusion. In Chapter 5, on page 181 (Figure 30), I use two images, screen captures of two animations on the JPL website, to demonstrate the anthropomorphization of the rovers. In the animations, the rovers are still images situated on a Martian landscape that constantly updates their respective relationship to the absence or presence of sunlight, allowing viewers to see the rovers "experiencing" solar time on Mars. These images initially caught my attention because they provided precisely the type of situational attention to the solar time on Mars that I thought was critical for terrestrial mission members.

Instead of receiving sensory experience simulating solar time on Mars, the scientists received a sense of solar time on Mars through numerical representations modeled on clock time. *Mars time was a representation of a representation of temporality on Earth*. Mars time was comprised of the same components as clock time, which is to say hours and minutes, with the adjustment that the clock ran forty minutes longer each day. But here is where I locate the second assumption that girded the enactment of Mars time. The act of exchanging one temporality for another assumed these two planetary temporalities were analogous parts of one big clock and thus interchangeable units. This is an assumption about knowing time through numerical representations of nature as opposed to physical experiences of nature. If we assume that time can be known through representations then we can construct multiple representations of times and interchange them. But if there is a physical component to knowing time, how can one person experience, or live in, multiple times simultaneously? A question that helps to dig further into the underlying assumptions supporting the temporal incongruities of agrarian relationships in post-industrial operations is the nature of the conflict between knowing time through representations vs. knowing time through physical perceptions. In the following section, I explore this consideration by drawing from a critique of artificial reason (Dreyfus, 1992). The parallel that I am attempting to establish is between the role of the body in organizing and unifying our experience of objects (intelligence) and the role of the body in organizing our experience of temporality. Starting from the theoretical considerations already investigated by Dreyfus, a case could be made for organizing the relationship between time and work in organizations with attention to the process by which time is enacted through physical experience rather than in the current relationship whereby time is reacted to through numerical representations.[63]

Leaving the body behind

The assumption of clock time and Mars time as interchangeable units presupposes that clock time provides a temporal pattern of the experience of the phenomena of time through numerical representations. This temporal pattern is

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[63] This point dovetails with the aims of human-centered computing (HCC) to construct work arrangements that centralize how humans do their work in situ rather arrangements of work that are constructed in the abstract.

assumed to be so completely embodied that it can be applied to order the phenomena of time in any space, in outer space, on another planet, while the human body left behind on Earth is able to perceive and enact the modified temporal pattern without being there. In trying to make sense of the nature of this assumption and expectation, I recall encountering an unexpected disposition among members of the mission community – that human factors were not considered in relation to the same laws of physics used to coordinate the distribution of time and space for the space vehicles and the communication of data. Considerations of the changing properties of physical materials as they moved through space mattered to the launch, landing, and operation of the rovers. And yet while mission members were not physically on Mars, they were nevertheless abstractly moving through space and time. Attention to the effects of time and space dislocation for the humans was marginal at best.

The treatment of astronauts, however, points out that paying attention to human factors, to the physical and mental experiences, of time and space dislocation is not atypical. Drawing a comparison between the ways in which astronauts are prepared for space travel and the mission members for managing extra-terrestrial time, the mission members did not receive the same attention to managing the external stimulus during the navigation to extra-terrestrial space. Using this comparison in conversation with mission members met with little agreement; the work of astronauts is "incomparable." Astronauts have such an ideology encrusted pedestal beneath them that even members of the community closest to them refuse to draw comparisons between their work and the work of astronauts. The astronaut distinction was such a strong part of the work culture that drawing comparisons between experiences of astronauts and mission members such as sleep deprivation and cognitive dissonance was sacrilegious. Nevertheless, what is special about the astronauts that matters here is that the attention to human factors that they receive is due to the fact that their human bodies are physically situated in space, while the mission members' outer space was a journey of abstraction. Even while experiencing some physical affects of temporal dislocation, mission members remained enveloped in the disposition that abstractions conducted while grounded on Earth were not weighed down with complexity of physically relocating space and time.

Another resistance to drawing on astronauts as a comparative was that it touched on a significant debate between mission members concerning the direction of Mars exploration: was it best to send humans to Mars or ever more sophisticated space vehicles. Responses to the problem of time management problems on site could almost be linked to which side of the debate one situated oneself. For the "humans to Mars" camp, the response was a re-direction of the issue into the future – such an issue could be resolved by sending humans to Mars. Such a response never allowed the conversation to remain on the present issue or, for that matter, on the possibility that the present issue would be repeated multiple times before a Mars mission sending humans could take place. On the other hand, for the "robots on Mars camp," the response was a re-location of the issue, shifting it from being a human problem to a computer problem that could be addressed with a new system/software/program. Although the move reframed the issue as a hardware problem, it still allowed for the conversation to remain grounded in the present as well as considerations for subsequent missions. I found the responses of these mission members quite compelling as they gave me the impression that there was an underlying current of faith in the machines that I thought had been dispelled after the failure of scientists to produce artificial intelligence (AI). When I encountered this undercurrent in another situation, observing mission members work to resolve data collection issues through computer solutions (not just software bugs but modifications to a program) rather than address social processes, I attempted to bring it to the surface with the comment, "Don't you guys know that AI failed?"[64]

My remark was impulsive but it was intended to interrupt the assumption that computers were the key to managing the work processes of data collection and analysis. No one claimed that they believed AI to be a reality or that the computers could be made to conduct all of the activities of the knowledge production process being carried out by mission members. Yet, the way in which some of these members talked about computer solutions to mission operations breakdowns led me to continue to question how the design, management, and evaluation of socio-technical processes were being informed by the notion that computer reasoning was *the* answer to solving problems. This is where I turned to Hubert Dreyfus' (1972) work on the failure of artificial intelligence to realize that faith in computers was something more than technological determinism: it was also an assumption about the possibility of constructing representations of the phenomena in the world *without* a representation for the process enacted, or the role played, by the human body. Mars time was a relationship between time and work that necessitated Earth-bound humans immersed in an industrial era time/work relationship to abstractly manage an agrarian relationship between time and work that relies on the physical experience of solar phenomena. The notion that humans

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[64] This comment was not informed by the distinction between Research AI and Engineering AI.

could abstractly manage the rendering of the solar phenomena on Mars time through numerical representations of terrestrial time overlooked the essential element of working in accordance with solar time – the physical experience of solar phenomena. And, the pervasive sense that work of inter-planetary mission operations could be successfully managed with the "right" representations in the "right" order helped to explain the assumption that the operability of Mars time could be based on the simple modified technology of clock time.

The assumption that the temporal pattern of clock time can be relocated to and rendered operable on a planet where the physiotemporal pattern is asynchronous to Earth is based, it seems to me, on the same assumption underlying the failure of computer scientists in the 1960's to produce AI. The failure of good old fashioned artificial intelligence, or GOFAI, as philosopher Hubert Dreyfus (1972) points out, was due to the not only false idea that the world could be entirely represented through values and arrangements of these values into patterns but the idea that machines could then replicate human information processing using the rules and facts, used by humans, to navigate these values and patterns. Dreyfus critiques artificial reason through psychological, epistemological, and ontological assumptions. It is primarily his conversation on the role of the body in intelligent behavior that I am drawing from here. The project of AI was to produce machine intelligence: a computer that could think and negotiate the world exactly like a human being and, even better, given a computer's capacity to run simultaneous complex calculations and contingencies with none of the human factors. Dreyfus' GOFAI interlocutor, Marvin Minsky, held the position that machines could be constructed to carry out all the same activities as humans –

computers (metal machines) and humans (meat machines) were one and the same. Both respond to the world through the stored set of values that represent the world and patterns that account for the various sets of interacting values.[65] A simpler version of this statement is that Minsky believed both could play ping-pong while Dreyfus argued otherwise.

The mere physicality of embodied consciousness of the human body draws out the differences between these two standpoints. Minsky's position was grounded in the Cartesian understanding that values can be assigned to the world and a computer can be programmed to know the world and react to it through pattern recognition. Dreyfus' position, on the other hand, was grounded in a Heidggerian understanding that values are meaningless until enactment through the human body takes place; in other words a hammer is not a hammer until a hand uses it to hammer. Dreyfus' argument was that machines could not be constructed to perform embodied information processing, the performance of which entails three processes: anticipation (or a response set in motion to partially determined data), figuring the whole before understanding the parts (or jumping to a conclusion), and enacting the response set in motion to the partially determined data. With the capacity to process information in this manner, humans can operate in the world without having to complete the infinite task of formalizing everything.

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[65] For a future version of this chapter, I imagine starting at this point, going into a body of thought that explores time through phenomenology. I did not begin here because my interest is in constructing a theory of temporal being that is particular to large-scale post-industrial organizations. Heidegger's (1992) notions on temporality and being with one another in the world provide some phenomenological grounding towards this end.

But if machines could not be made to operate like humans, could humans be made to operate like machines? One thing that would need to be addressed and radically refigured would be the role of the human body, and here we can follow Edwin Hutchin's (1995) description of attempts to remake the person in the image of a computer. While Hutchins is referring to the past direction of disciplinary ambitions in cognitive science, the process that he describes is analogous to organizational practices at NASA. Preceding the events on the MER mission by approximately thirty years, was an incident aboard NASA's Skylab that captures these efforts was brought to my attention by John O'Neill (2008). Henry Cooper's (1976) account of NASA's first space station (1973 -1979) highlights a revolt by the third crew to inhabit the space station. It was a revolt against the measure of time – the over planning of the astronauts' days, a schedule of activities precisely set to a time table constructed by mission controllers on Earth, humans who had never experienced the temporal rhythm of conducting work in zero gravity. Many of the science experiments took longer than the time allotted because the allotted durations had been established by timing the conduct of the experiment Earth. The members of Skylab, Gerald M. Carr, Edward G. Gibson, and William R. Pogue, were not shy about calling attention to the breakdowns of technologies and social processes and the scheduling of experiments. They were busy from the moment they awoke to the moment they went to bed, with experiments having been scheduled even during meal times. The astronauts vocal grumblings were unprecedented (the two previous crews had not complained about the timetable) and earned them adjectives such of bitchy and explosive. After refusing to work or directly communicate with mission control for one day, the astronauts finally got the attention of mission control and the schedule was slightly relaxed. This relationship of time and work clearly rings of industrial era Taylorism. In the final analysis, Cooper describes this revolt as a conflict between man and machine: mission control had tried to turn the astronauts into machines but the men refused to be robots. This refusal came about only after the astronauts experienced time management failures. In the words of Pogue, 'I came to realize that what we were doing was taking a human and making him function in a way that he was not designed to do… at this rate I made more mistakes, it was a gross failure (Cooper, 1976).' Cooper's conclusion that following this event NASA learned that astronauts needed more time to themselves while conducting missions is arguable. But the consideration of these lessons about time management and human bodies in relation to grounded mission members returns us to consider the human body and Mars time.

If working according to Mars time required severing the experiential aspect of the relationship between solar time and work processes and replacing it with the information processing aspect of telling time by reading a clock in industrial or post-industrial work, then it could be said that the role of the body was removed from the temporal rhythm of agrarian work. To this point, it is not a matter of whether or not mission members intended to produce mission ops that configured humans as machines through expectations of information processing sans body. The underlying assumption in the event demonstrates the continuation of constructing temporality in organizations along a continuum of distancing time and human motion and allows us to make some sense of an organization's use of agrarian time without recognizing it as such.

Returning to the time change first noted at the start of this chapter, while the standardization of atomic time had little affect on day-to-day time management it was an important consideration supporting the notion of accurate temporal ordering for the work of scientific knowledge production. If the development of time and work, and standards such as clock time, are re-inscripted, as they have been historically, through the work of scientists and organizations, there is reason to pay particular attention to the public representation of the success of Mars time. This representation implies that success of the temporal pattern of clock time is a universal phenomenon; that with this basic set of values, humans can be re-programmed to respond to any pattern.

The success of the MER mission promulgates the viability of space exploration, the extension of human life into extra-terrestrial territories, and the reputation of a country's technological prowess to defy nature. In this context, thinking about MER mission ops as agrarian work might encourage a few smirks. But rather than an indictment of intellectual regression, this temporal configuration suggests some new ways of approaching issues such as human bodily resistance to multiple temporalities and time management across temporal rhythms. Time management issues on MER support returning the human body to the foreground in the relationship between time and work, and considering the particular temporal rhythms produced in the environment of an organization

These conclusions are not being put to rest here. They will be present and unsettled, to some degree, in the next chapter where I consider the discursive construction of the rover as member rather than tool. Then, in my concluding chapter, I will revisit the issues I have raised here in relation to the particular organization of the MER mission and the general condition of terrestrial time management.

Chapter 5

Membering the Rover

Serving humanity like two canaries in a coal mine, the Mars Exploration Rovers had been rocketed 35 million miles away from earth to retrieve evidence that water had once flowed on Mars. The twin space vehicles were operated remotely by NASA scientists and engineers located at a terrestrial worksite in southern California and safe from Mars' poisonous atmosphere. Powered by solar energy, the rovers worked the dayshift on Mars, recording chemical compositions and terrain images, and transmitting these images to Earth before shutting down for the night. Conversely, the community of scientists and engineers were required to work while the rovers were "asleep" on Mars and to retire from work while the rovers were "awake."[66] For a small group of social scientists (of which I was one) tasked with studying the work practices of remote planetary science, the determination of which work-shift to follow, the scientists' or the rovers', seemed simple at first – "*You* are our Mars," one social scientist explained to members of the Martian science workgroup. But as my familiarity with the domain of the mission grew, so grew my sense (and that of my co-researchers) that the work practices of extra-terrestrial science were not easily understood by foregrounding the humans and categorizing the robots as their tools. Rather, it appeared that Martian

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[66] "Asleep" and "awake" were used to describe when the rovers were powered down and powered on, respectively.

science was constituted through symbiotic collaborations between the scientists and the rovers – without the rovers on Mars to collect data there would be nothing for the scientists to analyze and without the scientists' analysis directing the rovers, the rovers' movements lacked scientific value. This understanding disrupted the previous notion of who, or what, to follow – the scientists or the rovers? In seeking to understand the construction of interplanetary work operations and scientific knowledge production, *who or what was our Mars*?

In the cultural anthropology of science and technology, we move around domains where scientific knowledge and technology are produced by epistemic communities (Knorr-Cetina, 1999; Latour, 1987). There, among our subjects of inquiry, we construct an understanding of the culture(s) of the community members. Typically, the boundary between human and tool is taken for granted, made clear by the distinctions of who is a human being and what is an object. We, however, may be limiting ourselves in this endeavor by stridently imposing the categorization of technologies as artifacts. The need to examine these limitations arose while I was conducting ethnographic research of a community of scientists who, during NASA's Mars Exploration Rovers mission, remotely operated space vehicles to produce scientific knowledge of Martian soil and atmosphere. I found the category of artifact could not contain the technologies with which the scientists were engaged. Exploring the culture of a domain of scientific knowledge production that we know *requires* both people and tools – science is produced by humans and artifacts – what explains limiting our definition of the community members to the humans? And to the point of the MER mission, how do we take into account understanding that community members may engage with tools as though the tools have the same capacity for independent action, whether it is true about tools or not? If we understand that the properties of the cultural processes of a group differ from the properties of the individuals (Hutchins, 1995) then the culture of a community explored without consideration of the variety of community members gives an incomplete account. Without attention to the full spectrum of membership positions, situated in power, expertise, or gender for example, we risk neglecting attention to relationships, exchanges, inducements– considerations which matter for understanding communication processes, work practices, and for elucidating invisible work.

In this chapter, I locate a socio-technical construction of an unexpected relationship. I had not anticipated encountering this relationship before going into the field. But it emerged nevertheless as an absolutely essential constitutive component of the temporal rhythm of work on the MER mission.

Humanizing rovers: from artifact to member

Following the traditional ethnographic exploration, I had first encountered members of the MER community working on site; and, I identified the scientists as the community members and the rovers as the artifacts. My initial sense of mission operations was gained through reading stacks of mission manuals and other internal reports on the MER mission. Through face-to-face conversations, I pieced together the functioning structure of the mission and the hierarchy of the community members as well as (some of) the processes for scientific knowledge production. The Athena Science team was configured by theme as well as by instrument. Each science theme group was responsible for a particular category of planetary science, although overlap was encouraged and not penalized. And for each of the tools aboard the rover (see Figure 27) there was an instrument team comprised of scientists and engineers.[67]

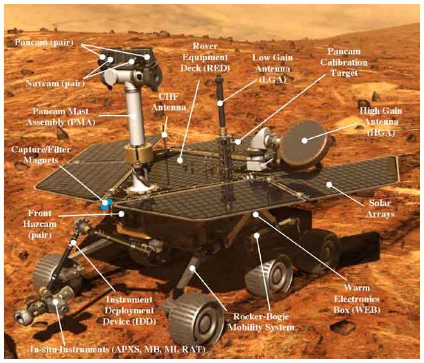

Figure 27 A rover "on" Mars and its suite of instruments

Gathering information from external news media,[68] from NASA news media, and from participant-observation among mission members, I found that common among these sources was the characterization of the rovers as mission members rather than mission tools. The anthropomorphization of the rovers by media was explicitly present inside the mission space and spilled into conversations between journalists and NASA press members who were regularly present to gather press release information. As well, public opinion was a concern to MER mission members for reasons of ego as well as funding. I observed some scientists counting the hits received to the MER

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[67] As I described in Chapter 1, the five science theme groups were atmosphere, geology, geochemistry and mineralogy, soil/rock physical properties, and long-term strategic planning; and the instruments teams: Alpha Proton X-ray Spectrometer, Mini-Tes, Mössbauer, Rock Abrasion Tool, Micro Imager, and Panorama Cameras.

[68] The primary source for public information about the rovers and the status of the mission was the public information offices of JPL and NASA HQ. Popular narratives anthropomorphizing the rovers were generated by NASA through its website in the weekly feature articles on MER. Journalists, regardless of nationality, were privileged to the same version of information.

website during different phases of the mission, and competing with previous records set by other missions. And sustaining public excitement and discourse was essential both in terms of satisfying Congress and securing funding projects.

Extracting from these discourses, I found that public (news media and popular fiction) and private (NASA) accounts of the rovers corroborated the narrative of the rovers as human. The public discourse of the rovers provided external reinforcement for the shaping of the rovers as more human than machine; and, inside NASA, the scientists' ways of talking about the rovers complemented the language used by news, and entertainment media. These anthropomorphizing narratives imbued the rovers with kinship, agency, emotion, and appendages. I will demonstrate how each of these took shape, and then discuss, specifically, the area of work practice where considering the rovers as members could have made a calculable difference in design and enactment.

Scientists and engineers anthropomorphized the rovers discursively, from the use of pronouns to the employment of birth and death narratives; and, through work practice, by attributing agency to the existence of the rover (an agency that could not exist without the rovers in operation). In the iterative process of data collection via tools, analysis by scientists, and further collection using tools, the scientists have absolute control over their tools. But, through particular acts of waiting for the tools to act, or emote, the scientists produced and engaged the rovers as collaborators. Below I list four attributes, and briefly a number of themes of anthropomorphization through which the rovers were constituted as human by news media, NASA media, and the popular press (radio, television, and print), and by the mission members themselves:

Kinship: a traditional category used in anthropology to map social relationships and familial lineages (Levi-Strauss, 1969). Several activities took place that granted the rovers' subject locations which mirrored those of the scientists. That is, the rovers' were related to the scientists through social relationships and the constitution of the rovers as subjects: a naming ceremony legitimized their conceptions and christened them with proper names; they were referred to as the progeny of the scientists; their dual inception was for engineering redundancy but which was fashioned as a conception of "identical twins";[69] and they were imbued with gendered identities.

Appendages: the space vehicles were discussed not as a composition of electronic parts but as bodies with appendages, both in design and in operation – arms, eyes, neck, and body.

Emotion: the space vehicles' technological status was often accounted for using adjectives descriptive of an emotional, physical, or affective state rather than a power or energy state. The rovers in other words were typically described as asleep, sad, sleepy, happy, and or pissed.

Agency: narratives of birth and death were employed to imbue the space vehicles with human temporalities of creation and demise; the rovers' human temporalities were used as rational explanations for expectations for the conduct of Martian science.

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[69] The status of being identical twins takes away from the equation the condition that the reason for having two is so that if one fails, the second can complete the mission. Taking this consideration, which is the logic of dual redundancy in engineering, into the lives of humans would mean that twins would be conceived to increase the chances that one at least one would live long enough to do something worthwhile.

The order of these attributes is not intended to reflect a hierarchy of importance or frequency of use.

Kinship, appendages, & emotions

During the design and launch stages of the MER mission, the space vehicles were referred to sequentially, according to their launch dates several weeks a part, MER-A and MER-B. Built in clean rooms, by doctors draped in gowns and wearing surgical hats and masks, the construction of the rovers took place in a setting that brings to mind human delivery rooms, see Figure 28. This similarity was not something that I learned about during my fieldwork. It is an example of my interpretation of something on the mission that I am analyzing from images. However, the following discussion on how the rovers were granted kinship status comes directly from events that took place during the mission.

Figure 28 Building a rover

The space vehicles were nicknamed "rovers" in reference to the manner in which they moved across the Martian terrain – roving, searching. "Rover A" and "Rover B" were used among mission members in lieu of the names first mentioned, MER- A and MER-B. Formally, the rovers were ceremoniously granted names shortly after they were launched into space.

Following the rocket launch was a period of gestation, during which time the rocket shed portions of its apparatus. The remaining components burned up in the Martian atmosphere, leaving the rover to drop to the surface of Mars ensconced in inflated white airbags. After rolling to a stop, the metal cocoon packed inside the airbag unfolded, and the rover emerged to unfetter itself from its (umbilical) cords and take its first steps onto the surface of the planet. Technically this process was called egress, but the entire procedure reads like a rite of passage.

Rites of passage have three stages (van Gannep, 1906), and the launch, landing, and egress for each rover maps precisely on those stages. The first stage of separation, where the subject is physically separated from the primary community, describes the launching of the rover via rocket into orbit. This stage has also been discussed as a period in which the subject is symbolically orphaned (a point which will matter later). The second stage, of liminality, describes the period of waiting wherein the subject is neither here nor there. Like the rover in orbit, no longer in sight of earth, traveling through outer space, while its community waited for news that the rover had reached the third stage, incorporation. In the last stage, the subject emerges with a new status, marked by new knowledge or the capacity to know.

During the stage of liminality, while the rovers were in orbit, a naming ceremony was held to announce that the rovers had been granted a new status. The naming ceremony, sponsored by NASA, Lego, and the Planetary Society, started with a competition among students in the United States.[70] Sofi Collis, of Scottsdale, Arizona and formerly of Siberia, won the contest and was invited to bestow the rovers with names in a ceremony with (then) NASA administrator Sean O'Keefe by her side.[71] The following is an excerpt from Collis's entry,

> I used to live in an orphanage. It was dark and cold and lonely. At night, I looked up at the sparkly sky and felt better. I dreamed I could fly there. In America, I can make all my dreams come true.... Thank-you for the 'Spirit' and the 'Opportunity'[72]

As 'Spirit' and 'Opportunity,' the rovers were produced as something more than hardware. They went from being something to being someone, through the endearment granted by an orphan whose own biography included geographic displacement, solitude, and hope. Indeed, once launched the rovers, like Collis, went through a rite of passage, orphaned and then re-membered. Collis was described by O'Keefe as having "in her heritage and upbringing the soul of two great spacefaring countries (Webster, 2003)." And with this statement, he appears to be acknowledging the 'other' great spacefaring country of Russia while his comment also seems to suggest that Russia's

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[70] It is interesting to note that together these three organizations demonstrate the cooperation of government, non-government, and private corporations in the exploration of space.

[71] Two of the nine judges were science fiction writers (one from *Star Trek*). The contest was sponsored by Lego (www.lego.com/rovers) and the grand prize provided for the winner and three family members to attend one of the launches at Cape Canaveral, Florida, Lego products, one year membership to The Planetary Society and a Planetary Society poster, and Lego products for the winner's school.

[72] From the Lego website (www.lego.com/rovers), as well NASA press release (Webster, June 8, 2003).

greatness is a part of the past. Once the naming ceremony had taken place, the rovers' new identities were respected in public accounts of the mission. Inside mission operations, these names were used interspersed with references to MER- A and MER- B.

Comparatively, this act of naming the rovers came at a much earlier stage than for preceding stand-ins for man sent into space forty-two years earlier. In the case of the H.A.M., the chimpanzee sent into sub-orbit, naming did not take place until his return trip to Earth in order to avoid providing the public with a identifiable astronaut to worry about (Haraway, 1989). Naming the rovers after rocket launch, but prior to landing on Mars, may have done the work of granting the mission a certain measure of success. Landing the rovers on Mars could be heralded as a partial mission success, salvaging a total mission failure in the event that the rovers did not survive the journey. After all, the construction of the rovers and a successful launch were still quite an achievement. The speculation of success ended in January 2004, when both rovers landed on opposite sides of Mars, emerged from their carriers, and began exploration of the Martian terrain. Their emergence, however, was less heralded as a beginning of the mission than as a signal to watch for the impending end of the mission. I will return to this when I consider the construction of kinship in terms of narratives of life and death.

In addition to the given names, the rovers' subject identities were fashioned through the scientists' use of third-person pronouns. Normatively, computers, satellites, pens and printers are referred to using neuter pronouns: it, they, or them. The rovers, however, were consistently referred to with both masculine and feminist pronouns: he and she. Sometimes, they were identified as twin sisters, most often in news media; and sometimes they were identified as male geologists, as discussed by the male mission members when referring to the design of the rovers which was intentionally set to mimic a human geologist's. The scientists were imbuing the rovers with agency, even if it was only supposed to be "imaginary" agency created by invoking the rovers through the pronouns of she and he, her and him. Referring to the rovers using male pronouns served as an aid in the task of determining how to have the rover conduct geology as their stand-ins.[73]

This anthropomorphizing language could be categorized, and was by some, as nothing more than humorous and sentimental, or simply an alternative to the use of "it." In contrast, I find that the pronoun usage, by journalists and scientists, calls for a separate treatment, a study of the vacillation of gender assignments and the contexts in which they were involved. The situation provoked questions about why this was taking place and what the possible effects might be on the engagement with gendered technologies. Did this usage have explicit or implicit meanings for the scientists?[74] Does this usage relate to any other activity? One possible explanation that I considered but ultimately discarded was that each rover was assigned a different gender in order to distinguish them from each other. Better answers to these questions require a more psychological exploration of the referents used by these particular scientists to inform their meanings of gender. In the context of my argument here, however, it is the

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[73] There are still several more aspects of the rover/scientist relationship to be taken up here, which will bring these considerations into direct conversation with scholars whose cork constitutes cyborg anthropology. In particular, Donna Haraway's (1997) work on kinship in the laboratory, and the relationship between animals used for technoscience.

[74] These questions raise the possibility of taking another direction, a conversation analysis of discussions among the scientists. Building on the work of Harvey Sacks (1992), the feminist analysis of conversation analysis has brought to attention gender construction in conversations of work (Ohara & Saft, 2003; Stokoe & Smithson, 2001).

constant presence of pronoun usage among the scientists that should be understood as constituting the norm.

Appendages

The description of the rovers' mechanical construction as human physiology further constituted the rovers as members, as subjects engaging in Martian science. This appeared through the depictions of the rovers' tools as appendages and the use of emotions to characterize hardware operations. These depictions were not limited to the public representation of Martian science. Rather, these depictions were employed as resources for conducting work, for sharing information about work processes among workgroups, and for bringing a physical, human, experience to extra-terrestrial geology.

The rovers were designed as stand-ins for human geologists. Regardless of the future of Mars exploration, whether it would, or will, continue through robotic or human missions, it would be beneficial to gather soil and atmosphere data. The main science objective, however, was stated as "a search for evidence of Mars' watery past," which could inform the question as to the existence of Martian life forms. And in conducting a search for potentially life supporting elements among the sediment of the Martian terrain, the rovers served as stand-ins for their human counterparts:

> Each rover is sort of the mechanical equivalent of a geologist walking the surface of Mars. The mast-mounted cameras are mounted 1.5 meters (5 feet) high and provide 360-degree, stereoscopic, humanlike views of the terrain. The robotic arm is capable of movement in much the same way as a human arm with an elbow and wrist, and can place instruments directly up against rock and soil targets of interest. In the mechanical "fist" of the arm

> is a microscopic camera that serves the same purpose as a geologist's handheld magnifying lens. The Rock Abrasion Tool serves the purpose of a geologist's rock hammer to expose the insides of rocks. (JPL, 2007)

Understanding the mechanical parts of the rover as representatives of human appendages mattered in the design and the implementation stages of Martian science on MER. In the design stage, the use of human appendages allowed the astro-geologists to plan for the robotic version of human geology. What tools would a human geologist take to Mars that the robot could take and use? How could the robot use the tools like a human?

During the mission, in discussions concerned with roving or with what a rover should do next and how, the prompt question was, "what would I do next?" and "how would I do it?" The scientists imagined what they would do if they came upon a basalt-looking rock, what tools they would use to poke it or taste it. A scientist arguing for a set of data collection to send to the rover would say, "If I was there, my next step would be to do such-and-such. And this is why the rover should follow this set of commands." There was a *tremendous* constraint to this enactment – the rover to human equation being used on the mission was that it would take the rover one day to complete the work a human would complete in 30 seconds (Squyres, 2005). Once imagining what a rover should do next, analogous to what a human geologist would do, the action had to then be broken down into a series of commands, involving point-by-point details that required collaborating with the engineers and scientists who designed and constructed the appendages (Wales, Shalin, & Bass, 2007).

As an abbreviation to explaining technical activity, the scientists would physically demonstrate the proposed course of rover activity, using their eyes, neck, arms, and fingers. These demonstrations occurred in conversations with engineers, who knew the technical constraints and affordances of the instrument's tools, and with other scientists, who may or may not have the same level of technical knowledge about the instruments. The constant use of the human body as referent for the rovers' instruments produced an accepted way of creating the work of astro-geology on Mars. The embodiment of the rovers' instruments brought the scientists physically closer to their Martian counter-parts, and enacted a physical dependency, or the need for collaboration, between them.

We can consider how these activities complicate thinking about the scientists speaking for the rovers, as ventriloquists for the rovers (Haraway, 1992; Hartouni, 1997). The normative view would be that the rovers served the scientists as devices that reported to Earth on the happenings on Mars. The scientists produced Martian science through their interpretations of data; their knowledge claims were grounded in giving voice to the silent data produced by the rovers. When we think about the scientists having to use their bodies as puppets, to simulate what the rover could or could not do, we have an image of the scientists as ventriloquist dummies of the rovers.

There were points of comparison that surrounded the activities described above. Many of the engineers, for example, working in groups that were responsible for writing and sending the technical commands to the rovers, as well as receiving data, viewed the rovers as hot rods, as vehicles that should be driven for speed; when they were asked what they thought the rovers should do, often they would reply, "put the pedal to the metal." Another comparison comes from the workgroup in charge of the instrument described above as the "geologist's rock hammer," the Rock Abrasion Tool. Referred to by its acronym, RAT, it was operated by a workgroup from the company Honeybee Robotics Spacecraft Mechanisms Corporation. Members of the RAT team anthropomorphized the tool in casual jest but not when it came to planning for commands. Sometimes they would talk about the RAT as though it were a rat, and using physical motions like a rat gnawing a piece of cheese when providing descriptions to lay-people. But these analogies were delivered with laughter, and usually only brought up in the private space of the workrooms. In observations of the RAT team at work, such analogies were not present. Images of the RAT as a cartoon rat anthropomorphized into a man was drawn by a non-RAT mission member (Figure 29), and the all-male RAT team was depicted as rats in a photograph that had been digitally manipulated, and hung outside their door.[75]

Figure 29 the Rock Abrasion Tool as a humanized rat

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[75] Another photograph replaced that one, which made some people a bit squeamish as it included a large rat with the face of the team lead and the team members as baby suckling rats. The picture that replaced it was one in which the members' faces were super-imposed over the faces of the Rat-pack, as in Sinatra, Dean, Davis, etc.

In the public space, the main science workroom shared by all scientists and engineers during operations, referring to the RAT as a rat was counter-productive. The RAT operated as a grinder not a blaster or a chipper. The RAT team was invested in having the precise representation of the operations of the RAT. Deviations from the appropriate depictions would be immediately corrected by the Honeybee Chairman, who was co-PI on the Athena Science team, whether it was made by one of his team members or anyone else on the mission.

Emotions

The use of emotions in relation to the rovers gave scientists and journalists a way of talking about technical conditions using physical states, rather than technical conditions with technical language. For example, consider two headlines that are demonstrative of using affective states: "The good news is that Spirit's 'mind' is updated and operating…"and, "For Spirit, Monday began much like any other day. She started her work day by taking some remote sensing observations of the sky and ground."[76] One may account for this shorthand as a condition of the public understanding of science, how to make technical jargon palatable for non-expert audiences interested in Mars exploration. Considerations of the public understanding of science would also help us to think through the many reasons that the rovers were presented to the public

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[76] The sources that maintained consistent coverage of the mission, such as Space.com, had journalists with consistent assignment to the mission. In addition, the press had their own section of the von Karmen auditorium from which to cover the mission, and received press kits at various stages of the mission.

as cartoons – mass appeal, identification, accessibility, and even kinship. As well, the relationship between NASA and Hollywood is a long one (McCurdy, 1997; Telotte, 2005; Wright, 1993), beginning in the 1960's with the Werner von Braun and Walt Disney collaboration (during the space race). Indeed, during the MER mission, I met several people who had previously worked in the movie industry. The idea of marketing NASA and its mission to the public is based in part on the need to gain public support for political funding attention. Another reason for disseminating information in such a way is to inspire future scientists and engineers, an activity of reproducing ideology and infrastructure (Hartouni, 1997). Despite these long standing rationales, whether it was necessary for the journalists to represent anthropomorphized rovers in order to talk about the latest conditions of the rovers or the status of the mission is still a matter of debate; and in the end sits to the side of the present discussion.

In the use of physical, affective, and emotional states among scientists working on the mission, we find more evidence of the discursive constitution of the rovers as subjects. There are many examples of the use of these states to talk about the rovers during the mission operations, rovers were described as: going to sleep (shutting down the rover while the sun was down), waking up (turning on and warming up the solar batteries when the sun was up), burping (or hiccups referring to glitches in the data), seeing (images taken by the cameras), touching (instruments that had direct contact with the surface of Mars), dying (when the solar batteries were weak or when they cease to charge), napping (pausing or temporary shut-down while the sun was up), being temperamental (not responding to commands), being sad (delayed response), and even lonely. And, although the rovers were "twins" they had different "temperaments." The daily discourse surrounding the status of the space vehicles sounded like discussions about people rather than machines.

The use of emotions as a shorthand for technical descriptions made it difficult to discern whether a scientist or engineer was masking a potential problem, making up for the inability to explain what was technically going on, or intentionally humanizing the rovers. Sometimes it seemed the case that the speaker did not know how to explain the technical conditions of a rover; thus, to explain the most important attribute that needed to be taken into account for the task at hand, an emotion or a human physical state was used. In other cases, the use of emotional states appeared as rituals for honoring the rovers. For example, each day of operations, at the start of which the rover needed to be powered on, the process was described as 'waking up' and was accompanied by a different song (as with the astronauts). For a short time, the song log was publicly available. For the most part, the songs were selected by the engineers or were requested by mission members.

Also, using emotions in lieu of hardware descriptions did do some work in demonstrating a certain closeness or familiarity between the scientists and the rovers. Usually, only when we know someone well do we allow ourselves to speak knowingly their emotional states. Scientists speaking for the rovers' emotional states is another example of the ventriloquism discussed earlier. It might be necessary to point out that the scientists are not, let's say, an overly warm and fuzzy bunch, closing meetings with hugs and kisses. Emotions and physical states of the scientists were not present in the public mission space, as the stereotype of the emotionless scientist would suggest. But emotions were present and expressed openly in the private spaces of the workgroups and through the anthropomorphization of the rovers.

Life, death, & agency: coming to life through the discourse of death

The condition of kinship, of social relationships, was created in part through the anthropomorphizing language that established the rovers as offspring of the scientists. Journalists and scientists, during press conferences, in print, and on the internet, referred to the rovers as children. The parentage of the rovers was most often attributed to the male scientist who served as principal investigator (Professor S. Squyres). The language of the claim to parentage was gender neutral – neither the word mother nor father was used. The claim to parent status was made using the language of birth, "Watching the rovers launch felt like giving birth;" and "Watching the rovers egress is like giving birth." These claims, as I witnessed them, were made solely by male scientists. The presence of women on the mission, in administrative, science, and engineering roles, did provide (me with) the sense that the male scientists were speaking of themselves as fathers. But they were, literally, referring to the birthing process experienced by women. Most interlocutors nodded in agreement or smiled in understanding. The birthing comments were made as statements, not questions, and left no room for response. Publicly, I never heard a woman scoff or roll her eyes in resistance. Privately, on the other hand, these statements were, on occasion, used to talk about the grand egos of the male scientists.

One exception stands out. During a press conference that was held to discuss hardware problems on Spirit, which could have left the rover inoperable less than three weeks into its mission, Pete T. (the mission manager) was asked by a journalist about his "sick child." When asking the question, the journalist first referenced previous public statements made by scientists about the rovers as their children. The journalist asked Pete to discuss the condition of the rover from a "parent's perspective." Pete's response raised the conversation a few decibels, as he refused to talk about the rovers as his children. It is not clear that Pete was one of the people who had specifically referred to the rover as his child. But in his refusal we can see an act of distancing the rovers from the humans, a return to objectifying an artifact which had been adopted into the category of human or granted provisional status as human.[77] If the rover was to "die," then it would be better for the scientists to have the rover seen as failed hardware, rather than a victim of parental negligence or infanticide.[78]

Underscoring the constitution of subject identities for the rovers through their status as children was the narrative of death that constructed the presence of life (Heidegger, 1996). Taking a piece of Heidegger's philosophical reasoning from Being and Time, and boiling it down, I think there is an argument to be made about the presence of life in objects through the actions of granting them death, by being clear

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[77] Loosely, the converse echoes moves made by NASA in the early days of the Space Race, following the launch of Sputnik 2 by the Soviet Union. Aboard Sputnik 2 was a dog. The act of sending an animal that was (is) a common household pet in America, an animal with its own prime time television show, Lassie (CBS, 1954 – 1974), allowed the US to demonize the Soviet Union – by sentimentalizing an animal that in many other contexts there is no traction for, such as communities in which dogs are not household pets or are used in the same manner as rats, mice, and monkeys.

[78] This shift in categorizing the rover brings up the different responsibilities which are present with respect to death. For example, if the rover, with the status of a child, were "to die" then the parents could be held accountable for their failure to support its life, or evaluated based on the criteria of neglect. By shifting categories, the scientist can re-define his responsibility. Along this line of thinking, he could have chosen to take up the argument that the rover was no longer a child, that having landed on Mars and left its pod, the rover was now an adult. This argument would have also served to re-define the scientist's responsibility over the demise of the rover.

about their expiration dates. Although this does not seem the proper context to take up this discussion, I wanted to make visible the presence of this reasoning in my perspective. Bringing the rovers to life through the discourse of death is not purely an abstract matter; it was, rather, an explicit way of talking about the rovers and working with the rovers.

Technically, the rovers were powered by batteries. And, their batteries, like any common battery, would eventually run out. More like cell phone battery than a watch battery, the rovers' solar powered batteries needed to be continuously recharged but at some point would be unable to take a charge. This condition was the primary reason for depicting the rovers as terminally ill – they had a condition that was fatal and there was nothing that could be done to remedy it. It was also possible that at any moment the rovers could stop working, for any number of known technical problems or unknown issues that could arise from operating a technology in an untested context. But these possibilities were not colored with the same urgency of impending doom that surrounded the battery life of the rovers. None of the rovers' assembly had ever been tested in the precise conditions in which they had to function, in an extra-terrestrial environment. While it was possible to simulate many of the physical challenges for the solar-powered rovers on Martin-like terrain, it was not possible to simulate the atmospheric conditions. Thus, if it wasn't the batteries that wore out, then it would be the inability of the solar panels to receive solar charge after being covered in Martian dust. Mission manger Mark Adler was quoted in an article titled, Mars Rover Spirit Update: 'Our Patient is 'Healed': 'We know the mission will end soon. The rovers land with a terminal disease, so we have to make the most of it (Rogers, 2003).'

The rovers' terminal status, grounded in the knowledge of the technical limitations of batteries – set in motion a sense of the rovers' life status. The enormous consequence of the rovers' end of life was fashioned through the organizational imperative to meet mission success criteria, which in turn would sustain the funding life of the organization. Thus, while the rover might die, its parental lineage would live on.[79] The formal criteria for MER mission success entailed the completion of six criteria and one of the six points was that the rovers would last through 90 sols (1 sol = 1 Martian day = 24 hours and 40 minutes) of operations. Thus, there were two time pressures driving rovers and scientists: one entailed the completion of mission success criteria within 90 sols; and the other concerned the inherently limited lifespan of the technology, made even more vulnerable in the untested terrain. For these reasons, the rovers were diagnosed from their moment of landing, as terminal – as terminally ill patients. They were depicted as terminal by the mission scientists and engineers as well as by the press to convey the possibility that at any moment and without warning either rover could lose functionality. Figure 30 contains two images of the rovers, presented to the public on the JPL website (April, 2005), to underscore their precarious life status.

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[79] This is a curious inversion of the notion that children carry on the life, legacy of their parents.

Figure 30 Affective rovers: these images from the JPL website demonstrate two points, the impending death of the rover, the emotional state of the rover, the human appendages on the rover, and the close relationship between the rover and nature (contrasted to the expectation of the rover as just machinery). (JPL/NASA, 2005)

The characterization of fleeting mortality emphasized the urgent nature of each "living" moment. Each movement planned was to be weighed against the looming shadow of death. But the terminal patient was not just an analogy; it was a diagnosis that required the patients' caretakers (the scientists) to take care not to work the patients too hard and drive them into the ground before their time. Planning ahead, but not too far ahead, required balancing the scientists' request for data and the physical health of the rovers. Keeping ever present the precariousness of time, decisions had to be made in directing the rovers that had the best odds of finding scientific evidence of a watery past on Mars, without however the guarantee that the rovers would remain functioning (as in the decision to send the rover (Spirit) to "Columbia Hills," an area well beyond the anticipated 600 meters of roving that was initially mapped).

By establishing the narrative of death to explain the loss of technical operability, a lifetime was created for each rover, a life time for which the scientists were responsible. The temporal rhythm, the sense of the physical experience of time, for a person facing impending death functions differently than for a person for whom death is an abstract notion, nowhere on the immediate horizon. Knowing when you are going to die most often shifts your perception about what is or is not important – what to spend your last days doing or caring about. Death is on everyone's horizon, and when it is the case that you receive an end date, possibilities do not appear so limitless. Time takes on an acute sense of preciousness, "of making each moment count." Locating that sense of preciousness in an artifact may create a relationship with objects that mimics the relationships the humans share while negotiating the knowledge of the impending demise of one or both of them. And, in the case of the mission, such were the relationships between rovers and scientists.

The temporal rhythm created by impending death, of urgency to make the most of precious time, is constructed through the actions and attitudes of the terminal patients and their caretakers. It is not always the case that knowledge of coming death alters one's attention to life. The point here though, is that the knowledge of death presupposes a presence of life. Shaping the rovers' technical limitations as "death" allowed the employment of the temporal rhythm of urgency to drive the sense of time on the mission.

One final comment on the rovers' life status is found in their capacities to reproduce. The aim of both rovers, after all, was to find the potentially life supporting element of water on Mars. Through their data collection activities on Mars, the rovers were at the forefront of the production of Martian life. The rovers' served as reproductive technologies, gathering bits that could be turned into evidence of life, once the data were received and processed through their partners (the scientists). In addition, as mentioned earlier, their reproductive capabilities are located in the production of new narratives of Mars exploration. These narratives found in media accounts, from news media to popular culture (including a cameo appearance in the film Transformers (Bay, 2007) and the feature role in a full length film Wall-E (Pixar, 2008)) intended to attract the attention of children, pique their curiosities and influence their futures towards the aim of producing new bodies of scientists and engineers for space exploration.

Exploring how these characterizations constituted subject identities for the rovers is not yet complete, though at this point it would be fitting to draw a cultural account of the transmutation of instruments into humans. By locating the anthropomorphized rovers within the work process, the account becomes an opportunity to understand how acknowledging the constitution of the rovers as such matters in the knowledge production process; it brings the claim of rovers as collaborators into focus. Through an examination of the attempts to simulate mission operations, in the weeks preceding the landing of the rovers, I want to foreground how understanding the rovers as members during the preparation stage may have allowed for establishing a work process that attended to the relationships between the rovers and scientists as collaborators rather than tool and user. Events that occurred during the simulation stage, such as communication breakdowns, misunderstandings, and unfinished socio-technical planning, were arguably instances that reveal the impossibility of interacting with a rover that was not yet alive, as it had not yet started the clock ticking for its ascent to death.

Simulating work without the time constraint of death

Several months prior to the nominal mission, which began once the rovers landed and completed egress on Mars, a series of simulations took place. As discussed in Chapter 2, these simulations, Pre Operation Readiness Trainings or PORTs, required mission members to come together in the mission space and to participate in run-throughs of the daily science processes. Each PORT was only a few days long, and, for many scientists, required traveling to California. The rover, on the other hand, was already there. A surrogate rover, as it was called, was housed in a building near mission operations, seen in Figure 31.

Figure 31 Rover in the sandbox with three mission members. To the right is the lander from which the rover emerged, once it arrived to Mars. In the upper left are the windows from which people can observe the position of the rover in the sandbox. During the PORT, signs were posted warning the MER mission scientists to stay out.

The PORTs brought the mission members together to practice mission operations in the unfamiliar time and space of the MER mission. The space, the several floors of a building at JPL, was specially designed and equipped for the MER operations. Time was specially designed too. Mission operations on Earth were scheduled according the operations of the rovers on Mars, meaning that the rovers set the temporal rhythms of work processes on the mission. An extra-terrestrial time standard was established – Mars time – a version of clock time that was modified to keep track of the 24 hour and 40 minute day on Mars. The scientists were required to do their work on Earth during the hours that the rovers were asleep, powered down, on Mars. Working to this schedule was part of the simulations. Two of the main reasons given for the PORTs, though they hardly needed justifications, were to work through the mission operations processes, allowing for unforeseen problems to occur with time for repair and to re-configure technology, information flows and decision processes if necessary. Had the PORTs been set up to actually simulate what took place on the mission, the mission members would have been able to engage kinetically in mission operations, which I believe would have given them a fighting chance of setting their temporal rhythms to Mars time.

During the PORTs, the scientists were not able to fully engage in simulating the work production process. Some of the reasons have to do with the timeline of work-space construction. The rooms for mission operations were not complete until a few days before the rovers landed on Mars. Computer access required procuring signatures and management approvals, and this in turn limited the number of scientists who were able to gain access prior to start of the nominal mission. Finally, the new software created to help the scientists manage the enormous amount of data returned from the rovers was not finished, bugs were still being worked out, problems were regularly encountered, and not all the scientists were even trained in how to use it. While I found these circumstances puzzling, it was taken in stride by most of the scientists as a normal way of putting together such an enterprise. We (the social scientists) were, of course, paying attention to different matters. And I observed that simulations taking place in an environment that did not replicate the actual environment made it difficult, if not impossible, to create the temporal rhythms of working with the rovers on Mars. According to some mission members, in the absence of actual rover participation simulating work was impossible because of the missing information, the missing imagination, and the missing momentum brought on by the urgency of the mission timeline and the potential demise of the rovers. Many scientists said, "When the rovers get there, it'll be different."

Here is the point at which we want to employ, retrospectively, an understanding of the rovers as members. This will shed light on why it was difficult for the scientists to engage in simulations that required the presence of a rover, even when there was a rover present! During the PORTs, an operational rover located at JPL would carry out the commands for data collection. This provided images for the scientists to analyze and for testing the rover's ability to negotiate roving un-even terrain. Each night when the scientists went home the surrogate rover would carry out the commands for data collection (see figure 5). Upon return the next day, scientists would receive data from the rover or verbal confirmation that the rover had collected data as planned. This would allow the scientist to begin a new day of running through mission operations, and the scientists' knowledge production process.[80]

Returning to work to complete another sol of simulation, and learning the outcome of their previous day's commands, the mood was anti-climactic. The temporal element of anticipation that emerges during an information exchange, where one person, having sent out a message, waits for information to return reception of the message, had been dulled by the knowledge that if the rover failed to carry out the commands "the gremlins," the engineers in charge of the surrogate rover, would physically manipulate the rover to where it "should have been." At first, the work of the gremlins seemed reasonable (and occasionally provided a good laugh). Physically moving the rover allowed the scientists to avoid getting stuck in one place, which at the same time allowed them to avoid working out a problem. A human geologist in the desert, so the reasoning went, has the capacity to quickly abandon an investigation and move on. And, the act of working out a problem occurring on fake Mars on Earth would not necessarily translate to figuring out a problem on Mars. But these helpful gremlins were actually mitigating the temporal urgency, the sense of unpredictability, and the threat of failure that would be present during the actual mission, when there would be no gremlins on Mars to help Spirit and Opportunity. As a result, there was no sense that the surrogate rover's life depended on the scientists' accuracy during mission

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[80] Data analysis, very simply put, describes the work of examining the images of Martian terrain; looking at an image (on a computer screen or projector) and interpreting it, using software and sight, and the spatial (Mars geographic location) and temporal context (solar time on Mars) in which the act takes place. Analysis work also entailed group discussions, negotiations, voting, and reviewing.

operations; they had the gremlins.[81] The scientists would wait for the team that *really needed them*, the rovers on Mars.

One issue this illustrates is the problematic nature of simulation exercises for work processes that require negotiations between two active engagers. In previous ethnographic research that I conducted among airline employees and customers, I found that one of the sources of miscommunications taking place at the airport counter was located in employee training (Wales, O'Neill, & Mirmalek, 2002). The airline employees were trained to manage customer relations, which includes the variety of regular travel breakdowns, through scripted handbooks and software. The absence of active engagement with real humans, active interlocutors that bring with them the elements of urgency and unknown reception and return of information, provided a false sense of the work processes. Experienced employees would encourage trainees not to worry about the discrepancy because once a trainee was dealing with actual operations the experienced employees would help them out with how things really get done.

For the mission scientists, the futility of the simulation exercises was located in the inability or unwillingness of some of the scientists to participate in what they considered work that was "too pretend." And, experienced scientists, like the

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[81] During the daily meetings run-throughs to discuss how the rover should approach a rock target to collect data, scientists would first imagine how they would collect data then imagine the rover as themselves collecting the data. Limitations with the rover's ability to move more than a few feet meant that it could take a day or two to get the images similar to what the scientists were imaging they needed to see to make an assessment, and that the requested movement may be easy for a human but may not be good for the health of the rover. Rather than work though these limitations sometimes the scientists would agree "to wait until it really happened," to figure out how to work through the problem. On such occasions, whether a groups' inability to reach a decision by the allotted time or an individual's tardiness to a meeting, there was a sense of ease, for the most part, and such deviations from "optimal performance" were excused with a smile or a nod.

experienced airline employees, passed along the wisdom that things would be different once "we are really on Mars." Mission members who were present with space exploration experience, going back to the Viking mission in the 1970's, were not necessarily able to inform on the present operation requirements. Although most scientists did not have previous experience of remote-science there were some scientists present who had participated in NASA's one other successful mission of remote science on Mars, the Pathfinder mission (July 4 to September 27, 1997).[82] The most striking past experience brought forward during simulations, which was circulated and employed, was the faith that even if all simulations failed it would have no bearing on the success of the actual mission. In their experiences, "things always go wrong until they need to go right." If simulating Space is difficult for people whose careers are invested in the highly abstract work of interplanetary astrogeology, then what does this say about the use of simulations for work training in other areas? Both have implications for the practice of work training, in general and specific, to particular workgroups. If astro-geologists find work simulation "too pretend," then how can testing of work processes get conducted satisfactorily? If the work of this community is abstract, even fueled by imagination and science fiction, then how can we understand the comment, "the work isn't real until the rover is on Mars?"

Understanding the rover as a co-worker, a mission member rather than a tool used on the mission, alters the way we look at the scientists' inability to stimulate work. It links this inability to the absence of a co-worker, an unpredictable human, rather than

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[82] The instrument and movement capabilities of the space vehicle, Sojourner, were quite limited in comparison to the capabilities of the MER rovers. Sojourner had fewer instruments, was tethered to the lander, and was expected to survive one-third the number of days of the MER rovers.

merely than the absence of a tool, a predictable object. For the scientists to do their work they would need to engage a co-worker, the rover, to whom they must translate their way of doing work into the co-workers' way of doing work. This can be understood in the difference between human and machine movements and work sites. Terrestrial geology performed by humans translated to extra-terrestrial geology carried out by robots. For the scientists trained to touch the objects of their examination – rocks that they can move around – and to look at several in one area before choosing one to look further into, conducting their work through a robot that moved at a pace of two inches per second, stopping every ten seconds to reassess its location.

Conclusion

Rather than a discourse of the unknown qualities of technology, the rovers were treated as members with greater agency than the scientists in Mars exploration. The rovers instigated activities, prompted workarounds, and set the temporal pace of mission operations. The rover was not solely a respondent; it was an interlocutor or a participant whose responses were not always predictable. Therefore, in my data collection and analysis of the work processes on the MER mission instead of listing the rovers in the category of artifact in my diagrams of information flows and work processes, I moved the rovers into the picture as participants – the mission members on Mars rather than objects on Mars controlled by the mission members on Earth.

Another indication of the rovers participating as mission members is found in their dictating processes in the work systems of mission operations. The focus on the rovers' activities in the work systems of mission operations so overshadowed the activities of the humans, that one social scientist shifted categories to describe the rover "as a customer" (Wales, 2003). Preparing to send commands to the rovers entailed receiving data from the rover, analyzing the scientific data as well as the rover's state of health, and negotiating what was good for the rover with what was wanted by the scientists. The condition of the rover was as anticipated as, if not more than, the scientific data in part because no one knew for sure what the rovers would do each day. The rovers could surprise the scientists, get sick, get tired, sulk, rebel, or cooperate. And, although the rovers were "twins," they had different "temperaments." The scientists would amend processes and science plans in response to what was perceived to be their changing moods.

Without disputing the value of traditional framing through anthropological categories, data from the MER mission seems to me to call into question the limitation of bounding technology as artifact. The Mars rovers emerged as members, not artifacts; discursively and in action, they were constituted as collaborators rather than tools. While we focus only on the humans as community members and seek to explain the culture of a techno-scientific community through their actions, we minimize the number of members actually contributing to the cultural constitution of the community. Maintaining technology as an object allows for a particular way of talking about matters that we do not wish to explain, or to explore. We give ourselves a way out of thinking about certain aspects present in the community which cannot be explained through rational actions, such as the reliance on luck, prayer, or fate.

In my account, technology considered as more than an artifact allows us to think about technology as a curious subject/object that engages, produces, sends, or receives information; a subject/object with whom/which meaning must be negotiated. With attention to the constitution of the rover as a collaborator rather than a tool, this distinction presents a possible move to shift agency and responsibility for determining the course of techno-scientific knowledge production of astrogeology. It opens up perspectives on the work flow, at the site of interaction, and adds to the understanding of devices employed by the group to leave unaddressed certain “irrational” or “illogical” events.

Conclusion

In this dissertation, I have argued that Mars time operated on the MER mission as a socio-technical process. As such, it bound together an organization of inter-planetary work and was rendered operable through cultural activities engaging all members of the community from humans to rovers. Although Mars time was to some degree an efficient technology for coordinating work, it was not entirely effective in its intended capacity as a work support technology. In fact, due to the nature of its construction, Mars time carried with it assumptions about the relationship between time and work that contradicted important requirements for the coordination of the multiple temporalities of an inter-planetary work system. Having been constructed to mimic clock time, Mars time was based on the assumption that time can be known entirely through the process of numerical representations regardless of space, or the relationship between a planet's axial rotation and the sun. The construction of Mars time also assumed that "time" could be modified to coordinate any activity without attention to the many critical but obscured phenomenological considerations of its enactment. The MER mission's attempt to use a temporal framework for which the experience of sunlight *is not* required ***and*** to coordinate work for which the experience of sunlight *is a* critical temporal factor raised an unasked but in my view critical question: was Mars time providing support for the scientists' work in situ or was it rather the scientists' work that supported the constitution of Mars time?

NASA is a precedent setting organization. Its successful operations are used for setting standards of technological achievement in space exploration as well as in the cultural consciousness. For this reason, the absence of formal and public attention, to some of the problematic social, technical, and cultural processes constituting Mars time is significant: indeed, one can reasonably assume that it could (and will) have an impact on time/work relationships within and outside of NASA. Temporal relationships built on the same framework of assumptions about time and work that constituted Mars time will in all likelihood reproduce similar time management breakdowns, workarounds, and membership responses. In addition, without attention to the phenomenological problems of using Mars time on MER, the apparent success of Mars time lends momentum to the construction of temporality in organizations along a continuum of distancing time and human motion. Without significant recollection of the centrality of the human experience in the production of time and work – and this is one of the important implications of my study – organizations may continue to support societal assumptions about clock time as natural time.

The organization of the MER mission community encompassed an inter-planetary landscape comprised of remotely operated space vehicles, scientists, engineers, and administrators. To make this territory familiar to the reader, I began in Chapter 1 by setting out some of the processes, people, and artifacts that comprised the MER community. I sought to demonstrate that in spite of the uniqueness of space exploration, the socio-technical work practices used for MER were not so different from those used in any organization. That said, I moved in Chapter 2 to detail some of the work practices (and problems) specific to the MER mission. In Chapter 2, I foregrounded Mars time management breakdowns and argued that within the MER worksite there were struggles to manage even the most basic and familiar of work processes – the ability to tell time. My analysis of the emergent time management breakdowns pointed to some of the inadequacies of the formal technologies for supporting a consistent conceptualization of Mars time and to some of the informal social and technical workarounds. The absence of any significant attempt to draw formal attention to the problems of time management on an organizational level led me to seek an explanation from mission members themselves.

Thus, in Chapter 3, I examined the role of mission members in making Mars time. This analysis was grounded in an account of the cultural processes of MER as members' interpreted these processes. In this sense, the chapter foregrounds the importance of considering human experience within the construction and operation of work systems. Using the participants' perspectives as a starting point, I offered one possible explanation for the absence of formal acknowledgements of temporal breakdowns, the presence of informal workarounds, and the characterization of time management breakdowns as a question of individual fortitude (and ingenuity) rather than infrastructural (organizational) distress. Media representations of space exploration constituted my point of departure because such representations were first invoked by mission members as a source of knowledge about work and community (within the organization of NASA). Noting that such representations can initially attract people to particular organizations, I argued that they convey only a partial, abstract, and kinetically inadequate picture of how an organization, and individuals within it, actually manages the relationship between time and work. Members' expectations with respect to organizational temporalities have often been formed prior to the actual experience of joining an organization and this can present a problem, I suggest, for developing a sense of temporality that reflects the conduct of work in situ. In the case of space exploration this problem can be especially acute. And with respect, specifically, to the MER mission, the phenomenon of stigma management offers at least one explanation of how members' responded to the experience of asymmetry between their preconceptions of the relationship between time and work and their actual experience within the organization.

Of course, mission members' responses to time management breakdowns cannot be entirely explained by the need to maintain their membership status in the organization. On MER, participants' motivations for producing a successful mission were very high and concerns for addressing any problem that could threaten the outcome of the mission were, at times, palpable. In Chapter 4, I offered a fuller explanation for the development, and absence, of social and technical processes for managing Mars time. By foregrounding some of the cultural historical underpinnings of the time/work relationship in organizations, I argue that the MER mission required mission members to address implicit phenomenological differences between temporal rhythms of clock time and solar time that the organization did not take into consideration in its construction of Mars time.

The underlying assumption about the operability of Mars time was that the framework used for knowing time, “telling time,” could be applied across any space. In other words, it was assumed that the social processes and technologies used to synchronize time between two *intra*-planetary time zones could be used between two *inter*-planetary time zones. What this logic failed to appreciate was that the distinction between clock time and solar time carries with it physical implications beyond those which are present in the act of locating a numerical representation to answer the question, “What time is it?” To put this in another way: Mars time can be mathematically ascertained from a location in Pasadena, California. However, this abstract form of temporal information does not provide a sense of timing – that is, a temporal rhythm – for work in an organization on Earth. In other words, central to the MER organization of work was the need to schedule the conduct of mission operations around the physical relationship between the rovers and sunlight on Mars. Terrestrial mission members were provided with numerical representations to track this relationship and around which to schedule and perform science operations. But, as I argue, the kinetic experience of solar time involves sensory perceptions of situational cues such as the appearance of light, its gradations, and/or its absence as well as surrounding environmental responses. However, in the framework used for coordinating a sense of synchronization between time zones, there was no provision for communicating the situational physical experiences of time: only numerical representations were privileged.

Finally, what also contributed to the temporal uncertainty that permeated the MER mission was the curious anthropomorphization of the rovers. I started the dissertation by introducing the rovers as artifacts because I wanted the reader to be able to consider, as I do, the significance of the anthropomorphization of the rovers in relation to the particular socio-technical and cultural processes in which members were situated. In Chapter 5, I argued that the discursive construction of the rovers as members was due, in part, to their role in constituting the temporal rhythm of work. The rovers contributed to the socio-technical process of Mars time beginning with their capacity as the only members to physically experience solar time on Mars. And although the terrestrial mission members had designed and developed the remotely operated space vehicles, this relationship did not provide the humans with absolute certainty of the temporal activities of their robotic collaborators. Thus, the temporal rhythm of work for MER included uncertain temporal durations such as waiting each day for confirmation that the rovers had received and followed data collection commands while also preparing work based on anticipations of the rovers' responses. In addition, there was also a daily assessment made of the rovers' ability to withstand material decomposition. In part, membering the rovers served as an explanatory device employed by mission members to manage these durations of temporal uncertainty. By constituting the rovers' temporal responsive as affective and physiological, terrestrial members were able to talk about temporal uncertainties without having to make reference to the fallibility of the technology they created. Uncertainty, doubt, and fear are not characteristics of a space explorer and avoiding the use of such languages is another example of stigma management.

In the absence of a culturally sanctioned language to talk about (1) the socio-technical uncertainties present in the temporal rhythm of mission operations or (2) the affective responses they might have triggered, formal acknowledgement of either remained just beyond the parameters of work that was supported.

This dissertation foregrounds the ways and extent to which Mars time was made up of incongruous processes. Despite a century or more of breakdowns in the time/work relationship, clock time continues to be adopted without question across organizations and even in an organization that is specifically a site of innovation. It appears that the process of knowing time through numerical representations is so inextricable from the cultural consciousness that even when given the opportunity to imagine and construct new organizations of work and temporalities, an ostensibly straightforward, naturalized version of clock time is invariably produced. The numerical representations of clock time provide at least the appearance of a language for which there is only one interpretation, a seemingly infallible communication tool for ordering work among heterogeneous organization members. But the appearance reveals a false expectation and this is that there is only one way to enact telling time. But is this self-imposed temporal ordering within organizations a long-standing habit? Or has clock time become the only way through which to know the human experience of time and work?

The analysis of MER mission operations as agrarian era work foregrounds the rigidity of time support technologies and social processes supporting the naturalization of clock time in organizations. This inability to create temporal technologies that support agrarian era work implies the possibility that technologies of time support are not amenable to supporting temporal rhythms other than those of clock time. One reason for this might be that these technologies are material manifestations of assumptions about the relationship between time and work. Social and cultural processes, similarly, maintain a certain kind of rigidity. I locate this rigidity, in part, in the reproduction of membership identities that resist developing in directions that go beyond enacting the traditional relationship between time and work. The social and technical responses to the task of constructing and managing Mars time seem, in the end, to imply that escaping the encompassing grip of clock time in organizations may require the kind of attention once devoted to defying gravity and sending humans into orbit.

In spite of these rigidities, I am still convinced that time *is* mutable. There is no physical law of nature that precludes constructing a socio-technical process for supporting temporal rhythms of work in organizations. It is quite within the realm of human capabilities to reconfigure how we arrive at knowing time within an organization and how we establish temporal rhythms for an organization and its members' particular time/work relationships. Organizations are still considered to be artificially constructed environments: the worksite has yet to be naturalized. The category of artificial refers to the construct of spaces of work as human endeavors, artifices of social process and material technologies. As such, the understanding of organizations as artificial provides one point of entry for bringing attention to the possibility that alternate temporal technologies can be introduced into this environment without assuming a complete upheaval of nature.

Clearly, the inescapable conditions of clock time are not waiting to be discovered in extra-terrestrial spaces. For this reason, the organization of space exploration allows us and requires us to consider anew the introduction and constitutive assumptions of each socio-technical process that emerges through or is brought to bear in the development of inter-planetary work systems. This is and will be the case whether humans or their robotic counterparts are sent on future space missions: attention to the temporal rhythm of work processes and to the on-the-ground experiences of mission members as they initiate, interface with, and elaborate these processes will be crucial. To date, within organizational culture at NASA, time management problems continue to be individualized: humans are expected to process the relationship between time and work like machines while machines are continually updated and modified to process information like humans. By directing attention to the choice of human or non-human exploration of space, cultural assumptions about the differences between these corporeally distinct organization members remain intact as the similarities of the socio-technical processes with which they operate remain in the background. Regardless of who or what is selected to take the extra-terrestrial journey, the work of producing space exploration will continue to require the organization of work systems that support humans, machines, and their interactions. And no matter to which destination they travel, or across which inter-planetary work sites we coordinate work, the problem of time will remain central.

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