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„Manufacturing Know-How and Quantifying to Conquer: Exploring the Engineering Company as a Site of Knowledge Production through the Work Practices of Employees“

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1 Introduction

1.1 Preface

It is my first day of field work. I know that I'm a few minutes early. It had been difficult to arrange a meeting and my contact had seemed busy; I don't want to waste his time. I enter the building, introduce myself to the woman at the front desk and take a seat while she announces my arrival into the telephone. In front of me are a table, a bowl of fruit, a coatrack: this seems normal in a room designed for waiting. To my left is a door that serves as the gateway to the rest of the building. There's a grey hallway behind it, and most people who walk in the front door while I wait head straight there. To my right, however, are another door and a large window that separate the room I am in from a very different one. Through the window I can see gleaming machinery and a man in a lab coat. People pass through the reception area as I wait, unlocking the door on the left with their badges and nodding hello to the woman at the desk as they stride towards the other room. The reception area seems strangely situated, like an awkward anteroom stuck between two more important places.

After several minutes and the passage of a few more employees through the room, my contact person arrives. He takes me through the door on the left – I have a badge now too, but not one that can unlock the doors – into the hallway and up the stairs. "It's good that we could finally make the time for this" he says.

Thus began my time at the Austrian offices of Company Z, an engineering company that designs and produces technologies for the space industry. I was there as an ethnographer, as a student of science and technology studies (STS), but also as an engineer. My aim was to explore Company Z as a site of knowledge production, paying special attention to the work practices of its employees. To me, it seemed that the engineering office was a site that had often been ignored within STS in favour of the laboratory or the research institution. I had an idea that engineering environments are particular spaces of knowledge production, and I wanted to figure out what kind of space this might be.

During my subsequent visits, I conducted interviews and had more casual conversations. I was given tours and I attended meetings, observing Company Z's employees as they interacted with each other and with some of their customers. The phenomena that I observed in the first few minutes of my first visit resonated throughout my time at Company Z: jumbles of different kinds of work spaces, issues of access, narratives of making, saving, and maximizing time. All of these ideas and many more contributed to my eventual impression that though this site, this company might be something distinct from a laboratory or a university, it also shares more than I had expected with other spaces and places of knowledge production.

1.2 Motivation and Project Development

But I should start at the beginning. In order to properly introduce this project and its case, it is necessary to devote some time to describing the origins and motivations of the study. The project in its earliest form was conceptualized in the spring of 2012 as a seminar assignment: a hypothetical grant proposal for a fictitious research project. Around that time, the American company SpaceX was making headlines around the world as the first privately-owned company to successfully launch a cargo payload to the International Space Station (Chang 2012). As an engineer with experience in the aerospace industry and a keen interest in space technology, the story fascinated me from a technical and practical standpoint. What kind of private company could produce something of this scale and level of sophistication? I knew that the levels of reliability testing and quality assurance required to launch a spacecraft are phenomenal (and phenomenally expensive), and this would have been only one comparatively small part of a multi-year operation involving countless actors. Surely this was the result of a long and complex collaboration with NASA and other organizations, and not the merely the headline-making action of a plucky start-up.

As a neophyte student of STS, this collaboration fascinated me on a different level. Maybe this kind of collaboration represented something fundamentally new for the space industry, or for the development of space technologies in general. Who were the different actors at work in such a situation, and how did they work together? How did they assign roles and responsibilities? What was their relationship to the technologies they created? How did they assess risk? What were their imaginations and understandings of "risk"? Had these changed throughout the processes of technology development, testing and launch? Reading Diane Vaughan's work on organizational culture and risk, written in the aftermath of the Challenger disaster (Vaughan 1996), I wondered how the collaboration between NASA and SpaceX might be similar or different to the one Vaughan describes between NASA and Morton Thiokol in the 1980s. What was the organizational structure of SpaceX like? How did this affect understandings and assessment of risk?

And thus was the idea for my hypothetical project born. I would propose to explore the collaboration between a private space technology company and an organization like NASA that would surely have advised and facilitated their work (and possibly funded it? Where did the money come from, anyway?). I would conduct interviews with actors from both organizations, and participant observations at both sites. I would use initial interviews to understand the organizational structures and cultures of both the "private" company and the larger, "public" organization. The observations and, later, more focused interviews would follow, allowing me to explore concepts of understandings of risk in more depth.

As the hypothetical project turned into the beginnings of a real Master's thesis, I was presented with some immediate issues. I was in Austria, which was where the research would also have to be. Austria has no real space program of its own; it works instead as a partner to the European Space Agency. Nor does it have private companies which design space shuttles or launch vehicles for the International Space Station. Despite this, the basic concept remained in place. I would find a private company in Austria that produced space technologies and investigate their work practices and collaboration with the European Space Agency.

I defined some initial research questions, found a company where I could begin my field contacts, and started a preliminary literature review. The initial working title of the project was *Risk and Accident Mitigation in Modern Space Technology Collaborations*. However, upon beginning research, some questions of definition presented themselves. The first concerned the meaning of the word "collaboration" in the title. The project was initially characterized as an investigation of public-private partnerships in the space technology industry, with the American company SpaceX and the European Arianespace both cited as examples of private space technology companies which produce objects under contract with larger, "public" entities such as NASA and ESA. However, it soon became clear that the line between "public" and "private" in this case is not a simple one to draw. One of Arianespace's largest shareholders is CNES, the French national space agency. SpaceX was established with private capital and is privately owned, but now holds ongoing contracts with NASA that make up the majority of its funding. I didn't know how my Austrian case fit into all of this. There was no way to unravel the web of ownership and project funding at my field contact without it taking over the entire project. Contracts within the space industry tend to involve a myriad of partners at different points along a public-private spectrum, and restricting the term "collaboration" to just one kind of partnership that may not necessarily exist in the way it was imagined would have been inappropriate.

Similarly questionable was the use of the term "modern". It was included because of an initial belief that the specific kind of collaboration mentioned above was a relatively new phenomenon that is changing the ways the space industry works. Leaving aside for the moment the contentiousness of the term "modernity" in the social sciences, early research showed that collaborations and privatization in the space industry are not necessarily modern even in the sense of being new or novel. As early as the 1980s, writers were commenting on the ongoing privatization of space (Levine 1986), and by the late 90s – still several years before SpaceX was founded – privatization had become an "explosion" (Moorman 1999).

I found that I had intended to investigate risk and accident mitigation across a kind of modern, public-private partnership which was now problematic or downright non-existent. So if I was not necessarily dealing with a "modern" trend and the partnerships in question could be characterized in the way I'd imagined, where did that leave me? Well, there were still the practices of the engineers and other employees of the company I'd found for my field work. The fact that these practices could not be categorized as easily as I'd thought only served to make them more interesting as research objects. I could still look at perceptions of risk and the actions taken to minimize or deal with it, but I had to ensure that the definitions of risk used were the ones provided by my field. There was still collaboration going on, in many different respects. Most of all, there was the question of what kind of organization an engineering company really is. Is it a producer of "knowledge" in addition to technologies? How is it different from a research institution or a laboratory? Thus, the project's aim became to explore the identity of an engineering company through an investigation of the work practices of its employees.

Scaling down the way the project is described was meant to denote openness to redefinition through ongoing fieldwork; an admission based in the tradition of grounded theory (Glaser and Strauss 1967) that the project's results and conclusions could only be determined after the work has been done and the data collected. With this premise in mind, the engagement with the field contact began.

1.3 Introducing Company Z

The research site is one part of the Austrian operations of a space technology engineering company, which I will call Company Z. Since the data protection and privacy issues common in the space industry prevent me from revealing the name and exact location of the company, I have anonymised its moniker with a grateful tip of the hat to Annemarie Mol's "mid-sized Dutch hospital" (Mol 2002).

Company Z is an international firm, with engineering and production facilities in different European countries. The company designs and produces high-tech products for many different fields; however, the Austrian branch where all field work was conducted concerns itself exclusively with the design, manufacture and testing of electrical, mechanical and thermal technologies for the space industry. The company's Austrian facilities include two buildings situated within walking distance of each other. The buildings are equipped with offices, meeting rooms, clean rooms and testing facilities, among other kinds of spaces and devices. The people who work there are predominantly engineers of different kinds, but also include project managers, receptionists, supply chain employees, payroll coordinators, and more. Field work for this project was carried out in these two buildings over three months in early 2013.

These buildings *are* a site of knowledge production, but those who work there might not characterize them as such. They would perhaps say that the facilities are more importantly places of knowledge *implementation* and of technology production and development. The company's output does not consist of academic publications; a project is finished when the hardware has been tested and delivered, or when the final reliability report has arrived on the customer's desk. Nevertheless, the amount of site-specific know-how within Company Z quickly becomes apparent to the outside observer. The company's employees develop techniques, strategies, theories and wisdom based on their experiences, and make use of these tools when moving on to the next project. They construct *facts* through and about their work that retain their relevance throughout the time and space of the company and its future projects.

As is common in the space industry, Company Z is far from an isolated actor. The products it designs are not intended for mass production or public availability, but instead are produced in limited and strictly defined numbers for a specific customer. Nearly all of its projects involve collaborations with other organizations, and its partners include other companies, universities, research institutions, and international bodies like the European Space Agency (ESA).

So how can we understand what kind of site Company Z is? It contains different kinds of spaces – laboratories, offices, production facilities – while resisting categorization as any one of them. It is not a research organization, yet it participates in research projects. It is a for-profit company, with a need to focus on its economic bottom line. It is a place of communication, where actors come together at different project stages to review, evaluate and discuss. It produces knowledge in a tacit way, without explicit acknowledgement of the importance of this knowledge as an output of its employees' work. Perhaps it exists on the boundaries of different kinds of knowledge-producing institutions, or perhaps it represents something altogether new.

1.3.1 A New Kind of Knowledge Production?

There has been much debate in and around STS on new modes and sites of knowledge production. Nowotny, Gibbons and their collaborators (Gibbons et al. 1994), (Nowotny, Scott, and Gibbons 2001) have articulated a view of knowledge production which holds that traditional boundaries between academia and industry are blurring – or even disappearing – with the development of a new mode of knowledge production called Mode 2. This new mode is characterized as being interdisciplinary and problem-based, in contrast to the more hierarchical, academic structures of Mode 1. If Mode 1 represents a system of knowledge production in which – for example – academia and industry are strictly separate, with "basic" research being performed by academic researchers and later "implemented" by industry, Mode 2 institutions and projects will not be fit as easily into either of these categories. Nor can disciplines be easily distinguished in this new mode of knowledge production. Departments or project teams may involve members with very different backgrounds and responsibilities, working together on a common theme. Mode 2 research is also "highly reflexive". It becomes, as Nowotny et al. put it, "an intense (and perhaps endless) 'conversation' between research actors and research subjects" rather than a detached examination of the "natural" world.

In *The New Production of Knowledge*, the first book published on Mode 2, the concept of Mode 2 knowledge production was developed through a number of different contexts. However, the authors did not intend the book to be an empirical study (Nowotny, Scott, and Gibbons 2003). After its publication, the concept faced criticism in terms of its validity as well as its value. Etzkowitz and Leydesdorff (2000) questioned the origin of the hierarchical and isolated image of scientific research that Gibbons, Nowotny et al. present as representative of Mode 1, claiming that Mode 1 is "a construct" that has never accurately represented the ways science and academia work. Others claimed that the dynamics of society as they relate to new forms on knowledge production had not been discussed, or that the concept was more ideological than descriptive (Godin 1998). In response to some of these criticisms, Nowotny, Scott and Gibbons published *Re-Thinking Science* in 2001 to further clarify and expand the idea of Mode 2 knowledge.

A major alternative conception of new forms of knowledge production was developed around the same time as Mode 2. Etzkowitz and Leydesdorff propose instead a "triple helix" model of innovation (Etzkowitz and Leydesdorff 1998) in which university, industry and government still exist as separate entities but work together in new ways through an increasing number of "linkages" between the institutions. Leydesdorff and Etzkowitz oppose the so-called "linear model" of innovation, citing above all increased globalized competition and the increasing recognition of research as a stimulus for economic growth as factors that have promoted cooperation and interactions between institutions of different kinds.

As Terry Shinn points out in his evaluation and criticism of both of these concepts (Shinn 2002), Mode 2 has been highly influential and is widely cited despite its criticisms. The Triple Helix was initially less dominant in literature but has since spawned annual conferences, academic working groups and international associations.

Talk of innovation and new modes of knowledge production has been a major part of European and European Union discourses on science and technology over the past decade. The European Commission's *Innovation Union* project (European Commission 2013) – part of the *Horizon 2020* proposal on the future of European research – sees innovation as a commodity that can be demonstrated, measured and encouraged. The project's aims include making the European business climate more "innovation friendly", competing with innovative "top performers" such as the US and Japan and maintaining Europe's "strong innovation lead" over countries such as China, India, Russia and Brazil. The 2012 *State of the Innovation Union* report (Directorate General for Research and Innovation 2012) evaluates the progress that has been made on these fronts since 2008.

A major point in the Innovation Union plan is to encourage both "public and private" investment in research and development. The report highlights the European aerospace and defense industry as a major player in the "medium-high" intensity category of investment in research and development. The report also encourages collaborations between universities/research organizations and industry, as well as between organizations in different European countries.

The potential relevance of the report and the Innovation Union initiative for an institution like Company Z is clear. Company Z already collaborates with both research institutions and companies in different European countries, in addition to conducting many projects – both explicitly research-based and otherwise – in partnership with ESA. As an international producer of aerospace technologies, Company Z fits the profile of the kind of technology and innovation leader that the Innovation Union program was designed to encourage. But what does this mean for Company Z as an institution? How do the employees of Company Z and their collaborators see their work as fitting into European innovation discourses, if they do at all? Is the Innovation Union's twin emphasis on collaboration and R&D reflected in work practices at Company Z, and if so, how?

Similarly, both the Mode 2 and Triple Helix concepts could be applied to the relationships between Company Z and other actors. Though the company seems to construct and understand itself as a member of the space technology *industry*, one that works together with other organizations as an industry partner, it could be argued that Company Z's research projects and collaborations blur the lines between economy, innovation and knowledge production. Ultimately however, the aim of this study is not strictly to categorize the company and its modes of innovation. Mode 2, the Triple Helix, and EU discourses on innovation are all very broad ways of thinking about knowledge production. It is sometimes difficult to apply these ideas directly to an institution: can we say what, exactly, is "Mode 2" about a given company or site? Can we pry apart the strands of the triple helix and discuss their relationship to individuals, rather than to ideas? None of these ideas deals with the practices of the people who work at or are involved with new kinds of knowledge production. It is this connection with which this project is concerned. The aim is to explore the work practices of the employees of Company Z and their collaborators, and in doing so to discover what these practices can indicate about the company as an institution and about its place in modern knowledge production. This project's methods and research questions were designed with these practices at the forefront. Employees' work practices will necessarily reflect the environment of collaboration and innovation they are embedded in, and it is the relationships between these practices and the positioning of Company Z within current innovation and knowledge production discourses which are of primary interest here.

1.3.2 Spaces and Places

The importance and variety of different kinds of spaces and places at Company Z has already been alluded to. The room that was glimpsed through the window of the reception area on my first visit turned out to be a clean room, one of several rooms within the facility where products can be assembled without fear of contamination or disruption. Other distinct kinds of places include offices, meeting rooms, and test facilities, each with their own associated set of accepted actors, objects, actions and behaviours.

The importance of place and space to knowledge production is a theme that has often been taken up by STS scholars, e.g. (Livingstone 2003), (Oudshoorn 2012). In discussing the geographies of Company Z, it is important to distinguish between notions of *space* and *place*. I follow Livingstone and others in using the term *space* to denote something that is set apart from, and more than, a physical location. At Company Z, the *meeting space* is related to the room in which a meeting takes place, but more importantly it is also a social assemblage. There are sets of accepted behaviours and outcomes that are associated with the meeting space, and certain actions which are generally expected to occur within it. Technologies, objects and documents are also part of the meeting space, and these in turn affect the actions of meeting participants.

A *place*, for the purposes of this study, is more strongly connected to a physical location. Gieryn (2000) lists three features which he deems "necessary and sufficient" to define a place: geographic location, material form and investment with meaning and value. For Gieryn, the geographic location can be as localized as a particular office chair or as general as a continent; it is sufficient that the location be finite and clearly bounded. The material form refers to the "physicality" of a place. In this way, Gieryn acknowledges the importance of humans working on or living in a place: recognizing the material form of a place also recognizes the social and work processes that occur there. The meaning and value of a given place are also related to social processes; however, in this case Gieryn refers to non-material associations that have been created by humans, such as names, identifications and representations.

Each of the two buildings that make up the research site is a *place*, as is each meeting room and office within them. The term place may be used in a more general manner to refer to the set of a particular kind of place within the site (e.g. the corridors of Company Z), or specifically to indicate a single room or location (e.g. Meeting Room III). The meeting *space*, on the other hand (or the testing space, or the development space), is a non-physical quantity. It refers to the set of behaviours, objects, actors and ideas that make up a "meeting". While they are distinct ideas, definite connections exist between the spaces, places and site of research. Both space and place are important to work practices and knowledge production. Gieryn suggests that places have stabilizing effects on social structures and hierarchies, as well as "arranging patterns of face-to-face interaction" and embodying intangible cultural quantities. Spaces can limit certain actions while encouraging and defining others. They present opportunities for particular exchanges while preventing or discouraging other kinds of communication. Between them, place and space help to build and define the structures, work practices and communication of Company Z.

One of the buildings that made up the research site was quite a jumble of such spaces and places. Clean rooms are next to laboratories are next to meeting rooms are next to offices are next to kitchens, and in between are twisting corridors with plans and charts on the walls. These corridors also seemed to be used as spaces of coordination or planning: for some projects, employees' names and availability would be noted on the wall charts, visible to passers-by who are interested in arranging their own or their projects' schedules. This mash-up of spaces was attributed by one interview subject to the age of the building and the growth of the company. Company Z has been in the building since before it had its current name, and well before it had expanded to its current size. As the company grew, it became necessary to have certain amounts of different kinds of spaces and places in the building, and so rooms with different functions were built next to or on top of each other, and one of the clean rooms ended up beside the front door.

The second building at the site was a study in contrast. Slightly newer, it had been built with the intention of housing only offices and meeting rooms and it has so far been kept to this purpose. The second building feels brighter and more open. The walls of its corridors are covered with pictures of the company's employees and products, rather than with charts. There is no blinking machinery here, and there are no lab coats. Employees at Company Z have a fixed location in one of the two buildings in an office or laboratory, and occasionally wander between the buildings when it is required for a meeting or inspection. Outside of meetings, however, work is generally done in one's own place, be that the desk or the lab bench, depending on the position of an employee within the company's structures.

1.3.3 The Structure(s) of Company Z

The working structure of Company Z was described to me by an employee as that of a "classic matrix organization". The matrix management structure is a classical form of business organization (Galbraith 1971).It indicates that all employees are pooled according to the similarity of their skills: electrical engineers, mechanical engineers, management, sales, etc. and assigned individually to certain projects, as necessary. Skill-based groups and project teams thus construct the two axes of the "matrix" by which the organization is defined. To a large extent, this is true of Company Z. All engineering employees are members of one of 25 "work groups"[1]. These groups are made up according to the skill sets of the employees, and projects do indeed draw from these work groups according to their needs. Yet to state that Company Z is basically a matrix organization is an

[1] *Arbeitsplätze*

oversimplification. Not only does this model exclude the many employees who do not belong to a work group (project leads, procurement, secretaries, etc.), it also downplays the importance that projects and project teams play in the day to day working practices of the company.

For each project that Company Z undertakes or decides to bid on, a so-called "core team" is defined during the project's early stages. This core team usually consists of a project lead, a project engineer, and representatives from all of the technical work groups that are judged to be important for the project (for example, an electrical engineer from the signal processing work group). This team is tasked with producing a number of different conceptual designs for the bid. After the team has produced several designs, the members review the strengths and weaknesses of each, choose the preferred design and convert the results of the review into a *trade-off study* which is submitted to the potential customer as part of the bid. In this way, the core team is responsible for both creating a design and evaluating it against stringent criteria.

The core team is maintained throughout the duration of a project, and though the roles of the members change with time, the stability of the team is highly valued by Company Z. The importance of a core team that has changed as little as possible throughout the lifetime of a project was emphasized repeatedly in interviews and conversations at the company. Even in cases where an engineer had been logistically removed from a team in order to begin work on new projects, he would still maintain contact with his former core team and provide support to them when necessary. In this sense, the *projectified* structure of Company Z sometimes overrides the work group-based hierarchies which are more often explicitly cited as integral to the company's functions.

Initial observations of Company Z reveal that it is an institution that produces knowledge in addition to technologies, though its place within STS/social science discourses on knowledge production and innovation remains unclear. It is also a collection of spaces and places: the company exists simultaneously in many sites across the world and in two specific buildings in Austria. It is understood by its employees as a "matrix organization", but the relations between and respective strengths of its skill- and project-based structures seem to be complex. This project uses qualitative interviews and participant observation of meetings at the company to delve into these themes in an attempt to answer its main research question: **what *is* Company Z as an institution of knowledge production, and how is this definition performed through the work practices of its employees?** In the following chapters, the "toolbox" of theories and methods that were used to answer this question are summarized and explored. Subsequently, the results of the investigation and a brief analysis of the results are presented.

2 Conceptual Background

My research questions and project conception draw both implicitly and explicitly on a large body of work within science and technology studies and beyond. In this chapter, I will attempt to provide a brief summary of some of the concepts and literature that have most influenced my ways of thinking about the environment and practices I encountered at Company Z, and to indicate how some of these concepts might relate to my empirical results. The selection is far from exhaustive and I have not been able to devote as much space to these works as their contributions deserve. Nonetheless, I have tried to highlight the theories, ideas and studies to which I feel my work owes the most.

2.1 Laboratory Studies: A Brief Review

So-called laboratory studies are considered to be some of the earliest and most influential works in STS. Latour and Woolgar's *Laboratory Life* (1986 [1979]) both introduced a new way of studying scientists and their work and helped lay the groundwork for the development of Actor-Network Theory. Karin Knorr-Cetina's work from the same time period (Knorr-Cetina 1981a) extended and refined the anthropological approach to the laboratory and to the (social) construction of scientific knowledge. In addition to introducing and arguing for the application of an anthropological, participant observation approach to studying the laboratory, these two pioneering studies were concerned predominantly with describing the (social) construction of *facts* within the laboratory setting. While the current project is *not* a laboratory study, both the constructionist ideas and ethnographic/ anthropological approaches of laboratory studies have influenced the development of the current work.

2.1.1 Fact-Making

Latour and Woolgar understood the laboratory as a "system of literary inscription", as a process that results – when it is successful – in convincing others that something is true. The outcome of the laboratory's work processes is knowledge that is accepted as fact. In one chapter of *Laboratory Life*, the development of the substance TRF(H) is traced from a starting point of uncertainty, where there was disagreement between groups as to the meaning and significance of TRF(H), to the establishment of the substance as a "stable object", the structure of which was understood and agreed upon throughout the scientific community. Latour and Woolgar describe how the advent of a "simple", three amino acid formula for TRF led to the quick diffusion and acceptance of the idea across different research groups. As the structure of the substance became accepted, TRF became "taken for granted" among new research groups, and the multi-year struggles and experiments that had contributed to its development became myths and stories highlighted by the media. Latour and Woolgar conclude that the laboratory is in the business of producing *order* out of *disorder*, and that this order is expressed in terms of facts.

Latour's later work on laboratories (Latour 1987a) continues the examination of fact construction and the resolution of scientific controversies, but embeds them more deeply in the context of *networks*, laying the groundwork for the development of actor-network theory (see chapter 2.6). Latour famously contrasts two "faces" of science, symbolized by the Janus head and representing "ready made science" and "science in the making" respectively. Latour counsels his reader to study scientists and engineers in the field, entering with as few preconceptions as possible. The call is to study "science in action", and to investigate knowledge as it is being produced, rather than in its later, publicly-accepted, fossilized form.

Knorr-Cetina also discusses the construction of facts within the laboratory setting. She highlights what she calls the "decision ladenness" of fact making, meaning that scientific processes rely on a series of choices or *selections* made by the scientist or technician. In identifying a function to describe a set of data, the scientist is presented with different options and must decide which one to use. If one type of function seems to "work" for a given data set, it is likely that the same type of function will be chosen again by the same scientist – or by her colleagues – when working with new, related data. Once similar selections have been made often and in different locations or contexts, the decision making process is reified such that, eventually, the laboratory becomes a collection of machinery and methods that represent a set of crystallized decisions, "a local accumulation of materialisations from previous selections".

But the work that is done at Company Z is not concerned solely with fact making. As employees of an engineering company, the engineers of Company Z produce objects as well as knowledge and things as well as facts. Furthermore, these objects are expected to be in good working order and to remain so throughout the scheduled lifetime of the technology and preferably beyond. While knowledge and facts are certainly a product of the work that is done at Company Z, the production of facts is not the main goal of the work. However, despite this important distinction, other aspects identified through different laboratory studies indicate areas of overlap between the laboratory and the engineering office.

2.1.2 Order, Expertise and 'Making Things Work'

> *If there is a principle which seems to govern laboratory action, it is the scientists' concern with making things 'work', which points to a principle of success rather than one of truth [...] scientists guard against later attacks by anticipating and countering critical questions before publication. (Knorr-Cetina 1981b)*

Knorr-Cetina argues here that the scientists in the laboratory she investigated were more concerned with gathering data that made sense – and could be defended against criticism – than in uncovering an abstract "truth". This runs contrary to many popular conceptions of science and scientists as unbiased and hyper-rational truth-seekers, but it also suggests that laboratory work may have more in common with work practices in an engineering office than might be assumed.

The engineers of Company Z have a very explicit goal of "making things work": as discussed above, they are in the business of producing working machinery as well as knowledge. To accomplish this and to try to ensure they have come up with the "best possible" design, they often follow practices similar to those outlined by Knorr-Cetina. During the bid phase of a project, the development team is generally tasked with producing a number of different possible designs for a given part. After one design has been chosen, a *trade-off study* in conducted on all designs, listing the strengths and weaknesses of each. For the development team, this study comprises one of the most important parts of the company's bid, as the trade-offs they have listed may both anticipate criticism of their chosen design and highlight important weaknesses in the designs of their rival bidders. Similar to Knorr-Cetina's scientists, the engineers of Company Z "anticipate and counter" criticism that could detract from the perceived feasibility of their work.

Another overlapping aspect of the engineering office and early laboratory studies is the attention paid to the ordering of practices and knowledge. Several laboratory studies (e.g. Collins 1991 [1985], Lynch 1985) discuss the ordering of scientific knowledge, and the "*indexical*" nature of scientific and laboratory work. Lynch describes the ordering, indexing and numbering of objects within the laboratory as being vital to the eventual creation of knowledge out of these materials. Similarly, practices of ordering tasks and issues are important to the work flows within Company Z. Everything from meetings to technical problems to tasks that are bundled off and divided up as "work packages" are numbered and indexed. During meetings, problems and tasks are listed by number and the lists are run through using the numbers as reference points for discussion. While in many cases it is abstract things – work or problem situations – that are indexed at Company Z, the importance of naming, ordering and indexing reflects similarities between the laboratory and the engineering company.

Theories of expertise also arise in both environments. Collins discusses notions of expertise in the laboratory through his use of Polanyi's (1958) concept of *tacit knowledge*. Tacit knowledge refers to a kind of knowledge that cannot easily be explained to another person or traced back to a particular point of acquisition. In Polanyi's original use of the term, *all* knowledge is rooted in this kind of incommunicable "know-how": as he wrote, "we know more than we can tell". Collins is less universal in his analysis, using the term to describe a kind of knowledge that is vital to scientific or laboratory work, yet is difficult to communicate to others. He uses the example of the ppTEA laser, which originally could not be replicated in laboratories far from the place where it was designed despite detailed assembly instructions, to demonstrate the kind of localized tacit knowledges that exists in laboratories. Though eventual dialogue and cooperation meant that the new lasers could be assembled, it was this process of collaboration which allowed the sharing of knowledge that could not effectively be communicated through written instructions.

The idea of tacit knowledge is connected to some of the notions of expertise and personal responsibility that exist at Company Z. As mentioned in the first chapter, the stability of the so-called "core teams" that develop the initial design of a product is heavily prized at Company Z. This is at least partially due to the knowledge of the product that is developed by the team members during the initial bid phase. This familiarity with the product can be seen as a type of tacit knowledge or know-how that cannot easily be communicated to an employee who has not been involved with the project from the beginning. Indeed, the ease with which a project progresses to the next stage of completion is often attributed to the stability of the project's core team and the respective teams at Company Z's collaborators.

2.1.3 Newer Lab Studies

More recent laboratory studies have moved away from the discussions of fact-making and fact construction that dominated early accounts. Park Doing (2008) has criticized the narratives of fact construction presented in the works of Lynch, Knorr-Cetina and Latour and Woolgar, claiming that these pioneering lab studies failed to demonstrate the relation between *endurance* of their constructed facts and the work practices of the laboratory. Doing sees this as a *black-boxing* of the ethnomethodological practices of the lab studies scholars themselves. Thus, Doing states, early laboratory studies are not the true challenges to the idea of "principled demarcation between science and common sense" (Lynch 1985) that their authors claimed they were.

Doing notes a movement in later laboratory studies away from the explicit discussion of fact construction and toward other phenomena or work practices: power and identity within a laboratory organization (Traweek 1988), scientific organization (Knorr-Cetina 1999), or Doing's own work on imaginations of "experience" in a radiation laboratory (Doing 2004). While Doing's arguments about the endurance of facts may be valid, they are not of particular relevance to the current study. The aim of this project is not to determine how or what kind of facts are produced by Company Z, nor even to focus on the technologies which are created by the company. Instead, the focus is on work practices and their relation to the identity of the company as an institution. In this respect, following more recent laboratory studies in exploring practices and experiences rather than making claims about the kinds of results produced by an organization is line with the focus of the project, though Doing's criticism of early laboratory studies is not of specific concern.

2.1.4 Laboratory Studies and Company Z

It has already been established that Company Z is a complex site and a difficult one to categorize. It contains places which are referred to as laboratories and others which are not. It conducts research but may not be considered by its employees to be a research organization. Its floor plan does not resemble that of Latour and Woolgar's laboratory, with its neatly demarcated spaces of 'office' and 'bench' work. Furthermore, the products of its employees' work are not simply knowledge or *facts*; they are also material *things*.

Company Z does not attempt to present itself as a laboratory, and the current project is *not* a laboratory study. However, it does draw inspiration from them. Above all, lab studies drew attention to the idea that *place* and *culture* were important in scientific knowledge production. This idea has proven to be a powerful and influential one: to argue today that an engineering office is a site of a particular kind of knowledge production with important cultural and organizational characteristics would no longer be a contentious point among STS scholars. If this point is accepted, it is the description and definition of the site which become important for the researcher.

Of course, there are many different ways to go about doing this. Whereas most early works in laboratory studies sought to characterize the nature of interactions and knowledge production in scientific laboratories, this project is concerned with understanding the *work practices* of engineers. I would like to bring this ethnographic focus to the engineering environment. In doing so, I recognize the engineering company as a kind of knowledge-producing entity that is distinct from academia and from natural science laboratories. It is the situation of the company as an institution and the relation of this to the work practices of its employees that forms the basis of this project. Laboratory studies have much inspiration to offer in terms of methodological approach, general outlook and specific concepts such as "making things work", preparing for potential criticism, ordering and indexing and imaginations of expertise and personal responsibility.

2.2 STS Studies of Engineering and Engineers

Recent STS studies of engineering and engineers have focused mainly on two areas: ethics (e.g. W. T. Lynch and Kline 2000, Coeckelbergh 2006, Van de Poel 2006, Downey, Lucena, and Mitcham 2007) and gender (e.g. Faulkner 2007, Paulitz 2008). Other STS work has been done on engineering education, (e.g. Lucena, Downey, and Hussein 2006, Downey 2008), much of which is intertwined with studies of ethics and reflects upon the ethical implications of an engineering education or the responsibilities of engineering educators. While much of this work is not directly related to the current project, as it is more concerned with issues or events than with work practices, many studies that situate themselves in either gender or ethics discourses of engineering contribute valuable ways of thinking about engineering work.

2.2.1 Internal vs. External Regulation

In contrast to a large body of work on engineering ethics that is concerned with disaster analysis or post-mortems (e.g. Lynch and Kline 2000), Coeckelbergh explores the dichotomy of internal self-regulation vs. external control of engineers' work in more abstract terms. While the current project is not concerned with exploring engineers' "moral imaginations" per se, Coeckelbergh's examination of the relevance of an engineer's personal moral responsibility or "autonomous judgement" is interesting to consider. Coeckelbergh argues that "engineers generally see themselves as having a social task", and that this perception of the engineering profession indicates a deep connection between personal responsibility and professional practices. He states that the risk related to engineering design should ideally be managed through a system of external regulations that respect the engineer as an "autonomous agent" and in so doing support his or her autonomous actions and allow the engineer to develop a moral imagination.

The idea that engineers see themselves as being primarily responsible to society is not entirely supported by my experiences at Company Z; however, the relationship between personal responsibility and regulation by other people or institutions was a recurring theme. Employees of Company Z cited personal responsibility as a factor when arguing for the importance of stability in project teams. If there was a problem with the proposed design, they argued, engineers involved in the project would have to take responsibility for the issue. Having been involved with the design from the beginning, they would not be able to assign blame to another person or group, and so would be required to resolve the issue themselves, as quickly as possible. It was also constructed as the responsibility of each individual employee to manage – on a certain level – his or her time and workload. Certain "external" impositions also exist: officially, an employee's workload is regulated through consultation between the manager of his work group and the project teams with which he is involved. Unofficially, however, it is expected that each engineer manages his own time and notifies the relevant actors when he has too much or too little work. Risk, too, is "externally" regulated by different procedures and standards. There exist official practices of problem reporting and recording, which regulate the times at which issues should be reported and the ways in which they can be officially resolved. In practice, however, employees have personal leeway in identifying and responding to problems. Issues that can be quickly resolved may be reported only after they have been "fixed".

2.2.2 Defining the (Gendered) Engineer

Wendy Faulkner takes up the definitions of an engineer in her work on gender and engineering identity among building design engineers (Faulkner 2007). Regrettably, I have not found the space in this project to discuss gender issues and their relationship with the work practices of Company Z, though gendered ideas and approaches were evident within the company's environment. During my visits to the company, I never came across a female engineer or project lead. The women I met at Company Z were receptionists or secretaries, with the exception of one woman who worked in product assurance for one of the company's customers. It must be noted that I did not conduct a thorough survey of the many projects and over 100 employees at the research site, and it is extremely likely that the company employs female engineers and managers. However, based on my close interaction with two projects and my casual observations of other parts of the company, women at Company Z are vastly outnumbered by men in technical and leadership positions. This is reflected in my frequent use of male pronouns throughout this paper when referring to "employees". Women are certainly employed at Company Z, but all of the interviews used for this project were conducted with men, and the aforementioned PA was the only female participant in any of the meetings I observed.

Faulkner is not explicitly concerned with the underrepresentation of women in engineering, however. Her work focuses on two contrasting views of engineers and engineering work practices: a "techniscist" understanding and a "heterogeneous or sociotechnical" one. The techniscist understanding, which Faulkner argues is often characteristic of engineering education, reduces the work of an engineer to figures and calculations, ignoring social and cultural aspects of a situation in favour of purely technical ones. The heterogeneous understanding, which Faulkner states is more representative of engineering *work*, is more inclusive of social complexity. She analyses the cases of two engineers employed at the same company – one male and one female – and uses stories from their experiences and career trajectories to explore "how *gender symbols*…*co-produce*…*engineering identities*" (emphasis in original).

While the current project does not take up gender issues or symbols, Faulkner's discussion of the dualisms of "hard/soft" and "technical/social" are helpful in understanding how some employees of Company Z distinguish the roles of project lead or project engineer from other positions which are understood to be more technical. In moving from a position as an electrical engineer to that of a project lead, an employee may be considered to be leaving the technical behind for the social, but he will not necessarily be abandoning the hard for the soft.

2.2.3 Other Ethnographic Studies

Ethnographic studies of engineering work practices do exist (e.g. Henderson 1991, Sims 1999), but tend to be outdated and may not reflect current technologies or modes of communication. In her work, Henderson looks at visualizations and engineering drawings as boundary objects and "network organizing devices". She refers to "conscription devices", a subset of inscription devices that encourage or demand group action and collaboration. This framework is insightful and useful: in focusing on the drawings and technologies as boundary objects (Star and Griesemer 1989), Henderson is able to draw interesting comparisons between different groups within the engineering environment and to investigate the influence of new technologies on work practices.

However, the world of the design engineers that Henderson describes is a world that no longer exists. At the time of Henderson's research, CAD tools and drawings were only just emerging. Drawing boards and physical sketches were still the basis of much engineering design work. Henderson devotes part of her study to looking at how social structures and work practices were shifted as a result of the introduction of CAD technology. At Company Z in 2013, this transition has long since occurred. While quick sketches may remain an important part of casual engineering communication, drawing boards have been entirely replaced by computer technologies. Henderson's study is an interesting and useful inspiration for future ethnographic studies of engineers, but it also indicates a research gap with respect to changing practices and technologies in engineering environments.

Sims investigates testing in an earthquake engineering laboratory, drawing from Collins' work on embodied skill in scientific practice (Collins 1974). Though the research site is a place where engineers work, Sims is largely concerned with the testing practices that go on there and with the nature of scientific practices at the site, making his work more of a laboratory study than a study of engineering work practices as they exist in Company Z.

All in all, few ethnographic studies exist of work practices in engineering environments, and those that have been carried out are largely either outdated or focused on more aspects more common in traditional laboratory studies. Thus an additional research gap can be identified: not only is the connection between work practices and the company as an institution something relatively new for an engineering environment, but very few contemporary ethnographic studies of engineering work practices exist at all.

2.3 Living and Working with Risk

There is a large body of existing, STS-related work on risk and risk assessment in science and technology. Much of this work references classical conceptions of risk: Beck's *risk society* (Beck 1992), Giddens' related works on reflexive modernity (e.g. Giddens 1990), Foucauldian theories of governmentality (Foucault 1991), or cultural theories of risk (e.g. Douglas and Wildavsky 1982), to name a few. All of these are high level, macro concepts which describe risk in terms of cultural or societal frameworks; they are concerned with the interrelation of society, modernity, risk and culture. As the aims of this project are more localized and much smaller in scale, such classical, macro conceptions of risk relate only tangentially to the study. Of greater concern to this project are studies which focus more specifically on the roles of risk and risk assessment in the lives and work practices of scientists and engineers. This chapter contains a brief summary of several such studies, ranging from investigations of academic researchers coping with risk in their lives and work to analyses of organizational understandings of risk in corporate engineering environments.

2.3.1 Risk in Research and Researchers' Lives

Lisa Sigl discusses different kinds of risk and uncertainty as perceived by young academic researchers in the life sciences in her work on "conditions of precarity" in researchers' lives (Sigl 2012). Sigl makes an important distinction between *uncertainty* and *risk*, noting that, for the researchers, risk "appears as a problem that is estimable and manageable with the right knowledge and skills", whereas uncertainty is more intangible and may or may not be manageable at all. As uncertainty – with respect to experimental outcomes, project funding, and future employment, among other things – is identified as a major factor affecting the lives and work of young academics, Sigl characterizes the different strategies of *coping* with this uncertainty that are employed by the researchers.

These strategies include both collective and individual methods. "Coping like a clan" means that the researcher situates him or herself within the hierarchical structures of the laboratory and sees the lab leaders as powerful, parental figures, capable of managing or avoiding uncertainty through their allocation of resources. "Coping like a collective", an alternative group coping strategy, relies upon the *sharing* of resources and the promotion of the importance of "individual skills and tacit knowledge" to the laboratory as a whole. Both of these modes of coping are about protection from uncertainty: in the first case, through the actions of the lab supervisor and in the second through the support offered by an egalitarian community of employees.

While future employment scenarios are not as precarious at Company Z as they are for young academics, analogies to both of these modes of coping can be witnessed among the company's employees. As will be discussed in detail in the subsequent chapters, at Company Z there exist both a reliance on managers and team leaders to manage work flows and thereby to decrease the chances of mistakes or delays *and* an expectation of the development of tacit knowledge through working together.

Individual coping strategies identified in the life science laboratory also relate to practices at Company Z. Sigl states that as researchers progress in their careers, they are expected more and more to be able to cope with and solve problems on their own. A post-doc, for example, is held to much greater standards of personal responsibility than a student, and must be able to implement personal coping strategies rather than always relying on the lab manager or the lab as a collective. This is echoed in the environment of Company Z, where many employees and especially more senior engineers and project managers are expected to work largely independently and to manage themselves and their time. Sigl identifies two strategies of coping with uncertainty individually: "coping like a manager" and "coping like a trickster".

Coping like a manager entails managing the balance between "secure" and "risky" research such that one's career is not thrown off track by unexpected or unsatisfactory results. This mode of coping requires the evaluation of the risk potential of a research project before starting it and the strict management and ordering of personal and research time. This mode of coping is focused on maintaining and preparing for a career in academic, unlike the alternative individual strategy of coping like a trickster. Coping like a trickster requires the consideration of other career tracks outside of academia and bending requirements or definitions in order to obtain funding or security.

All of the above strategies are methods of dealing with *uncertainty*, as opposed to *risk*. In the academic life science environment described by Sigl, much of the uncertainty is career-related. Young scientists must manage their research and career trajectories in a world where their next job depends on uncertain project funding. Uncertainty exists at Company Z as well, but it is not related to the individual career futures of the company's employees (most of whom seem to enjoy relatively secure positions). Instead, uncertainty is expressed around project timelines, delivery dates, test results, and the actions of other companies or teams. Company Z employees may not be as personally invested in these coping strategies as Sigl's young life scientists, since the outcomes do not relate directly to their career and economic futures; however, strategies for coping with uncertainty *are* directly related to the success or failure of a project and are still very much a part of employees' daily work routines.

In addition to uncertainties, concrete ideas about *risk* also exist at Company Z. Some of these are also mirrored in the concerns of academic researchers. For Sigl's life scientists, risk was a particular sub-category of uncertainty; one that could be managed and potentially avoided. "Risky research" referred to experiments or projects that had the potential to produce ground-breaking results, but might also end in failure. These projects were a contrast to "secure research", which generally promised "safe" results and assured publication, though nothing exciting or revolutionary. A researcher's choice of risky or secure projects depended on timing, personal interest and the current state of both the research field and the researcher's career.

The employees of Company Z do not deal with "safe" and "risky" projects in the same way. The relevance of project choice to one's career is not the same as in the case of young researchers in academia. For one thing, Company Z employees are not expected to publish their results, and the choice of a particular project may not have as direct an impact on one's career trajectory as it would for an academic researcher. However, this does not preclude the assessment by individuals of risky vs. secure options or risky vs. secure technological solutions. There is much to suggest that assessments of risk in life science laboratories may bear significant relation to similar calculations performed in an engineering environment.

2.3.2 Organizational Cultures of Risk

Individuals within engineering offices cope with uncertainty and risks using a number of different strategies, much as life scientists or others employed in science and technology fields do. But *how* is this risk identified and assessed? What role does the company as an institution play in the identification and regulation of risk, and how does this relate to the work practices of the employees? These themes have been taken up by social science scholars through the investigation of particular research or work organizations and the rituals and practices of risk that are associated with them.

In Diane Vaughan's work among engineers at NASA (Vaughan 1996) and air traffic controllers at the Federal Aviation Administration's National Air Transportation System (NATS) (Vaughan 2004), she examines the routine work practices and micro-level decision-making of employees as they relate to risk and accidents. She follows Star and Gerson (1987) in relating mistakes and anomalies to the "local and institutional context of work", rather than allowing them to be defined in isolation. In this way, she traces the "social organization" of risk through the different environments, describing the connections between daily work practices, institutional attitudes, and risk. Vaughan does this by examining the *technologies of control* which are used in the different settings. Technologies of control consist of rules and procedures related to risk, work practices, and surveillance technologies, which can be either procedures or objects.

Vaughan's approach allows her to draw conclusions about the kinds of organizations that NASA and NATS are. The fact that aircraft are established, well-regulated, global technologies which are in constant use encourages the use of "top-down" technologies of control at NATS. The intention is to regulate air traffic controllers' behaviour in the same way that the aircraft systems they work with are regulated. The controllers are trained and re-trained to think and behave in a particular way. In contrast, the more experimental nature of space shuttle technology at NASA allows and encourages the engineers there to weigh evidence, learn through mistakes and to expect anomalies and mistakes to occur.

Tacit knowledge gained from working within the environment is important in both cases for risk assessment and identification. Wynne (1988) describes the progression from experiential knowledge to tacit knowledge among engineers, though Vaughan notes that, in her experience, engineers at NASA were often required to discretize their tacit knowledge into a form that could be written down and shared with others. The air traffic controllers often relied on tacit knowledge – reading pilots' competency through tone of voice, being aware of what other colleagues in the room were doing – that was not recorded for shared use or teaching purposes.

Vaughan's overriding thesis is that technologies of control, including work practices, produce "taken-for-granted cultural understandings" of risk and error through the frequency and repetition of their use. Furthermore, these understandings are enduring enough that new employees in an organization will be "subject to the same influences" as current employees. Her further point is that these cultural understandings are "unintended consequences" of attempts to regulate and avoid risk based on the technologies that a given organization works with. This is a kind of technological determinism which is rooted in the two case studies that Vaughan uses in her analysis and may not apply equally in other situations. She acknowledges that evaluating the "certainty" or "uncertainty" of a technology may not be as appropriate in other scenarios, as is the case at Company Z, where many different products with different levels of "certainty" are produced and tested. Similarly, Vaughan does not account much for outside influences on organizational culture. As she points out herself, technologies of control do not originate from nowhere. Whether they are imported from another organization, influenced by employees' previous experiences or by national or regional culture, external factors surely exert an influence on work practices alongside the technologies themselves.

2.3.3 De-Coupling and 'Normal Accidents'

Vaughan's emphasis on the social and organizational aspects of risk is in contrast to other bodies of literature which focus on the nature of technologies and systems themselves, and their consequences with respect to risk and accident. Traditionally, a divide has existed between proponents of High Reliability Theory, which holds that organizations can prevent accidents through studying "safe" systems and processes (e.g. Weick 1987), and Normal Accident Theory, which states that accidents are inevitable within complex systems.

Normal Accident Theory is exemplified by Charles Perrow's work (Perrow 1984). Perrow uses the term to describe the inevitable, harmful events that occur increasingly in complex systems where two or more components can interact and fail in unpredictable ways. His thesis is that such accidents, while ostensibly unexpected and unforeseeable, are "normal" in that the characteristics of the system itself make it likely that an accident will occur. While we may not be able to predict the date, time or exact cause of a normal accident, we can (or should) understand that they are likely to occur.

Perrow discusses two characteristics of complex systems which increase the likelihood of accidents: interactive complexity and tight coupling, using nuclear power plants as an example of a system which is both complex and tightly coupled. Interactive complexity refers to the ability of multiple failures in a system to interact with one another in ways which are difficult to predict. A large number of unpredictable failure modes will increase the likelihood that a minor "incident" will develop unforeseeably into a major catastrophe, and therefore a very complex system will have a high probability of normal accident occurrence.

Tightly coupled systems have parts or sub-systems which interact swiftly and meaningfully with one another. A system which is not tightly coupled may have many, largely independent sub-systems which will not be greatly affected if one segment of the system fails, and it is more likely that a human operator could intervene to correct a problem without adversely affecting the system as a whole. The operator of a tightly-coupled system, on the other hand, will influence the entire system (or large parts of it) through intervention with a single part. A tightly-coupled system, says Perrow, will also increase the chances of a normal accident.

Vaughan attempts to bridge the divide between the two schools by suggesting that, though "routine non-conformity" does exist in all complex organizations, the constant "clean-up work" engaged in by the two organizations she has studied through their technologies of control acts as a kind of reliability feature. Other studies (e.g. Rijpma 1997) suggest that both High Reliability and Normal Accident Theory could benefit from "cross-fertilization" of their respective ideas.

Without fully accepting the validity of one theory or the other, the frameworks of the two theories provide useful starting points for an investigation of the systems and structures of Company Z. The technologies produced by the company are in most cases both complex and tightly coupled. However, in many circumstances, both regulations and employees' work practices seek to "de-couple" the *work* that is done to produce the technologies. Independent checks and tests are performed on the same part by different employees in different teams. The quality assurance department is seen as a completely separate entity from the other engineering teams. Generally, employees from different work groups are expected to proceed with their work without frequent input from other departments. These are often seen as risk-reduction strategies.

While they do not provide a template from which to work, risk and reliability studies such as those mentioned above represent important points of consideration for investigating risk assessment within an engineering environment.

2.4 Time and Efficiency

Deeply intertwined with notions and understandings of risk, *time* and *efficiency* were themes that appeared and reappeared at Company Z throughout the field work. In addition to speaking of time as a commodity that could be managed, saved, wasted or used efficiently, the time plans and longer-term timescales of projects or careers were evident in the testimonies and actions of Company Z employees.

Social science researchers have addressed the topic of time in different ways, both explicitly related to science and technology and otherwise. This chapter reviews several different conceptions of time from social science research and briefly explores their potential connections to the ideas about time that exist at Company Z.

The distinction between quantitative and qualitative time is a common thread throughout social science writing on the subject. Garforth and Cervinkova (2009) contrast the idea of time as a measured quantity with an imagination of qualitative time that is "experienced, embodied, contextual". Barbara Adam (1994) speaks of "timescapes" as compared to "clock time", where timescapes are the multiplicities of time which permeate and weave through people's lives and clock time represents the temporal pressures and divisions which periodically invade them. Clock time is a representation of time as a commodity that can be made, saved, lost or wasted. However, Adam and others have also disputed the binary distinction between quantified and qualitative time, arguing that it is an oversimplification which does not "exhaust the ways in which time matters". In the edited volume *Knowing and Living in Academic Research* (Felt 2009), which contains Garforth's and Cervinkova's chapter mentioned above, the authors follow Adam in looking at time as plural and multidimensional. Using Adams' terminology, their analysis of researchers' lives and careers makes use of descriptions of time that go beyond a clear qualitative/quantitative, binary division.

The first of these is *timing*, an organizational understanding of time that is "the means by which we fit everything together". This definition is not limited to daily or weekly coordination, but can also refer to the planning or fitting together over the course of a career. The second is *tempo*, which is related to "the speed, pace and intensity of practices and institutional change". The earlier discussion of new modes of knowledge production indicates the kinds of institutional changes which may be at work in current science and engineering environments. Temporal aspects of these changes are referred to in discussions of tempo.

Two additional terms employed in *Knowing and Living in Academic Research* are *trajectories* and *everyday time*. These relate to the ways in which people talk about and live time. Trajectories are "narrated time" and generally arch over months or years. They are the "stories that...actors tell themselves" about their pasts, presents and futures. Everyday time exists on a smaller scale and represents a more commoditized idea of time. Everyday time can be "spent and saved, used and produced, managed and accounted for...in concrete settings". While both of these conceptions of time can be observed at Company Z, it is arguably this everyday time that is most closely related to the daily work practices of employees.

At Company Z, time is commoditized in many ways. As discussed in subsequent chapters (see 0), a working hour is a standard unit of measurement at the company. Projects are described and compared using the number of hours that are thought to be required to complete certain tasks, and employees' own working time is measured in the hours spent on certain projects. The idea that time can be used well or poorly, saved or wasted, is strongly present at Company Z.

This commoditization of time is strongly connected by the employees to their ideas about efficiency and profit. Company Z is a privately-owned organization, and it exists to manufacture profits as well as technologies. Its employees, particularly its managers and project leaders, are therefore required to consider the financial impact on the company of their actions and decisions. However, this necessity to think about *money* is often translated to a requirement to think about *time* by engineers and project managers alike, many of whom seem to have taken the adage "*time is money"* to heart. Often, the whole situation is commonly expressed as a desire or quest for *efficiency*, which for the engineers of Company Z seems to mean completing the required work to the desired level of quality in the shortest possible amount of time.

In contrast to previous studies of life scientists and researchers (Felt 2009, Sigl 2012), the employees of Company Z did not express major concerns about precarity in the trajectories of their lives or careers. Nonetheless, the idea of a narrated time that weaves through employees past, present and future was identified in the employees' comments with regard to two major themes: employee development and project "life cycles" or "lifetimes".

As indicated in chapter 2.3, tacit knowledge and skills are important factors that help determine the worth of an employee to the company and/or his value to certain projects. These skills are understood to develop over the trajectory of an employee's career, and are often described as qualities which can only be obtained through experience and over longer periods of time. Project life cycles, while generally shorter-term than employees' careers, are similarly described as stories of ongoing development. Both of these kinds of trajectories feature goals, aspirations, and circumstances which change as time progresses. Both include different stages of evolution: both young employees and projects in their early bid phases are influenced by different actors and eventually grow into experienced engineers and completed project proposals, respectively. Notions of past, present and future, and the concept of growth over time are present in employees' accounts of these development processes, whereas discussion of the "everyday" management of time as a commodity more often presents this as a constant, static activity.

2.5 Boundaries, Roles and Organizations

The concept of boundary work was famously developed by Thomas Gieryn (Gieryn 1983) through his discussion of demarcation between science and non-science. It has evolved into a major concept in STS and is now used more generally to refer to the instances or ways in which boundaries between fields are created or reinforced. Gieryn wrote further on the subject, discussing the boundaries between science, social science and STS, an how these are understood by different actors (Gieryn 1996), but other studies have focused on aspects such as the development of individual scientific disciplines and the boundary work done to distinguish 'lay' and 'expert' authority (Eden, Donaldson, and Walker 2006).

Boundary work is done when actions are taken to construct or reinforce a social boundary, particularly between different sets of intellectual practices. Gieryn defines this work as the "attribution of selected characteristics to [an institution] (i.e. to its practitioners, methods, stock of knowledge, values and work organization for the purposes of constructing a social boundary". For Gieryn, the construction of these boundaries was often also implicitly value-laden. In his discussion of the exclusion of the social sciences from an museum exhibition on "Science in American Life", it seems that those who worked to exclude social science from the exhibition – and thus to create a boundary between the social sciences and "real" science – were simultaneously placing the social sciences below other branches of science on some scale of worthiness or usefulness. In this case, the characteristics attributed across the boundary were negative ones. However, it is not always the case with boundary work that one entity is considered to be less worthy than another. Boundary work can also be used to delineate borders between different-but-equal academic fields or between distinct institutions.

It is this latter case that is most often observed at Company Z. Rather than making value judgements about other companies, sites or teams, the employees of Company Z and their collaborators most often perform boundary work when contrasting "internal" and "external" actors or objects in seemingly value-neutral ways. Depending on the situation, these boundaries may be constructed between Company Z and other companies, between different sites within Company Z, or between project teams or divisions within one site.

Boundary work can also be used to distinguish groups which may not be separated physically, or indeed to delineate the different roles and responsibilities required of a single person. Employees at Company Z construct boundaries between engineers and managers, between employees within the "work group" structure and those outside of it, and between the different roles (e.g. communicator or technician) which are required of them at different times or during certain project phases. By noting the instances of boundary work that are practiced at the company, and by examining the ways in which certain boundaries are drawn by certain actors (under which circumstances, and at which times?), conclusions can be drawn about the roles and responsibilities assigned to different actors, perceptions of membership and belonging with the company's structures and the circumstances under which definitions of *internal* and *external* change.

The concept of boundary work was further extended by Star and Griesmer (1989) to develop the notion of boundary *objects*. These are objects which act across borders and boundaries by being differently interpreted by different groups, yet maintaining some kind of self-identity through their various translations. Boundary objects "are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites."

Boundary objects can allow different groups to work together to accomplish a common task, as Henderson demonstrated in her analysis of design engineers and engineering drawings (Henderson 1991). Her "flexible sketches" had different meanings for the various groups that worked with them, yet were still able to translate the necessary information across social boundaries. The sketches worked more efficiently than verbal communication did, avoiding potential issues of linguistic translation by allowing all parties to read out their own necessary information from the object itself.

Boundary objects also exist at Company Z, and are used particularly during meetings to transmit information between distinct groups. Objects such as sketches, charts or "meeting guides" can carry information between Company Z and its customers, management and engineering or electrical and mechanical departments, to name but a few examples. Looking at boundary objects and the ways they are used during meetings can help to explain the relationships between entities both internal and external to the company.

2.6 Actor-Network Theory

Thus far, this chapter on the conceptual background of the project has included summaries of relevant bodies of literature, analyses of concepts which have informed and inspired the project even where they are not used directly and some brief discussions of theoretical conceits which will be used in the analysis of the results. In the subsequent methods chapter, I will discuss the data collection and analysis techniques used during the empirical research of the project. Firstly though, in this section, I will briefly touch upon something that is related to both theory and method. Actor-Network Theory (ANT) is in some ways, as its name states, a theory [2], but it is also deeply connected to method. As Maximilian Fochler points out in his work on the patients' organization Debra Austria (Fochler 2003), ANT is difficult to describe in the way that other social scientific theories can be described: ANT "has no bible, but many prophets". This project does not use ANT in a concrete way; I do not make specific reference to it in my discussion of the results. Nonetheless, ANT has had a good deal of influence on the ways in which the project was conceptualized, planned and structured. It has also influenced my ways of thinking about the data, and about the relationships between actors. For this reason, it deserves a brief description here and a short summary of the ways it has influenced my thinking about this project.

2.6.1 About ANT

ANT was originally developed in the early 1980s in France, at first by Michel Callon and Bruno Latour in cooperation with John Law and others. It was developed out of material-semiotic approaches – the study of signs and their relationships to meaning and power. The "network" of actor-network theory is a different concept than the one normally suggested by the word. The networks of ANT do not simply represent a web of linked entities, nor are they intended to be topographical representations. Indeed, the "network" of ANT cannot really be separated from the "actor" (hence, perhaps, the hyphen). The actor-network is a "heterogeneous network" (Law 1992) which includes both human and non-human elements. Furthermore, these elements are to be understood as sociologically equivalent in terms of power relations; human actors (in theory) receive no privileges or special treatment within the actor-network.

In this spirit, ANT rejects the idea that stability or significant social changes can be brought about by humans (or artifacts) alone. While the theory does not reject the importance of the body, it holds that people themselves are heterogeneous networks, made up of the artifacts, ideas and

[2] Though it has not always presented itself as such (Latour 1999)

relationships that compose their daily lives as well as flesh and bone. Similarly, ANT studies of various objects and systems (e.g. Johnson 1988) illustrate the multitudes of actors, objects and connections that can be related to a single technology.

A core tenet of ANT is that these actor-networks are not static. The term *translation* is used to describe the ways in which these networks are "displaced, distorted, rebuilt, reshaped" and otherwise remade (Law 1992). As an actor-network shifts, 'blocks' may be formed that consist of many connections, actors or processes but which come to be seen as one item, leading to the 'black-boxing' of this part of the network (Latour 1987b). These blocks may form, break up and re-form, shifting the emphasis and visibility of different parts of the network.

In *Science in Action* (1987a), Latour presents a step-by-step manual for conducting an ANT investigation. Its guidelines include entering the field without assumptions about the kind of networks, technologies, techniques and knowledge production that exist there, and seeking out the titular "science in action" – that is, science that is currently being made or discovered – rather than "ready-made science". Not all of these guidelines were important for this study, and some of them are difficult if not impossible to follow; however, the basic principles of ANT and the basic instruction to try to see things independent of preconceptions have influenced my conceptualization of the project and my understanding of Company Z.

2.6.2 'Applying' ANT

ANT has influenced my ways of thinking, firstly about *what* Company Z is, but also about *how* it functions. In ANT terms, Company Z is an actor, but it is also a network. It is heterogeneous. It consists of people, places, objects, ideas, and the connections between them. At times, all or parts of this network are perceived as acting as one complete whole, for example when the company submits a project bid to a potential customer. In this situation, actors external to the company see the bid that the company submits as the product of one organization's work. Of course, the process of bid construction within Company Z is quite a different story. For the employees involved in the bid preparation phase, the report that is eventually submitted is a heterogeneous network in itself, created by and with the input of many different people, teams and technologies. For the employees of the potential customer, the bid-preparation network within Company Z is *punctualised* (Law 1992) into a single block. If the bid is a successful one and a long-term collaboration ensues between the two companies, this block may be deconstructed from the point of view of the customer as they become more aware of the different forces at work within Company Z. This is a demonstration of the kind of dynamic reshaping of actor networks that is crucial to ANT.

As indicated during the discussion of boundary work and boundary objects, assigning and delineating different actors' *roles* is an important part of work at Company Z. The ANT term for this is *enrolment*, which is a part of the translation process of an actor network (Callon 1986). Enrolment refers not only to the assigning of roles to different actors or parts of the network, but to the conscious and *strategic* nature of this assignment. This is not to suggest that there is some cynical or abusive intention behind the consignment of roles within the company, but rather to indicate the importance of intentions which push and pull parts of the network. Assigning roles consciously and with purpose requires forming relationships with other actors in the network, relationships which are bound to change over time as the other tensions within the network evolve. An ANT approach recognizes the both the connectedness and the dynamism of the interactions between employees of Company Z and their collaborators.

The timing and flux of enrolment within the actor network of Company Z is also connected to power relations within the network. Again, this does not mean that malicious intentions or power struggles exist at Company Z. Instead, fluxes of power within the network are understood through ANT as a natural result of changes in enrolment over time. The performance of enrolment can be seen as a demonstration of power, as can a thorough understanding of the actor and network which are being enrolled. For example, actions taken by employees and their collaborators during meetings can reinforce or create categories of enrolment and power. Often, this is done through the use of official documents or by the creation of 'tasks' and the assignment of these tasks to a particular actor. On these occasions, the documents and lists often act as boundary objects, endowed with a certain degree of authority and autonomy, but differently interpreted by different actors.

Finally, ANT recognizes the importance of technologies and objects within the network. It is not the intention of this study to analyze a particular technology or to contrast the relative impacts of the material and the social on work practices, but it is recognized that technologies – both those created by at Company Z and others, such as ICTs – have strong influences on employees and their work. Instances of the relevance and power of technology abound at the company: to provide a simple example, every employee of the company has a badge of the kind mentioned in the introduction. These badges serve as identification, but also as means of access. They are keys that can be used to unlock doors all over the site. The fact that visiting customers (and researchers) are given different badges which do not function as keys is an enactment of power and a restriction of access through a technology. It is also a kind of boundary work. If an employee should lose or forget his badge, his ability to work and to communicate with others at the company would be temporarily restricted. In this scenario, the badge as a material object is at once a product of various social actions and decisions and an important actor in its own right.

Recognition of the punctualisation of processes within Company Z, the assigning of roles to different actors, the importance of objects and technologies to the work practices of the company and the interplay and dynamic nature of these ideas are examples of what ANT has brought to this project. While the project is not a highly theoretical one, and little explicit reference is made to actor-network theory in the analysis of the empirical data, these ideas and ways of thinking have been highly influential in the investigation of the nature of Company Z as a knowledge producer and the work practices of its employees.

3 Research Questions

This project is an investigation of the engineering company as an institution of innovation and knowledge production. The subject matter represents a departure from more traditional STS studies of innovation and knowledge production in laboratories and life science research. The engineering office is neither a laboratory nor (simply) a research institution, and it remains to be seen how much of the knowledge gleaned from studying the life sciences can be applied in an engineering environment, and in which ways. In contrast to well-known bodies of literature on new and evolving kinds of knowledge production, such as Mode 2, which are often concerned more with trends or tendencies than with individual cases, this project is a case study of a specific engineering company, Company Z. Furthermore, the project uses the work practices of the company's employees as a lens with which to examine the identity of the company. The focus on work practices yields data which, in addition to being interesting in its own right, reveals something about the ways in which employees' work is situated within Company Z as an institution.

This concentration on work practices as they relate to an institution, rather than at their connection with ethical or gender issues, also sets the project apart from many current STS studies of engineers or engineering, which are often concerned with ethical or gender issues in engineering environments.

In summary, this project uses the investigation of work practices to consider the kind of organization that an engineering company is. It takes Company Z, a European space technology company with offices in Austria, as a case from which to draw conclusions in a localized context. The employees' work practices are necessarily related to the identity of Company Z as an institution, and this connection is as worthy of consideration as the work practices themselves. Therefore, the project's main research question is

> ***RQ: How is the identity of an engineering company as an institution of knowledge production expressed through the work practices of the company's employees?***

3.1 Sub-Questions and Lines of Inquiry

During the beginning of the empirical phase of the project, the research interest had not been much refined or expressed any more narrowly than it is above. The aim was to enter the field with as few preconceptions as possible and to allow the employees of Company Z to define their work practices for themselves. However, after conducting the first few site visits and introductory interviews, several lines of inquiry were identified that were actively pursued in later field work. The following sub-questions were developed as part of a continual process of data collection, analysis and refinement. As a result, they represent the evolution of the project as more time was spent with Company Z and its employees, and they are as much a representation of the discoveries that were made during the project as they are a reflection of its original intentions.

SQ1: How are the work and responsibilities of an employee of Company Z constructed, defined and managed?

The ways in which employees and projects are managed at Company Z help to regulate the work practices of the employees. The structures of the company and projects also serve to encourage certain behaviours and discourage others. These regulatory practices are part of what Diane Vaughan called *technologies of control*: guidelines, processes and objects that are deeply related to the ways in which employees work and to their attitudes towards risk and experimentation. Thus, the regulatory systems in place at Company Z are coupled to both the organization's understanding of its own technologies and its perception of how employees should work. Exploring the management and definitions of employees' work can reveal something about how the company as an organization views its products and its role as an institution. The question refers to both the employees' *own* explicit constructions and definitions of their responsibilities and to those which are embedded in the company's structures and the implicit statements of other employees (for instance, the ways that a manager understands the responsibilities of a systems engineer as compared to the systems engineer's own opinions).

Despite the presence of technologies of control, it should not be assumed that a top down, regulatory approach determines the actions of the company's employees. Instead, it is likely that the actions of the employees and the company/project structures have evolved through a process of co-production (Jasanoff 2004), whereby the practices and ideas of the employees affect the regulations and structures of the company, and vice versa. An important line of inquiry for the project will be to investigate how the practices of the company's employees are related to the prescribed structures and regulations of Company Z.

SQ2: How do employees of Company Z understand "risk"? How is risk identified and assessed?

In this case, the interest is not in situating the perceptions of risk at Company Z in any grand narrative of risk and modernity, but rather in using understandings of risk as another tool with which to connect the work practices of the employees with the organization's role in knowledge production. The intention is to analyze the risk-related attitudes and actions of employees and to ground them in the perceptions of Company Z as an institution. Classical risk studies will provide the inspiration but not the empirical starting point for the investigation of risk. The focus of the study will remain on the work practices of the employees and their connection to the idea of the company as an institution.

The first step in understanding attitudes towards risk at Company Z is to explore what the company's employees and their collaborators consider "risky", and how they define the term risk. During the preparation phases, considerable time was devoted to the question of how to bring up the idea of risk during interviews without seeming to evaluate, threaten or condemn the interview subjects and their work. These worries turned out to be unfounded, as many employees readily discussed their understandings of risk and the relations of these understandings to regulations, responsibilities, quality control and testing. An analysis of these understandings and the different definitions of risk held by employees of Company Z will form the beginning of this part of the study.

The assessment of risk and the development of a project are closely related to *objects* at Company Z. Often, project "milestones" are achieved when it can be demonstrated that certain risks have been mitigated or shown to be inconsequential. Particular documents, when they have been created or signed, serve to reify truths about the absence of risk and/or the related project status. An important aspect of this question is to explore the roles which are played by objects – certain documents in particular – in determining and confirming risk mitigation strategies and/or the achievement of project milestones.

SQ3: How do employees of Company Z collaborate and communicate with other organizations? How do these practices differ based on location, project status and membership in a company or project team?

Work in the space industry involves innumerable collaborations with different kinds of organizations. Customers, sub-contractors, manufacturers, regulatory bodies and other organizations make up the actors which are sometimes referred to as "external": actors which are not financially, geographically or legally part of Company Z. Within the company, collaborations between different sites, divisions, teams and individual employees also play a vital role in daily work practices. In addition to their importance to everyday work practices, collaborations with different actors are a useful way to investigate the boundaries which are drawn between different people, groups and organizations, and accordingly to explore the ways in which Company Z as an institution is understood by these different actors.

The definition of internal and external actors and organizations is a demonstration of the boundary work done by Company Z employees and their collaborators. "Internal" and "external" may have different meanings in different situations: they refer not only to "Company Z vs. Non-Company Z", but also to the boundaries between sites, buildings, project teams, and work groups. Exploring the boundaries drawn by different actors in different situations will shed light on the (changing?) definitions and roles of companies, teams and individuals.

Communication is a key part of the daily routines of Company Z employees and an important factor in assessing the kinds of boundaries which are drawn between actors and organizations. Communication practices tend to differ depending on the locations of the actors involved and their relationship to each other, including their status as belonging to a certain company, organization or project team. Temporal elements play important roles in communication practices, as types of communication change depending on the development of a project, the urgency of a given issue and the evolving relationships of employees. The *meeting* is one important instance of communication between actors at Company Z, functioning as a space where information is exchanged, project status is assessed and achievements or setbacks are confirmed. As the observation of meetings was an important part of this project's empirical work, some space will be devoted to the analysis of the limiting and border-making power of the meeting space as well as the enactments of collaboration within it.

4 Data and Method

As the research aims of this project are to investigate the work practices of the employees of Company Z and to learn about their connection to the company as an institution, a methodological approach was required that would yield as detailed an understanding of the company as was possible within the constraints of the project. The (at least partially) project-based nature of the company's work made focusing on one or more projects within the organization a logical choice. Since both the privacy concerns on the part of Company Z and practical ones on the part of the researcher made it difficult to coordinate any kind of long-term participant observation, the bulk of the data was collected through interviews and observations of meetings. This approach was chosen as to gain the deepest possible conception of the organization and projects permitted by the time frame.

Qualitative methods lend themselves to the project, considering its interest in exploring issues and themes rather than evaluating them. Though the project was originally conceived of as having two distinct stages, the lines between these stages blurred as the empirical research began. The intention had been to first conduct narrative, open-ended interviews along with an initial site visit, and to use these first interactions with the company as a kind of familiarization phase. Only after becoming somewhat familiar with the organization's practices and structures would the meeting observations be carried out, along with more focused interviews. This was intended to allow the researcher to spend less time "translating" during the observations – trying to understand what was going on at the top level – and more time analyzing.

However, as is so often the case with field work, things did not work out precisely as planned. The first meeting observation was conducted early on, before the initial narrative interviews were carried out. Interviews and observations were mixed between projects and interspersed with explanatory conversations and impromptu tours. The scheduling of interviews often meant that data from previous observations could not be sufficiently analyzed and included in the preparation for the interview. In the end, the data set used for the project consisted of four interviews, ranging in length from 40 minutes to just over an hour, detailed notes from the observations of three meetings, and assorted field notes from other, shorter visits and informal conversations.

The goal of this chapter, in addition to explaining how the research was carried out and the data analyzed, is to spend a moment reflecting on this "messiness", including the role of the researcher within the company. The first section explains how I came to the company, and why the two projects with which I engaged were chosen. Subsequently, the methods of data collection and data analysis are described and justified. Finally, I reflect briefly on my role as a researcher and on the interesting role that language has played in the project.

4.1 Negotiating Access

I first contacted Company Z via email in late 2012, after conducting an informal survey of friends and colleagues with ties to the Austrian aerospace industry. For practical reasons, I wanted to restrict my research to one company and its collaborators, and Company Z seemed like an ideal choice. The company was chosen primarily for the variety of opportunities it presented to investigate the relationships and collaborations of a deeply "networked" institution: it has multiple facilities in Austria as well as in other countries, and has worked with ESA and countless other actors in the space technology industry. It also works simultaneously on a number of different projects for different customers, and I was interested in looking at the kinds of relations and tensions that this creates within the organization.

After a series of emails and telephone calls and eventually a meeting at the company's facilities, access was negotiated for the duration of the project. Generally speaking, my access flowed through one contact person at Company Z. My main contact served as a kind of gatekeeper and interpreter, often suggesting projects or meetings which he felt would be interesting for my project and convenient for the company. At the beginning of the field work phase, my visits typically began or ended in a discussion with my main contact, as he explained the technical background of a project or negotiated my access deeper into the facility. As the field work progressed, however, and I established other points of contact within the company, these meetings ended and I began to deal with other people directly.

I would begin each visit by greeting the receptionist of the building I was visiting and being handed a temporary badge. The badge labeled me as a guest, an authorized intruder on the premises. My visits were always scheduled in advance, and the receptionist generally had the badge waiting when I arrived. The visits were also quite controlled. She would call my contact for the day upon my arrival, and I would wait in the lobby until he came to fetch me. My guest badge, unlike those the employees wore, couldn't open the facilities' locked doors.

Wherever I went, I was escorted through the building. My observations were mostly limited to the meetings I attended and the offices of the employees I interviewed. I came to see any informal chatter I managed to catch in the front lobbies of the two buildings, or in the hallways or the kitchens on my way to or from a meeting room, as a kind of special treat, an ethnographic bonus that could supplement my "main" sources of data.

This data was collected through interviews and meeting observations in connection with two of the company's many projects, in addition to introductory meetings and tours during which different individual projects and general information about the company were discussed. These two projects were chosen by my main research contact, in consultation with me and with the employees involved in the projects. Our goals in choosing the projects were both to maximize their interest and usefulness to me as a researcher and to minimize any disruption to the company's employees and project schedules.

The first project was being conducted at the behest of the European Space Agency (ESA) in relation to a satellite program. The project (henceforth referred to as *Copernicus* [3]) was a study; an attempt to improve upon a design feature that already exists (and functions) within the current Copernicus satellites. The study does call for actual hardware and testing, and prototypes were to be created at the company; however, it was not foreseen that the results of the study or the hardware it produces would be used on the first generation of Copernicus satellites. The Copernicus project was a collaborative effort between Company Z and ESTEC, ESA's research centre in the Netherlands. Compared to many of the company's other projects, the Copernicus study was a small-scale undertaking. At the time the research was conducted, only a handful of Company Z employees were working on the project, which already been running for several years.

The second project was larger and older, and was a full product development project rather than a study. The technology in question consisted of mechanical, electrical and thermal components for a joint mission to Mercury planned in part by ESA. Company Z was a subcontractor on the project (henceforth referred to as *Merkur*); their direct customer was another international space technology company, Company A. *This* firm acted in turn as the subcontractor for *another* company, Company B, who were the direct suppliers to ESA. Yet another firm acted as a supplier on the same level as Company B, though they were not involved in the work that took place in Austria. The Merkur project had been running at Company Z for several years already, longer than the Copernicus project. At the time of research, the project was in the production and testing phase. Merkur has generally required more of the company employees than Copernicus, though the number required fluctuated depending on the project phase and was, at the time of research, already considerably smaller than it had once been.

[3] Project names have been changed.

The prototypes for both projects had been developed, produced and tested (or were scheduled to be produced and tested) at the company's facilities in Austria. Outside partners of various kinds were important to the projects in many ways; however, the technologies were designed and physically constructed in the facilities where the research and planning was also conducted.

There are several important ways in which the two projects are different from one another. Firstly and most obviously, the Copernicus project is a study and the Merkur project is not. While hardware was to be built for both projects, the Merkur hardware must be assembled in a clean room under controlled conditions and then tested to increasingly demanding levels before being delivered to the customer for further tests. The Copernicus hardware requires neither a controlled assembly environment nor the same levels of testing as Merkur.

But differences in assembly and testing requirements are not the only things that distinguish a study project from a "normal" one. The study/non-study distinction, as will be elaborated in the subsequent chapter, is also related to employees' understandings of time, risk and efficiency as they relate to workload and project schedule.

The projects also differed in their types and levels of collaboration. The Copernicus project involved one department within Company Z's Austrian facilities and another department of Company Z at a facility elsewhere in Europe. On Copernicus, Company Z had a direct contract with ESTEC and interactions with other organizations were minor compared to the Company Z – ESTEC relationship. Merkur was a different case, as Company Z acted as the subcontractor to a subcontractor of ESA. The Austrian facilities were the only site within Company Z that worked on the Merkur project; however, all three departments that are represented at the Austrian site – electrical, mechanical and thermal – were involved. This meant that more actors were involved in typical negotiations on the Merkur project than on Copernicus. The discussion of an urgent issue on Copernicus may require representatives of Company Z in two different countries and possibly actors from ESTEC, whereas a serious issue on Merkur may necessitate communication between three different groups within Company Z in addition to their respective partners at Company A, Company B, and in rare cases ESA as well.

Finally, the Merkur project was nearing completion at the time the field work was conducted. The Copernicus project, while already past its initial stages, had not yet reached the hardware construction and assembly phase. As will be explained in the subsequent chapter, this meant that different actors within Company Z were involved in each project, and that the roles and responsibilities of these actors differed significantly.

Meeting observations (one Copernicus meeting and two Merkur meetings) as well as interviews (one with an employee who worked on Copernicus and two with employees who worked on Merkur) were conducted on both projects. Additionally, one interview and several informal conversations were held with other Company Z employees, including those (such as a public relations employee) who were not directly involved in either project. The following sections will describe the specific methods chosen for data collection and analysis and explain why and how each was used.

4.2 Data Collection

4.2.1 Interviews

Interviews were chosen as the primary method of data collection in order to provide insight into the personal imaginations and work practices of Company Z employees. The initial interviews also served as introductions to the company and the projects which were chosen for research. Four interviews were conducted with employees in different positions, the number being limited by the time frame of the project and the availability of the employees. The interview subjects held different positions within the company but were all male, all relatively well-established in their careers and all long-time, permanent employees of Company Z. Thus, this study cannot claim to represent perspectives that may have been offered by contractors, younger or newer employees, or by those who work outside the company's work group/project structure. However, the interviews with established employees of Company Z demonstrated the ways in which the company's structures and regulations act on imaginations of its employees. Since all of the interview subjects were well-versed in the traditions of the company, all were able to discuss their work practices in ways that can be considered to reflect the influence of the company's policies and organizational identity on the employees.

All of the interviews were semi-structured; however, the first interviews were less structured than the final one. The first interviews that were conducted – with project leads and with an employee from the company's public relations department - were informal and narrative. The aim of these interviews was to establish a basic understanding of the organizations and their aims, structures and work practices, in addition to a basic technical understanding of the projects that were to be used in the investigation. These introductory interviews also served as an introduction to the specialized language and vocabulary used by Company Z employees in specific circumstances. Finally, the interviews were meant to inspire avenues of inquiry for later interviews and conversations into the employees' understandings of risk, time management, and communication.

These initial interviews were intended to be "semi-structured life world interviews" (Kvale and Brinkmann 2009), meant to provide first glimpses of the points of view and perceptions of the interview subjects. Some basic research was conducted prior to the interviews, largely by visiting the company's website and reading publicly available press releases; however, the intention was not to guide the interview subject too much, and instead to let him arrive at the topics which he felt were most important or relevant. The interviews and interview subjects themselves thus provided an "insider" perspective that enhanced the researcher's understanding of the company environment. These were also narrative interviews in the sense that it was the interview subject's stories and opinions which were of interest; however, they were not conducted in the classic style (Schütze 1983), whereby the interviewer asks an initial question and simply allows the interviewee to tell a story without interruption. While the interview subject did retain a level of control over the interview topics, the role of the interviewer was interpreted more actively, allowing for numerous follow-up questions and the explicit introduction of various sub-topics. This format allowed the researcher to "grasp the interviewee's concept of a story" (Matthews and Ross 2010) and to identify topics that the interviewee sees as important surrounding issues of risk, communication, regulation and partnership.

These "life world" interviews provided an introduction to the environment and work practices of Company Z, and helped to identify the issues which were of greatest importance to the interviewees. These issues, in turn, provided important data and insight for the subsequent stages of research.

With the final interview, some of the themes that had been identified through earlier interviews and observations were built upon to develop more focused lines of inquiry. The basic understanding of the company's structures and the engineers' specialized vocabulary that had been established through the initial field work was used to construct questions about work practices, risk and collaboration that had been "translated" into the kind of phrasing that would be recognized by the interview subject. This translation work was a major part of the interview preparation and an important by-product of the narrative interviews and initial observations.

4.2.2 Meeting Observations

The field work also included participant observation in the form of three meetings: two concerning the Merkur project and one on Copernicus. The Copernicus meeting and one of the Merkur meetings were "internal": aside from the researcher, they included only participants who were employed by Company Z and whose normal workplaces were at the Austrian facilities where the meetings took place. The second Merkur meeting also included "external" actors: two representatives of Company A, who were both physically present at the meeting, and several others from Company A, Company B and ESA who participated via telephone. I attended all of the meetings in person and was introduced to the participants as a researcher who was conducting a project on engineering communication practices.

The intention of the meeting observations was to provide examples of Company Z employees "in action", something which could not be conducted via interviews and which proved to be too difficult to negotiate in a setting outside of the meeting room. Aside from informal observations gathered from passing through offices, labs and corridors on the way to other appointments, the meetings were the only times during which I was able to observe employees actually *working*, rather than simply asking them questions about their work. The meetings, therefore, were invaluable sources of data on employee work practices, particularly with regard to communication and boundary work. At the meetings, I was able to observe the ways employees speak to each other, the processes by which they discuss problems and assign tasks, and witness the assignment of roles to different actors within the projects. I was not able to make audio recordings of the meetings; however, I took extensive notes which were later coded along with the interview transcripts.

My approach to the meeting observations was influenced by the work of Emerson et al. (Emerson, Fretz, and Shaw 2007 [1996]) on ethnography and participant observation, who state that an ethnographer must seek "immersion" in the worlds of the field contact, "in order to grasp what they experience as meaningful and important". As a researcher, I tried to recognize the importance of my participation in the meetings as well as my observation of the others' actions. As Emerson et al. write, a researcher "cannot and should not attempt to be a fly on the wall". The presence of a researcher in an unfamiliar environment necessarily disturbs the standard work practices of the meeting participants. Rather than attempting to erase this disruption, the aim was to immerse myself in the surroundings (to the extent that this was possible, given the limited nature of the empirical research phase) and to reflect upon my participation and its possible influences on the observed phenomena.

This immersion was not only important in terms of physical proximity and technical understanding, but also in terms of establishing *co-presence* (Beaulieu 2010). Co-presence as Beaulieu defines it does not depend on the geographic location of the researcher, but rather on the development of mutual understanding and trust between the researcher and the actors in the field. A researcher who can establish co-presence will be better positioned to gain a deep understanding of her empirical data, in addition to gaining easier access to the field. Some strategies and experiences of developing co-presence in the field are elaborated in chapter 4.4.

4.3 Data Analysis

Coding and grounded theory were used to process and analyze the data collected during the interviews and observation phases. Grounded theory was introduced by Glaser and Strauss in the mid-20th century (Glaser and Strauss 1967), and later elaborated and further developed by Strauss and Corbin (2000 [1998]), Clarke (2005) and Charmaz (2009). Broadly stated, it is a system of qualitative data analysis in which the data themselves guide the direction of analysis and the development of conclusions. Its intention is for themes and topics emerge from the data that has been collected, rather than from the preconceptions of the researcher. Grounded theory is a method (or a set of methods) that consists of "systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories 'grounded' in the data themselves" (Charmaz 2009).

Grounded theory was chosen as a method of analysis in part due to its suitability for analyzing heterogeneous data types. Data for this project included interview transcriptions, field notes from meetings and other site visits as well as a small amount of visual material (presentation slides and pictures) obtained from the company. Grounded theory allowed for data from these different sources to be compared and analyzed together. Grounded theory also encourages the definition of themes and theories based in the data, and allows for the categorization of data into thematic groups. This grouping, coding and re-grouping was essential to the foundation of themes and the development of lines of analysis.

Charmaz understands grounded theory as a set of suggested practices rather than as a regimental guideline for analysis, and this project's data were analyzed according to this principle. The interviews were transcribed in a very basic style, and the rough notes taken during meeting observations and other visits to Company Z were expanded into more detailed field notes shortly following the encounters. All of this data was then coded, firstly using "open coding" (Strauss and Corbin 2000 [1998]), whereby codes are assigned to each line of data or to a group of related lines. This initial phase of coding was followed by more focused coding, where the emphasis moved from "comparing data with data" to comparing "data with codes". During focused coding, the most important or oft-repeated codes were identified and subsequently compared to other parts of the data. This process allowed categories to be identified and the data to be sorted according to the most relevant themes.

All interview transcripts and field notes from meetings and other observations were coded in this way. Particular attention was paid to *in vivo* codes, codes that are based on participants' own special terms and language. Given the propensity in the engineering world for developing specialized vocabulary, there were a great many instances observed of these kinds of "condensed meanings".

The lines of inquiry outlined in chapter 3.1 were developed alongside the initial coding phase. The aim of the subsequent focused coding analysis was to explore employees work practices along these lines. Accordingly, groups of codes and citations were made which corresponded to each of the sub-questions. Later, as these themes were developed in more detail, the aim of the data analysis shifted to connecting the themes and statements with applicable theory to using this to develop an idea of the identity of Company Z as an institution. During all stages, the analysis of the empirical data was intended to draw out themes and narratives that would not have been apparent after a first reading. Some of Adele Clarke's work on situational analysis (Clarke 2005), particularly her methods of situational mapping to illuminate connections between actors and narratives and to overcome "analytic paralysis", was also used during the early stages of data analysis.

4.4 Methodology and Experiences: Some Reflections

4.4.1 Lost in Translation?

Language and national culture are not aspects of the project to which I was able to devote much space in this account. Nonetheless, language in particular has been an important part of the research and writing process, albeit one that has mostly vanished from this final representation of the results. I would like to take the opportunity here to briefly reflect upon the role that language and culture have played in the research. As has been stated, Company Z is both an Austrian and an international company. The offices that I visited were in Austria and the employees I interviewed were Austrian, as were most of those I encountered during my site visits. Accordingly, German is the spoken language of Company Z. It is the language that is heard in the company's hallways and kitchens, and it is almost always spoken during informal conversations between employees. At the same time, the Austrian offices of Company Z are one part of an international firm with operations in different European countries and customers and partners around the world, many of whom are non-German-speaking. For this reason, English also has an important presence at Company Z: in addition to being a common spoken language between the company and its many international collaborators, it is the language of the reports and presentations that make up one important part of the company's products.

The two "internal" meetings and all of my informal conversations at the company were conducted in German, while the meeting that included the Merkur customers was in English. Although I am a non-native German speaker and this report is written in English, I also chose to conduct the interviews in German and to translate passages for citation when necessary. This choice was made for several reasons. Firstly, I was not aware at the beginning of the project what the English proficiency levels of my interview subjects would be. As it turned out, everyone I spoke with communicated regularly with non-Austrian collaborators and spoke English comfortably. However, this could not be established at the beginning of the project.

Secondly, even in cases where the interview subject spoke English well, I knew that a native German speaker would be most comfortable speaking in his mother tongue. Conducting the interviews in German was an attempt to put the interview subject at ease and to encourage candid statements and the development of a *conversation*, something that is vital to the flow of a good interview (Hermanowicz 2002). Of course, choosing not to conduct the interviews in my own native language increased the level of discomfort on the part of the researcher, but this was judged to be less important than the comfort of the interview subject (after all, I had time to prepare!).

Finally, I wanted to use language as a way of establishing *co-presence* (Beaulieu 2010). As a researcher I was an outsider at Company Z. My status as "other" was further compounded by my age (I was significantly younger than all of the interview subjects), gender (nearly everyone I encountered at Company Z was male), and background (though I informed my interview subjects that I had been trained as an engineer, I was most often perceived as a communications scholar or social scientist) and nationality. Since I did not have the luxury of a long period of observation time during which I could "integrate" myself into the company environment, I wanted to use both language and my technical background to establish common ground and understanding at the company between myself and the employees.

After all this talk of interview languages, it must be noted that the interviews were not, after all, conducted entirely in German. The international nature of the space industry and the fact that Company Z must produce reports and documents for non-Austrian customers means that English terms are widely used within the company. Documents, mechanical and electrical assemblies or parts, meetings and milestones have English names and often these are not translated by speakers, even when all participants in a conversation are speaking German. Acronyms like CDR or NCR are often pronounced in English, reflecting their Anglo-American origins. Since it was apparent that I was a non-native German speaker, interview subjects usually made no attempt to translate English phrases to German or to "correct" English phrases that slipped into their speech. This resulted in such entertaining sentence fragments as "[the products] fliegen to Mercury", "[our customer will participate] auch in person und es wird unser Shadow Engineer kommen" and "wir kommen zwar [...] aus dem Engineering, engineeren aber nicht mehr" [4].

This construction of a specific language and terminology in speaking about projects and meetings can be understood using Galison's (1997) notion of the trading zone, discussed at length in a later chapter.

4.4.2 The Researcher's Role

In addition to the confusion over language, I faced a dilemma over how to present myself to the company as a researcher. On the one hand I was an engineer, holding a degree in aerospace engineering and employed at the time of research by an engineering company (not Company Z or

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[4] Rough translations of the three citations are as follows: "[the products] fly to Mercury", "[our customer will participate] also in person and our shadow engineer will come" and "we come from engineering, but we don't engineer any more".

any of its direct partners or competitors). On the other hand I was at the company to conduct social science research and not to do engineering work. My background had certainly informed my decision to take on such a project as well as shaping some of my preconceptions about the company, but it was only indirectly related to the research I was there to carry out. I wondered whether the employees would take me more seriously if I presented myself as an engineer, or if being perceived as "one of us" might grant me some kind of insider status in the field. Alternatively, perhaps introducing myself as an engineer would only serve to confuse them about why I was visiting the company in the first place.

In the end, I briefly mentioned my background in engineering as a source of inspiration for the social science research project I was conducting. For better or for worse, I soon discovered that my own experiences in engineering had little to do with the kinds of technical work which are done at Company Z. I had no more of a technical understanding of the company's projects than a freshly minted university graduate would have had. Due to this and to the focus of my research, which had formed the basis of my introduction to the company, my impression was that I was perceived by the employees largely as a social scientist. My background in engineering, when referred to at all, was mentioned in passing or as an afterthought. Most of the meeting participants whom I did not subsequently interview were entirely unaware of it.

This was reflected in the way I was introduced to meeting participants. During the early stages of field work, when the research focus of the project was not yet clear, I had settled on "engineering communication" as a shorthand description of my research interest when speaking with the employees of Company Z. While this broad term did not reflect all of the thought and planning that had gone into the project, it proved to be a notion that was easy for the employees to comprehend and also allowed me to pursue lines of questioning related to collaboration and communication-related work practices in the interviews. The general acceptance of this terminology as a description of the research project meant that it continued to be used even as the project evolved. I was introduced at the beginning of most meetings as "communications researcher" or a "communications expert". This was of particular relevance during the meeting with Company Z's customers for the Merkur project, who had not been previously informed of my attendance. During breaks in the meeting as well as immediately before and, the participants volunteered information about their experiences and practices of engineering communication. They also posed questions to me about my "communications research" and background. In this way, the assignment to me of the role of social scientist/communications researcher endured well beyond the initial phases of research and had a significant effect on the kind of information that I was able to collect.

5 Results and Discussion

In this section I present the empirical results of the study of employees' work practices at Company Z, along with a discussion of their meanings and implications. The results are presented in three chapters, which respectively address employees' understandings of expertise and responsibility, ideas about risk, time and efficiency, and performances of boundary work within the "meeting space" at the company. These chapters correspond roughly to the three sub-questions discussed in chapter 3.1, though elements of all three lines of inquiry are present in all of the discussion themes. In the final section of the study, I will draw upon these discussions to draw conclusions about Company Z as an institution of knowledge production.

5.1 "*We'll need to find a role for you*": Assigning and Distinguishing Responsibilities

Near the end of one of the interviews, I asked the project manager with whom I was speaking about the meeting I would be observing on his project later in the week. Did the members of the external company – a customer of Company Z – that would participate in the meeting also know that I would be there?

> *No, they don't know yet. It was too last-minute. But I think we'll find some kind of role and we'll do it somehow. We'll have to talk about it today, but I assume it shouldn't be a problem that you participate. But I definitely have to tell the customer, when we know internally which role you'll have in the meeting. (Q1, third interview, 12.03.2013)*

As we parted ways, he assured me again that arranging the meeting observation wouldn't be a problem. "*We'll just need to find a role for you.*" In the end, the customer found out about my participation on the morning of the meeting, just a few minutes before my arrival. When I entered the room, I was introduced as a communications researcher and a partner of Company Z, who was conducting a study of engineering communication in the space industry with the goal of improving the communication practices of Company Z. I open with this incident not to reflect upon this representation of myself as a researcher (see chapter 4.4.2 for that), but to emphasize the importance of determining and assigning roles at Company Z, particularly within the space of a meeting and especially when dealing with participants external to the company structure. Employees are assigned roles through the coordination of tasks, via their participation or non-participation in a project and through their membership in a skill-based *work group*, to name just a few different practices. This kind of *enrolment* does not always happen explicitly. Roles can be assigned implicitly – even unintentionally – through actions, comments, or through the distribution of work.

The chapter begins with a discussion of the importance of structure and the roles of different organizational regimes to the function of Company Z and its collaborations with customers. I begin by describing two of the company's organizational regimes they are understood by the company's employees: the project-based regime and the competency-based regime. The notions of belonging and expertise that are connected with these regimes will be explored.

Subsequently, I relate these organizational regimes to notions of personal expertise and experience within Company Z. The tacit knowledge of the employees and their collaborators and the importance of durable knowledge are related to the necessity of "stability" within projects and especially within a core team, on both the company and customer sides of a project.

Finally, I discuss role assignment and the switching or multiplicity of roles on an individual level. This role assignment is often related to one's job title but also has more complicated dimensions. A project manager does not always serve the same function in a team: the stage of the project and the kinds of work to be done influence his relations with the other members of the project team, other company employees who work "outside" the project team structure and employees of customers' or partners' companies. I also discuss self-identities of engineers and project managers, including the ways in which they experience the differences between technical and social aspects of their work.

5.1.1 The Roles of Organizational Regimes

As previously indicated, different structural systems exist within Company Z. The Austrian site at which the research was conducted is broadly divided into Electrical, Mechanical and Thermal divisions. Most employees belong to one of these divisions, though others such as procurement staff or marketing employees do not. Most employees are also members of one of 26 work groups, which are organized according to the special technical skills of the employees, for example "processing systems" or "integrated electronics". The work groups range in size from two employees to nearly 20, and each is headed by a group leader. This work group-based structure is what I will refer to as the *competence-based* regime of organization at Company Z.

The other major organizational regime is *project-based*. In this structure, employees are organized based on the projects that they are currently working on. Each project has a project team, or "core team", which is generally established during the proposal phase or shortly after. This team, which will ideally remain the same throughout the duration of the project, contains members from different work groups who have different kinds of expertise and who can all (in theory) contribute something unique and necessary to the project. A project leader from Company Z explains the company's structure as follows.

> *In the company we're organized in groups and these groups send employees to the projects. It's a classic matrix organization. And already at the proposal, or at least by the start-up of the project a project team is decided on. That means there's a project leader, a project engineer – that's the main technical officer, so to say – and there's always a PA Responsible and then there are Responsibles from Analysis, Design and AIV – that's Assembly Integration Verification, which also includes Manufacturing. (Q2, Interview III, 12.03.2013)*

A core team (or "project team" in the above case) does not include everyone who works on the project. Instead, as indicated in the quotation above, it demands representation from all of the competences which are deemed to be important – in this case Product Assurance, Analysis, Design and Assembly/Testing – as well as the project engineer and project leader, who are assigned responsibility for managing the technical and non-technical sides of the project, respectively. This team is responsible for outlining the initial design of a product, planning and organizing the work that will need to be done, and deciding which other employees will work on the project. Eventually, the work that is defined by the core time will be distributed amongst employees from the relevant work groups, who then also become connected to project. As introduced in chapter 1.3.3, the "classic matrix organization" that the project manager refers to is a management style by which project-based and competence-based working groups form opposite axes of an employee matrix. In creating a core team and later deciding how work will be distributed (both to members of the core team and to others outside of it), delicate negotiations go on between the project-based and competence-based regimes.

> *And these people responsible for the work groups, the group leaders as we call them, they have the job of somehow keeping the projects satisfied and yes. Naturally there are conflicts and then you have to, through a Resource Coordination Round, discuss everything and when you can't reach a decision on the inter-project level then you have to go one level higher and it escalates. Yes, yes, but I think it's relatively, relatively transparent, the way we do things here. (Q3, Interview II, 04.03.2013)*

Of course it is important to remember that, in many cases, the same employees are involved on both sides of these negotiations. Most of the engineering personnel at Company Z are simultaneously members of one work group and multiple project groups. Most of the management personnel manage more than one project at the same time, in addition to being members of the set of project or group leaders. Usually, each member of a core team and each employee on a project will have multiple "allegiances". These negotiations are not, therefore, dialogues between two distinct groups: they are complex choreographies of belonging and responsibility.

So how do understandings of belonging and responsibility differ between these two organizational regimes? One possible answer is that the goals of each regime are different. The aim of a project team is to ensure that a project is completed successfully and within a certain timeframe, whereas the aim of a work group is to build and maintain a strong, skilled set of "tools" or "resources" with which to supply the projects. Belonging to a project team means taking collective responsibility for a project, whereas belonging to a work group entails a responsibility to maintain and improve one's own skills. The kind of work that each structure demands is also different: working on a project demands cooperative, communicative work from employees, whereas membership in a work group demands technical competence. A project leader describes the work that was done by a core team at the beginning of a particular project:

> *We thought about the project structure, how we would split up the work in the project structure plan, where we could allocate the budgets that we have in terms of hours and material and who the key players are. The people who were sitting together at the end, that was the core team, and by core team I mean these people are responsible for the work packages […]. Yes, and they have…this core team worked out who could work together and who would be the best fit. At the start of the project, we somehow got the detailed plan together decided how we wanted to work internally. And then like I said we started to order the work packages chronologically. (Q4, Interview II, 04.03.2013)*

The project leader describes the work done by the core team as largely organizational: allocating budgets, defining work packages, choosing the employees who will later do the technical work required for the project. But this work is not the only work that is done by the core team, and the core team is not the only representation of work under the project-based organizational regime. The core team also defines the technical basis for a product and writes the original proposal, something that requires a great deal of technical understanding and experience. Later, other employees are enrolled in the project-based regime without being tasked with any organizational responsibilities. To some degree, membership in a work group also involves collective responsibilities: the group, after all, is responsible for making sure that the skills and personnel necessary to complete a project are sufficient and available, in addition to taking part in the assignment of tasks and the organization of employees' time. To state that the project-based regime demands communications skills and reflects collective responsibility while the competence-based regime requires technical skills and personal development would be an oversimplification.

Rather, the overlapping and intertwining of the two regimes creates a complex network of enrolment and responsibility. The project leader's description of Company Z as a "classic matrix organization" is true only insofar as this definition allows for real interplay and exchange between the two regimes. It does not seem to be the case that the work groups exist only to 'feed' the projects with the necessary skills at the required time; the work groups themselves play important roles in employees' self-identities and in the development of the know-how – both technical and organizational – that is so valued at Company Z.

5.1.2 Expertise and Personal Responsibility

It is this appreciation of know-how and expertise which I would now like to discuss with respect to enrolment and personal responsibility. As in many other fields, technical and non-technical alike, the skills and experience of Company Z employees are seen as valuable company assets, which should be developed and maintained. What may be more unique to technical or engineering environments is the expression of these skills in quantified terms. Employees and their skills are seen as "resources" which can be added, subtracted and compared, as expressed by a project leader in the quotation below.

> *Yes, yes, like I said, that's our big problem, that we always have too much to do, thank God. And that we always have this problem with resources, especially with good, experienced ones, there's, ah, as we say in Austria "a großes G'riss darum"*[5]*, that you always have the right people sitting in your project. (Q5, Interview II, 04.03.2013)*

Accordingly, a given amount of knowledge and resources can be "lost" when an employee leaves the company or moves to a different project. This was particularly noted with respect to individual employees' membership in project core teams. The core teams, as stated above, are established at the beginning of a project and are generally intended to remain "stable" with regard to personnel over the course of the project's lifetime. Many employees regarded the stability of a project's core team as vital to the smooth development and eventual success of the project.

> *And so, yes, this project core team should, if possible, stay stable over the course of the whole project. (Q6, Interview III, 12.03.2013)*

This reflects the idea that knowledge and skills are not easily transferable between employees, i.e. it assumes a kind of *tacit knowledge* among the company's employees. Despite the large amounts of

[5] a big tear-up about it, a big conflict [over resources]

documentation and review that go into each step of project, the departure of an employee from the group still signifies a loss of knowledge that cannot easily be replaced or passed on. While the departure of an employee from the company is considered to be more harmful to a project than an "internal" switch between projects or positions, both of these movements are seen as having negative effects on the progress and efficiency of a project.

Diane Vaughan notes in her discussion of organizational cultures at NASA that, while engineers are seen as developing and possessing a great deal of tacit knowledge, they are also expected to record this knowledge and to render it as accessible as possible for others within the organization. Company Z presents an interesting dichotomy with respect to this issue. Engineers *are* expected to record their work, and the importance of the masses of information stored on computer servers was expressed often by Company Z employees. For a given project, each problem and its eventual solution are committed to paper (or at least digitized) and assigned a name and number such that they can be easily searched for and found in the future. Each project produces hundreds of pages of reports, meeting minutes, test results and other documents and all of these are stored in a manner that makes them accessible to all Company Z employees. The intention of this is as much to assist employees with future projects as it is to create backed-up versions of old work for emergency situations or to provide to customers. However, the idea that knowledge can be effectively passed on in this manner is contradicted by the actions and attitudes of employees towards the movement of engineers and managers between projects and companies. Each departure of a key employee is viewed as an automatic loss of knowledge and experience that will inevitably lead to delays, or at least difficulties.

To combat these negative effects while still maintaining the dynamic working structure required by Company Z, employees often demonstrate a willingness to reach across organizational boundaries in order to ensure that the projects they are somehow acquainted with continue to proceed smoothly. This *durability* of project or team structure exists even in cases where an employee is no longer officially involved in the group, as demonstrated by the quote below from a systems engineer.

> *And on the EPPM, that's the other project, I'm not the project engineer there anymore and it's actually done by someone else, but it's still a topic for me and we do it together. We shouldn't lose knowledge or anything like that. (Q7, Interview IV, 17.04.2013)*

In this case, avoiding a potential "loss" of knowledge is more important than rigid adherence to the procedures and team structures put in place by the company. Though the engineer has been assigned to different projects that require his expertise, he maintains a connection to past projects which is not reflected in the company's official bookkeeping or scheduling. Despite the importance of quantifying resources and maintaining an overview of their current status, the durability of an employee's ties to a project or group remains. This is also a statement of the importance of individuals to the development of knowledge and products at Company Z. In a situation where understandings of expertise are governed by tacit knowledge, the value of the individual employee and his experience increases. Accordingly, individual knowledge or skills and their inherent *flexibility* are sometimes represented as being more important or valuable than the original planning that went into a project.

> *We have…there's another project, it's similar to this project and we started with that one, before we started this project. It wasn't supposed to happen that we finish this project [first]; we were supposed to build up this project from the older one. But it overtook the other project and now we have…**but actually it doesn't matter, I'm doing both projects**. So, it's, ah, now we're carrying the development costs on Merkur, on the Merkur here and now, now that should flow over into the other project. (Q8, Interview IV, 17.04.2013, emphasis added)*

The above situation was, in a way, improvised. According to the expectations of the company management and the project core teams, one project was supposed to develop technologies, know-how and procedures which would subsequently be used by Company Z to produce another, similar product for a different customer. However, unexpected delays on the "development" project meant that the required know-how was not yet in place by the time the second project began. From Company Z's point of view, the potential danger of this situation was averted through the flexibility of the company's working conditions and the individual expertise of its employees. The additional time and resources that had been allocated for the first project – the "development costs" – were transferred internally to the second project, and the fact that the same employees were involved in both projects allowed the necessary expertise, once developed, to flow between the projects as planned (just in the opposite direction). In this situation, the people who were involved in developing the technologies were more important to the success of the two projects than following the course of the schedule as it was originally conceived. Individual expertise and tacit knowledge developed over time allowed a divergence from the project plan to proceed in a relatively unproblematic fashion.

In addition to the understanding that expertise is lost when an employee departs from a project, there is also a sense at Company Z of personal responsibility to the work that one has done on a project proposal. This is often expressed as a point of professional pride, or a sense of duty to the statements that have been presented in a bid or project proposal.

> *That's always good, when you're on the project from the bid phase on, because, ah, the one who makes the offer, he promises certain things at a certain price and when I'm the one who made the offer I have to finish it and I can't make excuses to anyone that someone else offered something badly or wrong. That's totally important, that's, ah, we always try to do it like that, that the one who makes the offer also keeps working on the project. (Q9, Interview IV, 17.04.2013)*

This represents another argument for maintaining the stability of a project team throughout the lifespan of a project. Not only does the departure of an employee from a project represent a loss of tacit knowledge, it also indicates neglect of one's personal responsibility to take ownership of the work that has already been contributed to a project. These two concepts – loss of tacit knowledge and personal/professional responsibility to one's own work – form the basis of Company Z's position of the stability of the project team.

However, the importance of the stability of personnel is not only understood as a phenomenon internal to Company Z, nor are the effects of unstable teams only relevant within the company. The customers and partners of Company Z are equally important to maintaining the stability of the network. When there are changes in key personnel on the customer side, the results can be equally unsettling for Company Z and for the general progression of a project.

> *Unfortunately on this project on the customer side, P is I think the fourth or fifth [customer contact for Company Z] that we've had. That's tedious. That's extremely tedious, when key personnel are changed. We try to avoid that as much as possible, but the customer somehow didn't manage it. (Q10, Interview IV, 17.04.2013)*

The above quote equates the continuity of the "key personnel" on the customer side with the stability of the project team at Company Z. Actors from both organizations play an important role in the development of a project, and disruptions at either company can be detrimental to both the success of the work and the ability to finish within the desired timeframe.

5.1.3 The Enrolled Engineer

Hardly any employee at Company Z has the "luxury" of working on only one project at a time. Instead, everyone from test engineers to product assurance personnel to project managers works on multiple projects and manages their time and responsibilities accordingly. In most cases, one employee will stick to the same position (e.g. systems engineer, project leader) on all of the projects he works on, but this does not mean that he always does the same job. Responsibilities evolve along with projects and technologies; the most important task of the project leader in one month is not likely to stay the same for the next. Nonetheless, there exist established notions of the roles and responsibilities that are associated with different job titles, as indicated in the following quote from a project leader. These ideas, seemingly common throughout the company, reflect widely-expressed views of the "typical" responsibilities of certain employees.

> *These five people are the Core Team, and of course they have other projects to manage, so the percentage, that's Mr. S, that's the project engineer. There's the role of project lead, that's what I am on this project. And project engineer, that's always sort of ... **the project engineer is the one responsible for the technical and the project lead for the organizational**. (Q11, Interview II, 04.03.2013, emphasis added)*

These typical role assignments could function as a kind of shorthand for describing the roles of different actors to those who are unfamiliar with the company and its work practices. This terminology – as exemplified above in the description of a project leader's role – is used not only by the project leaders themselves, but also by other company employees. Here, a systems engineer discusses the project manager's role as a communicator and the importance of this job for the rest of the team.

> *Then there's the project manager, that's what G does in this case. He's very important as far as communication is concerned. If he can handle the communication well...that's very important for the project. The project manager is definitely the most important one in the team, as far as communication goes. (Q12, Interview IV, 17.04.2013)*

This construction of the project manager's work as organizational and communication-related harkens back to Faulkner's descriptions of the different definitions of an engineer. When discussing the responsibilities of project managers, employees tend to reference the "heterogeneous" or "sociotechnical" side of engineering rather than indicating that project managers do "hard", technical work. On occasion, this kind of work is represented as not being engineering work at all, even by project managers themselves as indicated in the quote below.

> *Most of us come from Engineering, but we don't engineer anymore. (Q13, Interview II, 04.03.2013)*

The project manager who made that statement had a technical background, as most of the project managers at Company Z do; however, he equated the kind of coordination and organizational work that he does as a project manager with the tasks of a non-engineer. Interestingly, some employees who do perform work that can be explicitly technical, for example systems engineers, still spend much of their working time communicating information and performing organizational tasks.

However, the importance of this work is often downplayed in comparison to their others duties. The exchange below comes from an interview with a project and systems engineer.

> ***K:*** *Do you have a lot of contact with the customer, or mostly just with other people from [Company Z]?*
>
> ***J:*** *No, with the customer too. For the customer, for the, I'm the contact person for the technical group, that means I have one contact person there [at the customer], I don't have five that I have to explain things to all the time, I have one contact person [...] and most of it goes over email or other things, totally normal. And if something has to go more quickly then we talk on the phone. We talk once or twice a week on the phone, briefly.*
>
> ***K:*** *And email? Every day?*
>
> ***J:*** *Yes, yes, pretty much. (Q14, Interview IV, 17.04.2013)*

This engineer has email contact nearly every day with his partner at the customer's company. He attends every review meeting and important teleconference between Company Z and the customer. He also attends weekly meetings with the project team at Company Z, where he is responsible – along with the others at the meeting – for negotiating the assignment of tasks and coordinating the schedules of the different employees involved in the project. All of these tasks require communication and organizational skills. They also form a large part of his daily work routines. And yet, the same engineer defines his role on the project thus:

> *As project engineer, that's the technical leadership, and there are always some [...] they're also systems engineers, they help out because you can't do it alone and then there are analysis engineers and things like that as well. (Q15, Interview IV, 17.04.2013)*

The engineer sees himself as somewhere between a technician and a communicator, "helping" the project engineer and performing something in between Faulkner's "hard" and "soft" skills. This despite the fact that communication seems to be as important to his daily work practices as it is to those of the project manager. The main difference is the type of content that he is communicating. Whereas the project manager talks about budgets and resources, the systems engineer's communication has to do with technical problems with the assembly, test results that fell short of the required values, and other issues which are more directly related to the technology being produced. The content allows the engineer to conceive of the work he does using "soft" skills as technical rather than organizational.

Occasionally, an employee who has held one job title on most projects will be required to fulfill a different role on a new project. Employees pay lip service to the idea that it is important for engineers to work outside of their comfort zones and to experience different aspects of the company and the development process, but in practice it seems that these occurrences are relatively rare. One example, that of a young design engineer who was moved into assembly and manufacturing for one particular project, was given by a systems engineer who works with the designer in question.

> *Ah, that's the design engineer and assembly, he does both. We had, in that phase we took somebody who…basically he does design. We had the problem in Manufacturing, that we didn't have enough people, and people were off sick and, ah, we asked if he would do it, if he could try it, and he was trained. He's really, I mean he was at a HTL*[6]*. He's technical, he can basically already do it, but he's not the typical AIV personnel […] but he did it and now he's mostly with Assembly, only for this project of course. For the next projects he'll go back to Design. And it's also always really good to work a little bit across the technical boundaries because you get important feedback. Because a design engineer shouldn't just design his whole life, and a systems engineer shouldn't only do systems his whole life. (Q16, Interview IV, 17.04.2013)*

In this example, the young design engineer has moved beyond the standard definition of his role at the company and has been successfully trained to execute new kinds of tasks, namely those of an employee in manufacturing or verification. Despite this, he remains a "design engineer" in the eyes of the other employees on the project. Even though he worked predominantly in assembly on the project in question, the systems engineer's understanding of his role at the company had not moved beyond his original job title, which is also where he was expected to return at the conclusion of the project. In the eyes of many Company Z employees, working "across the technical boundaries" is a positive thing, but the boundaries themselves remain steadfastly in place. Role definitions at Company Z are far-reaching and difficult to overcome.

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[6] *Höhere Technische Lehranstalt* or "institute of higher technical education": a trade college or polytechnic in the Austrian education system that allows students to graduate with a university entrance qualification and professional training.

5.2 "*You can't just sell the hours*": Measuring (Risk) in Time

> *I enter the office and sit down, thanking the interview contact for "taking the time" to speak with me. I confirm that the time and planned length of our interview – 30-60 minutes – is all right. "Sure," he says, "I've got a good half hour before my next meeting." (Field Notes, 04.03.2013)*

I had told the project manager in advance that the length of the interview would be 30-60 minutes, because I wasn't sure how long we would need. My first interview at the company had taken only 45 minutes but had yielded a lot of useful data. The intention had been that the interview subject would reserve a full hour and we would probably spend all of that time talking. If we didn't, he'd have been forewarned and would ideally have something else to do to fill up the remainder of the hour. However, this approach had underestimated the importance of scheduling time "efficiently" to the employees of Company Z. To the project lead I was speaking with, "30-60 minutes" meant that he could schedule another appointment after the first 30 minutes had expired. We would find a way to conduct the interview efficiently and finish "on time", i.e. when he expected it to finish.

This chapter is about the understanding and enactment of time at Company Z, specifically as it is used as a tool of measurement. There are different understandings of time at Company Z: timescapes, or a more qualitative perception of time, are understood to exist over the duration of a project or career. The "life cycle" of a project is a reflection of a variation on a timescape, one with a concrete beginning and an expiration date at the end. However, the most prevalent of all of these conceptions of time is the idea of time as a quantifiable object that can be used to compare and equivalence different things like people, projects, risk and amounts of work.

The management and scheduling of time count among the most important kinds of work done at Company Z. Throughout the field work, the notion of time (in particular, hours) as a unit of measurement appeared repeatedly. Stories of saving time, making time and maximizing time were told by each interview contact with respect to different circumstances. Hours are used, by various actors, as a unit of measurement for cost, project status and risk. For the employees of Company Z, measuring in hours allows things – project plans, employees' work – to be quantified and compared. Expressing terms in hours simplifies the comparison and evaluation of quantities that would otherwise be difficult or impossible to assess.

I open this chapter by discussing the fictitious concepts of the "full time equivalent" hour and employee. This construction, used by different actors within the company and its customers, assumes a perfect "efficient engineer", who switches between tasks and projects with no recalibration or distraction. It also assumes the interchangeability of hours between different employees, tasks and projects.

I will then discuss the measurement of risk in hours, based on concrete examples from interview data. Subsequently, I will move to discussing time in terms of longer periods (timescapes), and analyze the roles of "milestones" in confirming or reifying the status of a project. Finally, I will explore the understandings of "delay" that exist at Company Z.

5.2.1 Full Time Equivalent: Constructing an 'Efficient' Engineer

The employees of Company Z use the idea of "full time equivalency" to express and compare the numbers of hours and people required for work to be finished on different projects by different departments. When asked how many people were currently working on a given project, employees most often gave a number in full time equivalent terms, i.e. the number of people that would be required if everyone who was working on the project was working on it full time and without delays or mistakes.

> *But it's always difficult, because different numbers of people work on [the project] at different times. There's always a phase when we produce, then naturally Production is involved, who have absolutely nothing to do with it for the first few months. Then there's the phase where we do the, the PCP layout, the Printed Circuit Board Layout, then Layout is involved. But if you calculate it on average based on Full Time Equivalency [7] so to say, then it would be about three people full time. (Q17, Interview II, 04.03.2013)*

The Full Time Equivalent engineer is an admirable creature. He always works at the same speed, never gets sick, never requires advice or assistance that might take away from his working time, and it exactly as efficient doing one kind of task as he would be doing another. In addition to talking about the number of people required for a job, full time equivalency is also used to express the number of hours that a piece of work requires, assuming that it is executed by this fictional, perfectly efficient worker. The measurement assumes that the work done by one person in an hour is equivalent to the work done by another during that same amount of time. In other words, under the rubric of full time equivalency, all employees are equally skilled and equally fast, and work that is done by different departments is compared without making allowances for the nature of the tasks.

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[7] *Vollzeitadäquat*

K: *How many people [...] are working on [the project]?*

G: *Now there are...Full Time Equivalent, as we...I would say I work about 30% on this project, I still work on lots of other projects too. The Systems engineer about 50% and then there are at the moment four, three people in AIV who are working on it 100%. And there is now still in the Electronics department a 50% Systems engineer who's taking care of the TPPRE [...] In the next weeks, that will keep about one full-time person busy with the tests. So in end effect there are maybe five people working on it now, on average. But it used to be a lot more. (Q18, Interview III, 12.03.2013)*

As the above quote demonstrates, expressing the number of people involved in a task in terms of full time equivalency reduces the human dimensions of the work. The work in the electronics department is done, not by a named individual, but by a "50% systems engineer". Describing the work of a person in this way creates the impression that all workers (or at least all workers with the same job titles) are the same. Similarly, it is not stated that one individual will be conducting the tests, but that the work will be done by "one full time person". In practice, this work could and likely will be shared between multiple employees, according to their individual schedules and abilities. The expression of full time equivalency de-situates the work that will be done, removing it from the work practices of an individual and creating a translatable, anonymous task.

It is acknowledged within the company that full time equivalency is an imperfect tool. As discussed in the previous chapter, there is an awareness within Company Z of the importance of individual skills, experience and responsibility, and several employees expressed discomfort at the clash of this awareness with the "flat" rubric of full time equivalency. Despite this acknowledgement, however, full time equivalency is widely used for projections, evaluations and planning, both in situations that involve the company's partners and for "internal" purposes. This dichotomy is constructed by the employees of Company Z as unfortunate but necessary. They are aware, to some degree, of the implications of assessing and scheduling work in this way, but argue that this procedure is necessary for the kind of work and project atmosphere that exists at the company and in the space industry in general.

The idea of full time equivalency also has regulatory effects on the employees of Company Z. In Vaughan's terms, the full time equivalency rubric is a kind of *technology of control*. Though employees do not explicitly relate the concept of full time equivalency to risk in their discussions, measuring and thinking about people, work and time in this way does render employees and their work quantifiable and comparable. Employees are expected to act within the boundaries that are created through this way of describing work. If they are overworked or given tasks which cannot be completed in the amount of time that was originally specified, employees are expected to speak up and inform others that they require assistance.

> *[...] and then you see right away, you go through the project and you see right away if someone has double or triple, double or triple workload, then of course he just shouts immediately, "hey, but that won't work!" (Q19, Interview IV, 17.04.2013)*

The concept of full time equivalency acts as a technology of control by putting pressure on employees to produce work at a speed and quality which correspond to standardized measurements based on a fictional, perfectly efficient employee working on a project with no unexpected problems or delays. When the employee cannot live up to this standard, the onus is on the employee him- or herself to point out that assistance is required.

5.2.2 Measuring Risk in Hours

At Company Z, an hour is a very valuable commodity. As discussed above, hours and percentages of working weeks or days are used to represent the numbers of employees or amounts of time that will be required to complete a task. In addition to this, however, hours are also used to represent and quantify risk. The value of an hour is thus not only important for the scheduling of individual or group time, but also for communication with partners and for determining which course to take when a problem arises. In the following exchange, a systems engineer explains his understanding of risk assessment with regard to the manufacture of hardware.

> ***J:*** *...it's always the question, 'what is the risk?' Then we tell that to Mr. L from Quality Assurance, Mr. K, then we decide together, then we...*
>
> ***K:*** *How do you assess the risk?*
>
> ***J:*** *Yes, simply that we say, um, if we break the Helicoil and have to swap it out, then I know exactly, when we have to destroy the thing and then put it back together, that costs 100 hours, with the tests maybe 150 hours. And that's simply the risk. Everything is done in hours, everything in hours, or when we need hardware then it's money, but basically I always calculate from the money back to the hours, so that I can have an overview. Money doesn't interest me, I always reduce it to hours. (Q20, Interview IV, 17.04.2013)*

Immediately before this exchange, the engineer was asked about the procedures that are followed when problems arise with the hardware. It is important to note that this understanding of "risk" – which was also reflected in the statements of other employees – has very little to do with the chance that a product will break or malfunction while in service. Instead, the risk is related to the possibility of falling behind schedule, of delivering a product late or of failing to meet requirements in time for a milestone review. "Risk" in the sense of technical malfunction, particularly after a product is delivered to the customer, was not addressed by the employees in our discussions of product assurance and problem-solving. In general, a project ends for Company Z upon delivery of the technology which they have been contracted to produce. Thus, the entire discussion of risk at Company Z differs sharply from classical understandings of risk, including the organizational culture and normal accident theories discussed in the conceptual background chapter, in that it does not deal in accidents or disasters. Because Company Z is not responsible for the operation of the products it designs and manufactures, the risks that are most important to the company's employees are those which could affect the delivery dates that have been agreed to with their customers and partners. The fact that these risks are already so closely related to scheduled time partially explains the importance of hours, quantification and comparison in the company's risk management strategies.

In his statement, the systems engineer talks about the importance of hours to him as a unit of measurement. Hours are what he uses to evaluate and compare problems. For him, the "risk" involved in a particular scenario is the number of hours that a proposed scenario might "cost". In the initial stage of assessment, this idea of "risk" is decoupled from the *likelihood* that a given outcome will occur; it is only the potential *result*, the potential lost time, which is important. Though he states that he prefers to think in hours rather than in money, it is clear that for the systems engineer, hours do represent a kind of currency. They are a unit of measurement with which he is familiar and comfortable ("so I can have an overview").

Later in the same interview, the systems engineer discussed the importance of the weekly meetings held by the core team on a certain project:

> *It takes an hour or an hour and a half, the meeting. Naturally that is working time that is lost for everyone somehow, but it [the meeting] is important anyway. (Q21, Interview IV, 17.04.2013)*

This represents an interesting understanding of the term "working time". In this case, time that is spent communicating with others on the project, discussing problems and working out potential solutions is not characterized as "work". This representation corresponds to the idea, discussed in the previous chapter, that the communicative and organizational work done by a systems engineer does not hold the same value or importance that it does for a project manager. Though the communication of information is a vital part of his job, it is not understood as real "working time".

This strict and quantifiable measurement of risk can be understood as a "coping strategy" on the group or organizational level (Sigl 2012). Engineers deal with risk by using a defined set of procedures to reduce the amount of uncertainty that is inherent in the production and testing of space technologies. They also rely on the clear definition of roles within the design and production process: one person tests, another checks his work, problems are addressed to specific employees in a specific order when they arise.

> *There's an analysis engineer, a design engineer, a systems engineer, then…then what else…product assurance, that's anyway completely separate, that's Mr. L who sits there. He works completely autonomously, I mean he's only under Mr. K. It's like the federal courts, which the politicians aren't allowed to say anything to. (Q22, Interview IV, 17.04.2013)*

This reliance on roles and hierarchies within the company demonstrates some similarities between Company Z and the actions of Sigl's lab researchers in "coping like a clan". However, Company Z lacks the powerful, individual figureheads at the top of the working hierarchy which exist in life science research in the form of lab leaders. The engineers depend on certain roles, but they also assume that each employee in the company will contribute something to the project, and that each employee will take personal responsibility for his actions. The employees of Company Z are reliant on structured working roles, but also on each other as parts of a collective whole. Their group strategies for coping with risk and uncertainty fit somewhere in between Sigl's notions of "coping like a clan" and "coping like a collective".

Sigl's discussion of the differences between risk and uncertainty are also relevant to the understandings of risk at Company Z. To assess risk in this quantified way is to assume that risk is countable and manageable. In other words, the engineers of Company Z display similar attitudes towards risk as Sigl's laboratory scientists did in a different context: they see risk as something that can be dealt with, provided one has the right tools and takes the correct courses of action. This idea of risk does not preclude the presence of *uncertainty*, which Sigl characterized as being unpredictable and unmanageable. For the employees of Company Z, uncertainty exists with regard to longer-term time trajectories of project life cycles; one cannot know how "stable" a core team will remain over the course of the project, or how changes at the customer or at other partner companies will affect the work flow and scheduling. However, the risk that a product will malfunction or that problems will occur during the manufacturing process is seen as something that can be measured and (usually) avoided. When problems do occur, this same attitude of manageability allows the employees of Company Z to continue working with and around the issue.

As a final point of discussion, I would like to return to the above quote from the systems engineer about autonomy and independence. The engineer states that the quality assurance department works completely independently from the engineers in the project team, comparing the two groups to the political and judicial branches in Austria, whose responsibilities are strictly separated and defined by the constitution. This separation may be most obvious between the product assurance group and the other engineers, but separation between the work of different engineers and departments in a phenomenon that exists across the organization. At the project team meetings, members of the core team come together and exchange information about ongoing tasks and upcoming challenges on the project. The project leader often had the most complete overview of what everyone else in the team has been working on, but in many cases this information was old or outdated. The core team meetings generally gave the impression that each member of the project team was responsible for a task that was worked on more or less independently of the others. Basic status updates were given at these coordination meetings that seemed to be new information for the other meeting participants. In addition to this, many engineers stressed during conversations the importance of having work 'checked' by an employee or team that had not been involved in the work itself.

These *de-coupling* actions were observed throughout the two different project teams and over a range of meetings, interviews and conversations. I see the importance of de-coupling work and review processes at Company Z as a response or coping strategy related to the understandings of risk and accident at the company. In general, the employees of Company Z know that they cannot avoid occasional problems – the technology they produce is too complex and their situations too uncertain to assume that problems can be entirely eliminated or avoided – but they do require that problems are identified and managed as quickly as possible. This represents a kind of compromise between "normal accident" and "high reliability" schools of thought, with the important disclaimer that the "accidents" in the case of Company Z are not large-scale disasters but issues of design or manufacturing which could delay the delivery of their product. The company's employees are aware that issues are likely to occur, but at the same time they feel that these issues can be identified and managed through the de-coupling of work processes and the strict review of proposed solutions. At Company Z there is acceptance of mishaps and problems but little tolerance for the repetition of these problems or for allowing them to expand in scope.

5.2.3 Living with Delays

Given the awareness at Company Z of some of the contradictions and difficulties with measuring time, work, risk and progress in (full time equivalent) hours, it is perhaps unsurprising that delays are a normal and expected part of work practices at the company. The introduction of delays and interruptions to an original project schedule is understood as a standard – if unwelcome – part of work practices at Company Z.

> *Normally everyone takes on a bit too much work for themselves and that delays everything a bit. And that's good, because the workload is totally important for the company, that everyone is 100% occupied with work. (Q23, Interview IV, 17.04.2013)*

As the systems engineer states, delays are sometimes caused by employees simply volunteering for more work than they are capable of doing within the proposed timeframe. This is a kind of structural delay which is not related to unexpected circumstances like illness, accident or changes in the project proposal. It is simply a result of individuals taking on too much work. However, as the engineer indicates, it is also understood as a positive phenomenon, or at least a necessary one. Below, the same engineer goes on to clarify why he thinks overloading of employees is important for Company Z.

> *There are two problems for the company. One is when it has big jobs or contracts that somehow don't work, that can be a problem for the company. And the other problem is the workload. And the workload is the bigger problem, actually. Because you can't just sell the hours [...] Everyone that you can't occupy with work, that costs a certain sum of money. And you have to imagine, for example when a project goes well, it makes about 10% profit. That means, when you lose 100% of one hour, because [an employee] isn't fully occupied, then you need ten times as many hours on a project that's running well to get it back. (Q24, Interview IV, 17.04.2013)*

Here, the engineer further articulates the connection between hours and money that was first made clear in his discussion of risk assessment. One hour of work done by an engineer who works "efficiently" and is not delayed by unexpected circumstances is the base unit of work at Company Z. Therefore, it is important to keep every engineer working 100% of the time, because otherwise time that could potentially be converted into productive work is wasted. However, the method that is usually invoked to ensure a constant, regular workload for all employees is to encourage or allow individuals to take on more work than they are capable of doing, which also results in delays. While this leads to schedules not being met, it does not lead to employees' time being "wasted": everyone always has enough work to do (and often they have a bit too much). It is perhaps for this reason that this structural deficit of time is accepted as a necessary evil at the company. One employee describes the situation as inevitable:

> *Of course it makes the company as a whole more inefficient, but I think this is the same everywhere. How else would you do it? (Q25, Interview I, 04.02.2013)*

Both of the projects that this paper is concerned with had experienced major delays over the course of their life cycles. As both of them had moved beyond well beyond the initial planning stages at the time of research, delays had been experienced that stemmed from different causes, including the structural delays described above. In conversations with employees, both the practice of overloading employees with work and the project-based organizational regime of the company were described as a blessing and a curse.

> *It's not always easy, of course it's difficult when you have many projects. I mean, I really liked working on some of these big projects where you have a fixed core team, and you've got five or six people who are 100% on the project, or nearly 100%. Then of course you can work much more effectively, much more efficiently. The problem that we have with work overload, this constant jumping between projects and trying to fill holes, that makes the organization relatively inefficient as far as I'm concerned. (Q26, Interview II, 04.03.2013)*

The project manager quoted above went on to say that the system is accepted because no viable alternatives exist, which was a common opinion. Some delays, however, occur outside of this cycle of overloading and switching between projects. Other reasons given for project delays include those stemming from Company Z itself (employee sickness, unforeseen manufacturing issues, unexpected test results) and those which were seen to have been caused by external actors (the delayed delivery of parts required for manufacturing or indecision on the part of the customer as to their requirements or schedule). In these cases, the employees of Company Z were careful to assign blame to the actors they felt had caused the delay.

> *We delivered our data packages. It's ESTEC's fault, the ESA technology centre in Noordwijk, there's, the project is very weakly covered by ESA and, and there aren't very many people who have the time there to work on it. They say that [the project] is very important for the development of the Copernicus program but in the end they just don't have the resources to take care of the project adequately. (Q27, Interview II, 04.03.2013)*

> *In the past, that wasn't always the case. That cost us a lot of time and money during the initial phase. […] it's very important, to have a competent customer. (Q28, Interview IV, 17.04.2013)*

However, even in these cases, where the cause of the delay was characterized as coming from outside of Company Z, the employees seemed resigned to the fact of the change in scheduling. There were few complaints about the nature of the delays; they were generally characterized as normal and unavoidable, even in the "external" circumstances discussed above. This adds another dimension to the understanding of risk at the company: risk is conceived as the potential for deadlines or delivery dates to be missed; however, when this occurs, it is considered normal and largely unproblematic.

5.2.4 Milestones: Reified Progress

Keeping score along the road to product delivery – and noting the re-scheduling of projects due to delays – are the signposts of project development known as "milestones". These are the status signifiers by which the lifecycle of a project at Company Z is measured. Official milestones have their own names, common throughout the company from project to project (Kick-Off, Test Readiness Review), which are most often abbreviated and spoken of as acronyms (a Preliminary Design Review is almost always referred to as a PDR). The normal life cycle of a project starts with a Kick-Off meeting, progresses through the initial design phase to the Preliminary Design Review, continues through detailed design to the Critical Design Review, and prepares for manufacture and testing before completing the Test Readiness Review. The completed testing and verification of a product are subsequently signified by the results of further milestone reviews. All of these milestones require a meeting and official confirmation from the customer before they can be declared "successful". On many projects, the meetings that occur to determine the success or failure of a milestone review are the only occasions on which the employees of Company Z meet with the customer face to face.

Generally, however, the result of a review meeting is not a suspenseful outcome. The degree of preparation and communication between both sides (and sometimes more than two) that goes on before the meeting normally means that a successful or unsuccessful outcome is expected well before the actual meeting begins. In this way, review meetings often act either to reify an idea of progress or to confirm a lack of progress that has already been understood and accepted. Nonetheless, milestone reviews are a very important part of work practices at Company Z. They serve many purposes in addition to their evaluation of the project's progress, including acting as motivating factors, as discussed in the following quotation from a project manager.

> *And when you have to build hardware, then naturally you have to set certain internal milestones. For a, when it's simply a paper study then you always believe, I mean everyone knows that, when you've already done some Bachelor, Master's thesis. You're always optimistic because it always works out at the end. But when you have to have hardware on the table and measure it, test it, then it's relatively, ah, motivating that you produce early, that you get the things together on time. (Q29, Interview II, 04.03.2013)*

Aside from providing some personal consolation to me during the writing of this thesis, the above quote reflects the importance to a project of milestones as a motivating factor. The project manager who is quoted above was working on the Copernicus project, a study for ESA on the feasibility of a proposed new technology. The hardware that was built and tested for the project will never actually be put into operation. Nevertheless, a set of dates for the production and testing of the study's hardware had been defined, and these review dates were characterized as making the project "more like a real project" than a study. In addition to connecting the importance of project milestones to the actual completion of work, this also says something about the materiality of built technologies as compared to reports. The requirements that hardware be produced meant that it was more difficult to postpone the delivery of results: the necessity for material goods was responsible for holding the project to a stricter time schedule than would have been possible if the product had been solely written.

Part of the reasoning behind this motivation concerns the function of milestones as logistical gateways between different kinds of work. A project does not officially begin until a Kick-Off meeting has been held, and other actions such as beginning the manufacturing or testing process should not be taken until the milestone review which allows them has been successfully completed. Of course, actors can act outside of these guidelines and structures. Hardware can be built before the CDR has been passed, and tests can be conducted prior to the Test Readiness Review. However, such actions are generally understood by the employees to increase the *riskiness* of situation, which in most cases means increasing the chance that time will be "lost" due to unforeseen delays.

> *And that's the problem now, that we're actually formally only allowed to build hardware when the CDR is behind us, but because of the main time schedule we're on it earlier and so we carry the risk along with [our partners at a different Company Z site], that we build the hardware earlier [..] the CDR actually should have been in February. (Q30, Interview II, 04.03.2013)*

In this case, the risk that the project manager refers to is once again possibility that time will be lost or wasted. From his point of view, delays on the side of the customer have pushed Company Z into building hardware before the milestone of the CDR has been officially achieved. However, doing this carries with it the risk that new problems could be discovered in the design or that the requirements for the project could change. If something like this were to occur, it is possible that hardware might have to be scrapped or rebuilt, which would represent a loss of working time – and accordingly, money – for Company Z.

In order to reach a state where the next stage of the project can continue unimpeded, a milestone must be declared "closed" in addition to being "passed". That a difference between these two terms exists is made clear during the following exchange, which occurred during a meeting between Company Z and its customers on the Merkur project.

> *There is a minor dispute about the status of several items which were left open after the CDR. P says he understands that Company Z is very busy and that the team is doing a lot of things at the same time (building FMs, testing FMs, testing QM, writing test reports) in addition to trying to "close" the CDR items. However, he states the importance of closing CDR items so that the customer CDR can be closed. G: "The CDR is closed." P: "No, the CDR was declared successful." (Field notes, 15.03.2013)*

When a representative of Company Z argues that the company is justified in building and testing models because they have passed the CDR, the Company A representative corrects him. The CDR has been declared *successful*, meaning that the customer is confident in Company Z's ability to complete the next phase of the project. Company Z has official permission to begin building and testing models. However, the list of "action items" that was presented during the CDR meeting has yet to be completed, meaning that the tasks associated with the CDR are not yet *closed*. Company Z has the right to begin the next stages of work but also the responsibility to finish up the additional tasks in parallel.

The discussions, debates and action item lists that surround project milestone reviews further exemplify the uses to which time is put at Company Z. The original schedule that is created at the beginning of a project is a framing device: given the company's structures and traditions, it is not realistic to expect that events will proceed as outlined in this schedule. However, the original schedule is used throughout the duration of the project to evaluate, compare and sometimes to predict. Milestones are useful signifiers within the web of the project's schedule with which progress can be evaluated, even when this evaluation is more a product of ongoing review than the result of an individual milestone meeting.

5.3 Collaborations, Boundaries and the Meeting Space

This final discussion chapter focuses on a more specific aspect of the Company Z environment than those previously explored, one with temporal and spatial boundaries that are more strictly defined than role assignment or risk assessment within the company. In this chapter I take up the idea of the *meeting space*. Meetings, in addition to forming an important part of the empirical research on this project, are an integral part of the work practices and communication structures of Company Z. Meetings occur multiple times per week for each project; they are spaces of communication, coordination and review. There are many forms of meeting at Company Z – formal and informal, arranged and spontaneous, in-person and via telephone – and these meetings serve many different purposes. For this project, empirical observations were made of three planned meetings, all of which featured participants who sat in the same room as one another. One of the meetings also included participants who were linked via telephone. These observations formed the basis for the analysis found in this chapter.

The most frequent kind of meeting attended by employees of Company Z involves only other engineers and managers from the same company. These may take the form of regular weekly or bi-weekly "coordination meetings" or "core team meetings": gatherings of the members of a project's core team to discuss the progress they have made, the organization and budget of the project, and any issues which have arisen. Two of the three meetings observed for this project were of this kind. However, meetings with actors from other organizations are also an important part of employees' work practices. The milestones discussed in the previous chapter are all finally achieved through meetings with customers. It is only through the official coming-together of Company Z and its partners that a project's progress can be officially confirmed. The third meeting observed for this project was a "technical review meeting" between members of a core team at Company Z and their customers. While not a milestone review meeting, this gathering evaluated the progress that had been made since the CDR and estimated the likelihood that the next milestone could be reached on time.

In referring to the *space* of a meeting, I do not only mean the room in which a meeting happens, though physical locations are related to the meeting space. The meeting space is a social assemblage. It is a set of behaviours and imaginations which affect the kinds of actions that are allowed or discouraged within a meeting setting. Meeting spaces are constructed by the actors (human and non-human) and the work practices that participate in them; they are the result of years of professional experience at Company Z and at its partner companies, and their respective traditions, regulations and communication practices. In the first part of this chapter, I look at the boundary work that is performed in and around meetings, comparing definitions of "internal" and "external" in different situations. Subsequently I discuss the communication within a meeting space using Galison's terminology of the trading zone. I then explore the roles that different documents play in defining and restricting the meeting space, before finally looking at the progression from "issues" to "tasks" that often takes place during meetings.

5.3.1 Performing Boundaries: Definitions of 'Internal' and 'External'

One meeting space is not always like another. Nor does a meeting that occurs each week always include the same types of actors and discourses. The human and non-human actors involved in a meeting – employees of Company Z, their customers, their deadlines, the produced technologies, the test regulations, the strategies for communication – are constantly engaged in translating the roles of actors and the relations between them. One of the ways in which this is done is through *boundary work*, the work of making distinctions between groups and organizations.

One of the most commonly used boundary-making strategies at Company Z is the labeling of actors and organizations as either *internal* or *external*. These definitions are fluid, much like the work and roles of the actors who perform the labeling. What is internal in one situation for one actor can easily be perceived as external by an actor with another point of view or at a different point in time. The following examples show explicit definition of internal and external entities by Company Z employees during interviews.

> *On average every week there's an internal project meeting, a team meeting where the status is discussed. Unfortunately this didn't happen too often in the past weeks because of external appointments or illness, but the plan is to have a project meeting every week or at least every two weeks. And then there's, that's the internal organization so to say, but there's also an external review organization that we have to observe. (Q31, Interview III, 12.03.2013)*

In the first sentence, the meeting is "internal" because all of the participants are members of the project team. No one from outside of Company Z is involved, nor are any Company Z employees who are not already involved in the project. This meeting, ostensibly held each week, was repeatedly postponed due to "external" circumstances: external in this case means either outside of the project team ("external appointments") or simply non-work-related. The "internal organization" referred to in the final sentence represents a shift compared to the first time that "internal" was invoked. In the second case, the project manager refers not only to organization inside the project team, but also the coordination activities inside of Company Z. This is contrasted with the "external review organization" – the milestone reviews and customer requirements – which exists beyond the control of Company Z.

> *And the last negotiation meeting is also the kick-off meeting with the customer. And then we're formally kicked off, then the ATP [Authorization to Proceed] comes or the whole contract [...] Then we started to work in fall 2011 and we had an internal kick-off meeting. Internal means that we here in [the Austrian site], we thought about the project structure, how we would divide up the work. (Q32, Interview II, 04.03.2013)*

The internal meeting in the case of this project was not an official milestone review. This internal meeting took place after the "kick-off meeting with the customer", which represented the official start of the project. The internal meeting happened after the project was "formally kicked off": its purpose was to discuss the project structure and the division of labour inside of Company Z, and specifically inside of the project's core team. The project manager also indicates the geographical borders which relate to the idea of "internal" that he is presenting. He does not refer to all of Company Z, but instead to the specific site in Austria where the project team is located.

> *The participants discuss whether or not a certain drawing already exists. This seems to be related to a delivery that the customer is expecting. The existence and status of the drawing remain unclear. One participant says that they shouldn't bring it up: "we'll deliver A, B and C and that's it. We'll write in in the internal test procedure." (Field Notes, 17.04.2013)*

In this situation, which occurred during a Merkur project team meeting, "internal" refers to a document. The test procedure that the employee mentions is a document which, as a rule, is not presented to the customer. Its creators and users are all employees of Company Z, notably those responsible for the testing and evaluation of a product. Furthermore, all of the employees who are involved in the creation or use of the document work at one site: the same one in Austria where the meeting took place. Thus, "internal" here makes a distinction between Company Z and its customer as well as signifying the locality of the test procedure.

During the Merkur meeting involving the customer, however, definitions of internal and external were very different. The representatives of Company A, Company Z's customer for the project, constructed a distinct "us vs. them" mentality with regard to the participants in the room (from Company A and Company Z) vs. those participating via telephone (from ESA and from Company B, the organization to which Company A were sub-contractors).

> *Throughout the meeting, P refers to ESA as "the customer", implying that Company A and Company Z are working together to produce something for the others. This is reinforced*

> *through the distance between those in the meeting room (all representatives of either Company A or Company Z) and the others on the phone. (Field Notes, 15.03.2013)*

The physical nearness of the representatives in the meeting room compared to their colleagues on the telephone, as well as the status of both Company A and Company Z as sub-contractors on the project to larger organizations, allow the representative of Company A to construct the idea that the representatives sitting in the meeting room are working on something together immediately, whereas those on the phone are much further removed from the project, with respect to both their responsibilities and their physical location.

In this way, milestone meetings between Company Z and other organizations can be used, at least on the part of the customers, to establish a kind of "common ground" (Olson and Olson 2000) that is more difficult to cultivate via long distance communication. They can also perform boundary work that separates and distinguishes different classes of partner organization from each other.

5.3.2 Trading Zones and Meeting Communication

The meeting space at Company Z is above all a space for the exchange of information. In order to accomplish this exchange, however, all participants must be able to communicate with each other. This is not always as simple as it sounds: first a common language must be established, since Company Z's customer and partner companies are often based outside of Austria and their representatives usually do not speak German. Meeting participants often come from different academic and professional backgrounds and are responsible for different parts of the project. They may not understand each other's technical terminology, even when they are speaking the same language. Cultural differences between employees with different nationalities and experiences mean that participants' associations and preconceptions may not be the same. In order to work around these differences, the employees of Company Z and their collaborators have established special procedures and a particular kind of language to use within the meeting space. In this section, I will discuss these practices using Galison's work on *trading zones* (Galison 1997) as a framework.

A trading zone is a space in which partners from different places or cultures can "hammer out a *local* coordination despite vast *global* differences". The term trading zone itself refers to a space both geographic and symbolic, i.e. the concept contains elements of both *space* and *place* as they have been defined in an earlier chapter. To illustrate his concept's connection to physical location, Galison provides examples of floor plans from different buildings in a physics laboratory. Some of these represent "disciplinary" schemes – where each floor houses a different discipline and most individuals have their own offices – and others are the contrasting "interdisciplinary" environments, where each floor contained "thematic" rooms such as classrooms or stock rooms which are used by all disciplines interchangeably. The interdisciplinary places allow for the establishment of trading zones as researchers from different disciplines come into frequent contact.

But this constant physical proximity is not strictly necessary for the development of a trading zone. Trading zones can flourish wherever groups from different cultures[8] must work together to reach a common goal. In the examples given by Galison and by Gorman in a later work (Gorman 2004), the groups that work together do *not* meld into one organization over time. In fact, the trading zones themselves are usually temporary constructions. The two groups "maintain their distinctness" while developing ways of communicating and working together within the trading zone. As Gorman points out, trading zones that exist between "relatively equal" partners – as is the case for Company Z and its collaborators – tend to demonstrate the development of an *interactional expertise* (Collins and Evans 2002) whereby the partners improve their ability to work together over time.

A key part of the trading zone idea is the development of "contact languages". These are not necessarily languages in the standard sense of the word (despite the influence of anthropological studies on the trading zone concept), but can instead range from collections of "function-specific jargon" to more fully-developed creoles. The important characteristic is that a linguistic terminology is developed which can support the collective practices of the groups in the trading zone. Galison writes that a contact language often includes approximation, a common result of translating terms between different linguistic and cultural traditions. This does not render subject matter unusable; instead, it creates objects and terminology which are "good enough" for the continuation of negotiations, while not purporting to represent the absolute truth.

The jargon that Company Z and its partners employ during meetings (and via other channels of communication) can be understood as a kind of contact language. Meetings with customers and partners from outside of Austria and Germany are conducted in English, but it is a special kind of English that is filled with terms particular to engineering profession, the space industry, and in some cases to the particular collaboration between Company Z and a specific partner. I will not analyze the language itself, but I will present several examples of this meeting jargon and discuss the ways in which it is used.

One example of meeting space jargon is the prolific use of acronyms and codes. CDR, PDR, CR, RFW, RFA, NCR, CCN, FM, QM, PM, TRB/DRB are just a few examples of the shorthand forms that

[8] "Culture" refers here to professional or organizational cultures in addition to national or regional ones.

are used to signify milestones, meetings, documents, technologies and approvals. Some of these, notably those used to refer to meeting types or milestones, are used commonly throughout different engineering environments. Others, especially the codes used for individual technologies, are specific to a given project. In addition to these generally-understood codes, individual tasks or issues are given signifiers (sometimes multiple signifiers) made up of numbers and letters. Thus it may come to pass that a meeting agenda contains an item such as "CR0015: based on RFW from CDR, to be discussed at next PM" which is immediately understood by all those involved.

The procedure of a meeting follows certain guidelines that help to delineate the boundaries of the trading zone/meeting space. For all but the most informal meetings, an agenda is developed in preparation. The agenda will often build on the results of a previous meeting, and is usually based on an established template that has been used many times before. One of the participants generally "runs" the meeting, leading the group through the agenda and ensuring some conclusion or future action has been established for each item on the agenda before moving on to the next. The more the meeting involves "external" actors, the more strictly these guidelines tend to be followed. At meeting with customers, the agenda is projected on to a large screen, such that all meeting participants – at least, all of those who are physically present – can see which point is currently being discussed.

Despite the presence of such formal guidelines, the communication that was observed between Company Z and Company A was relatively relaxed and informal. One project leader explains this informality as a *result* of the strict guidelines that govern their interaction.

> *The communication with our customers is…it's not really "casual", but it's somehow very…with all these regulations that we work along together, it's relatively, not very technically strict. In principle you speak informally [9] on a project like this, in the space industry. Because I think that's easier in the Anglo-American world. (Q33, Interview III, 12.03.2013)*

For the project manager, the requirement that all parties work within strict communications guidelines gives them the leeway to be more informal in terms of personal communication. He also indicates that the Anglo-American backgrounds of some of the company's collaborators make more casual communication "easier". Personal connections also develop between Company Z and its customers over the course of longer projects. The customer meeting that was observed between Company Z and Company A included many jokes, informal personal chat and references to

[9] *per du*

incidents which had occurred in the past. This was the case despite the fact that neither of the participants from Company A had been involved in the project since the beginning. The interactional expertise and experience between the two companies had allowed the shorthand and meeting procedures to carry over despite the introduction of new personnel. In turn, the new participants had managed to establish their roles in the trading zone/meeting space and to build personal rapport with the employees of Company Z over a relatively short period of time.

5.3.3 The Roles of Documents

Trading zones, however, are not only expressed via the verbal communication between two groups. Objects can also be used to enact "local coordination" within a trading zone, and the example of the meeting space provides several examples of these coordinating objects at work. Some of the most evident examples of objects' roles in local coordination are the documents which are used and referred to during meetings. Often, these documents also act as *boundary objects*, delineating the distinctions between two groups while also allowing them to communicate with each other.

One example of this is the *meeting guide* that was produced for the review meeting on the Merkur project between Company Z and Company A. The meeting guide was a document produced by an employee of Company A, based on the minutes of a previous meeting and on a report that a project manager from Company Z had written in preparation. At the beginning of the meeting, copies of the meeting guide were printed and distributed to the participants. The contents of the guide were also displayed via screen and projector for all to see, and the guide was also emailed to those participants who were not physically present for the meeting. The guide contained a rough outline of the proposed meeting minutes, as well as pictures, lists and graphs that were expected to be discussed by the participants. In some cases, the meeting guide went so far as to include the proposed conclusions or outcomes of discussions which had not yet occurred at the time the guide was created. The idea for the meeting guide was attributed to P, an employee of Company A, and the document was credited by several participants with increasing the speed and "efficiency" of the meeting.

> *During a break, it is noted that the meeting is running more than an hour ahead of schedule. This is jokingly attributed to the fact that a certain engineer who was meant to take part via telephone is not there (allegedly he asks a lot of questions); however, the serious praise is given to P for his preparation of a meeting guideline to supplement the minutes and PowerPoint presentation. P himself indicates that the meetings have been running much more smoothly since he has started to prepare these documents in advance. (Field Notes, 15.03.2013)*

The meeting guide is an object that both limits and enables. It limits the likely outcomes of the meeting by presenting pre-formed conclusions and asking the participants to agree to them. It was never explicitly stated that the conclusions which already existed in the meeting guide should be preserved; however, in practice they were very rarely changed. The desire of the meeting participants to conclude their business "efficiently" encouraged them to work with the meeting guide and to accept it as a tool that would helpfully increase the speed at which the meeting could be conducted. From this point of view, the guide performed its task admirably. It did enable the swift conclusion of the meeting by focusing the discussion and limiting the introduction of new topics or points of debate. When discussions started to veer off track, P or one of the Company Z employees often noted this via comparison between the current discussion and the contents of the meeting guide or agenda. The guide also greatly sped up the recording and approval (post-meeting) of the minutes, since many of the points of discussion could simply be copied from the guide.

> *The review of the minutes also functions as a kind of training for O. [...] O has noted down quite a bit of detailed information during the meeting, which she states was as much for her information as for the minutes themselves. The vast majority of these details are removed from the minutes during the correction phase; the stated reason being that the information is already given in P's meeting guide. (Field Notes, 15.03.2013)*

The meeting guide is seen by the participants as a success and a good idea, because it allows them to finish the meeting quickly (in this case, even more quickly than expected) and to officially resolve or assign solutions to the issues that were listed in the meeting agenda. The ideas that exist at Company Z about the material value of employees' time (see chapter 5.2.2) and the nature of an engineer's "real" work (see chapter 5.1.3) mean that a meeting that finishes ahead of schedule is a successful meeting, provided that all of the issues listed in the meeting agenda have somehow been addressed. One fewer hour of meeting time means, for the employees, one hour more which they can spend "working".

The meeting guide is only one example of the documents which permeate the meeting space. Despite the influence that the guide has over the nature of the meeting, it remains an *unofficial* document. In other words, it acts on and with the participants of the meeting, but it has no binding legal or contractual meaning for them. It is created and used by the meeting participants, and though it may well influence behaviours outside of the meeting space, its defined role expires once the meeting ends.

Other documents exist which have different meanings and influences for the employees of Company Z. The documents which are signed and sent back and forth between the company and its customers – test records, change requests, project reports and a legion of others – have the power to allow or to halt certain tasks or phases of work. These documents are often expressions of the *results* of a meeting (or of a test, or a series of emails and telephone conversations), rather than outlines of its contents.

But not all of these *official* documents are created equal. As indicated in the quote below, "internal" documents do not have the same kind of power that "external" documents do.

> *It is stated that the results should be added to the internal test report and sent off. Later, however, someone notes that this document lacks the official heft to effect the changes that Company Z would like to see. It is "only internal". (Field Notes, 17.04.2013)*

In this instance, "internal" refers to a document that only has the official power to effect change *within* Company Z, and not for the customer. The internal test report is created by the employees of Company Z for the benefit and information of other company employees. It is not signed by the customer, nor does this document have the power to allow or discontinue any action on the customer's part. Nevertheless, after the above exchange the meeting participants spent several minutes discussing the power of the internal test report and the possible alternatives to this document which they could present to their customer. Even this document which is "only internal" is an object which does work within the meeting space and which affects the actions of the participants.

5.3.4 From "Issues" to "Tasks"

The meetings that were observed at Company Z for the purposes of this study had specific, stated purposes. The review meeting between the company and its customers was officially intended to provide the customers with an overview of the Company Z's current status and to let Company Z know what its customers' priorities were. An additional purpose was to review a list of open *action items* from previous meetings and to establish which of them could be formally *closed*. The "internal" project meetings had different goals. One of these was, as expressed by one employee, to take a list of *issues* or things to be accomplished and to package them into doable *tasks*.

> *M explains what goes on at a core team meeting, which involves the participation of all the main, managerial actors on a project. He says that one of the meetings' functions is to "turn issues into tasks", and subsequently to create work packages based on these tasks. (Field notes, 04.02.2013)*

In this scenario, *issues* represent wishes, desires or goals. They can also be problems or gaps in understanding or technique. Issues arise when actors agree that something needs to be done, but before they have decided how to do it or who will be responsible. Tasks, on the other hand, are ordered, planned, assigned and have expected outcomes. Tasks are the things which are recorded in meeting minutes and in personal notes. As the systems engineer indicated in an earlier chapter, tasks are also assigned people and completion dates, which are intended to render the task measureable and to ensure its completion.

This represents once again a quantification of employees' work and time for the purposes of recording, scheduling and comparison. It is also a strategy of governance and a technology of control. By explicitly assigning an employee a task, he is also assigned a role. By making him personally responsible for that task, the "risk" that the task is not completed on time is reduced, in the eyes of the company.

> *Everything that I wrote down now I'm going to do myself, I wrote down my name everywhere beside it. If it's someone else, I write down the other names beside [...] There's always someone who's responsible, and normally also a date. And somehow, that's normally in one week, for these weekly meetings, and also when the customer was there, these Actions get distributed and in that case there's always the company and we always write the name and the date beside, because anywhere where there's no name or date, that doesn't get done. (Q34, Interview IV, 17.04.2013)*

The development of a task from an issue over the course of a discussion or meeting focuses the work to be done and quantifies it by establishing a time in which it should be completed. It also assigns responsibility for the completion of the task to individual actors, rather than to the company or team as a whole. In the case of the *actions* which are developed in consultation with a partner or customer during "external" meetings, the responsibility is assigned to one of the companies involved in the discussion. In both cases, the creation of a task or action from an issue forces the narrowing of the scope of the work to be done. It is a strategy for making the work *doable* as well as for assigning responsibility in order to make its timely completion more likely. In setting up work that needs to be completed as an action or task, the employees of Company Z are creating bundled work and responsibility that exists on a scale small enough to be understood and tackled by one person or small group of people.

6 Conclusions

In this final section, the empirical results and discussions from the previous chapters will be related back to the main research question in order to address to the original research interest, namely the identity of the engineering company as an institution of knowledge production that is expressed through the work practices of the employees of Company Z. I don't presume to offer complete or definitive answers to this question – in any case, any conclusions presented are based on a very specific case, place and time – but the results that were found do demonstrate some interesting phenomena that I hope can prove useful as a starting point for further STS investigation of the engineering company as a site and institution of knowledge production.

6.1 Projectified Worlds: Back to the Laboratory?

During the initial phase of field work, a project manager from Company Z described the company as a "classic matrix organization". By this he was referring to a type of organizational management structure under which project-based and skill-based groups exist concurrently, with the skill-based groups supplying the projects with employees according to their needs. As has been explored in the earlier discussion, there is more interaction and coordination between these two regimes than is indicated at first glance by the idea of the matrix organization. Much of the work that is done at Company Z is governed by the idea of the *project*: work flow and deadlines from projects control an employee's time and determine the people with whom he will collaborate in the course of his work.

In addition to exerting control over an employee's time, the company's project-based organizational regime also has a strong determining effect on the future of the company. Company Z needs a continual supply of projects in order to earn the money it requires to continue functioning, and this supply of projects is governed by an often unpredictable bidding process that involves many other actors. Thus, much attention is paid to the winning of new projects through successful project bids, and to the development of knowledge and employee skills that will contribute to the company's ability to continue to win projects from customers.

In this respect, Company Z is similar to many modern research laboratories, which rely on the continual attainment of project-based funding to survive and expand. As discussed in previous STS studies of modern life science research environments (Sigl 2012; Felt 2009), the increasing *projectification* of academic research has a tendency to package scientific work and problems in a more formal way, rendering them "doable" in the same way that the employees of Company Z rely on strictly-defined work packages and assigned tasks to tackle their issues.

Fujimura has discussed this phenomenon with respect to cancer research (Fujimura 1987), concluding that constructing doable problems entails *articulation* and *alignment* between different levels of work organization. In cases where the articulation of problems is difficult or left incomplete, the construction of effective, realistic solutions will be challenging or impossible. In the engineering environment of Company Z, problem-making is a more hybrid act than it is in many academic research institutions. In the engineering project, partners and sub-contractors abound and the customer – through frequent communication and regular formal review processes – is never too far removed from the work practices of any individual company or working group.

This leads to the creation of different kinds of doable problems. The considerable amount of quantification, formal enrolment and labeling that is conducted at Company Z can be seen as a response to this situation. The technologies of control which are implemented to assign tasks, create schedules for completion and track the progress of both projects and employees exist because of the complexity of the network around Company Z, its collaborators and their technologies. The quantification of time and risk at the company is a coping strategy for creating doable problems out of the immense web of actors and requirements associated with each project.

One notable difference between the projectified nature of Company Z and that of research institutions in the life sciences is that individual employees' career trajectories are not as closely tied to winning projects and funding as they are in academia. Naturally, the effect that winning and losing project bids has on the company as an organization will exert some influence on the stability and security of an employee's job. However, no direct connection between project funding and employment exists in the engineering company as it does in academic research, and the employees do not express tension or concern for their personal futures with regard to the company's success or failure at attaining projects.

Thus, Company Z is in some ways more similar to the life science laboratory than one might assume. Both exhibit some level of *projectification* in their work processes, and both experience tensions related to ongoing, project-related struggles. The first part of the answer to the question '*what kind of institution is Company Z?*' is that it is a project-based organization that relies on a regular supply of new projects for its continued operation. Yet the engineering company is not *only* a project-based institution. Its continued operation also relies on the development of employees' individual skills and the interplay between its project-based and competence-based organization regimes.

6.2 Manufacturing 'Know-How'

If classical laboratories are institutions that are concerned with making facts, and new modes of knowledge production mean that boundaries are blurred or cooperation is increased between traditional research environments and business or government, what does this leave Company Z as a producer of knowledge? The company, and engineering companies more generally, are explicitly concerned with producing technological objects to sell. However, as discussed in previous chapters they also produce knowledge in more implicit ways. Most notable among these is the production of tacit knowledge and skills among the employees of Company Z.

This employee "know-how" is related to technical objects and processes, but also to the "soft" social and communicative practices required by the company, particularly those which relate to collaboration between Company Z and its partners and customers. Since the company often argues its strengths in project bids based on previous projects and technical experience, this know-how is one of the most important results of the company's work practices. Not only are tacit knowledge and experience important for the company when submitting bids for new projects, they are also vital to the development and promotion of individual employees within Company Z. Engineers and managers alike are valued for their individual skills and for the "resources" that they bring to their work groups and project teams.

Company Z is therefore an institution that produces strategies, tacit knowledge and technical skills in addition to making technologies. This tacit and experiential knowledge is related to both the development of the company's employees as individuals as the evolution of the company itself as it strives to present itself as an innovative leader in the space technology industry.

As was the case for Vaughan's NASA engineers, the tacit knowledge that is developed by the employees of Company Z is intended to be passed on and shared – to whatever degree possible – with other employees of the company. This is one of the engineers' stated reasons for the level of detail of their project reports and for the written descriptions of each "issue" that is identified on the project, as well as its subsequent solution. However, the practices of Company Z employees somewhat contradict this commitment to preserving tacit knowledge, or at least acknowledge that the system used for recording the information is imperfect. Engineers and project managers alike demonstrate connections to the projects they have worked on which are not discarded when the employee is transferred off of the project. When they deem it necessary, employees will help out colleagues and former team members on projects to which they are no longer formally assigned. Furthermore, this behaviour is understood as normal and seems to be accepted, despite the contradiction between these actions and the commonly-cited importance of the project structures and time schedules laid out during the early phases of project organization. The *durability* of an employee's connection to a project on which he is no longer intended to work, and the expression by employees of personal responsibility towards former projects, is a recognition that some kinds of knowledge cannot be passed on simply through documents and pictures. In these instances and in cases of project delay, the employees of Company Z show a willingness to depart from the official structures imposed by the company, and in so doing an understanding that these structures are imperfect.

Another definition of Company Z as an institution is therefore that of a producer of "know-how" or tacit, experiential knowledge, as well as of the technological objects in which this knowledge and experience are inscribed. It is an institution that also tries to preserve its employees' tacit knowledge in the form of pictures, reports and meeting minutes, despite an understanding among employees that these practices are not entirely successful. Company Z is also an organization that allows employees to work around ostensibly strict guidelines and time schedules, provided that this is done in ways which have become normalized parts of the company's work practices.

6.3 Making Boundaries and Defining the Engineer

Information about the knowledge produced at Company Z is not only expressed through the company's structures or through its documentation of issues and tasks. It is also apparent in the roles and definitions of employees' jobs and through the employees' communication practices. The roles that are assigned to and played by different employees, particularly in the rhetoric around meetings and communication with customers, demonstrate the kinds of boundaries which are drawn both within Company Z and between the company and its collaborators. Through an analysis of this boundary work performed by the employees and others, the identities of actors and organizations can be explored by paying attention to what they separate themselves from. In other words, an entity can be described by looking at its own understanding of what it is *not*.

"External" boundaries were frequently drawn between Company Z and the organizations with which it collaborates. A meeting that involved the customer was referred to as an "external" meeting, whereas one which only included the project team was "internal". However, during the so-called "external" meeting, the actions and rhetoric of participants from both companies constructed the idea that the actors in the meeting room were part of a team, to which those participating via telephone did not belong. Boundaries between Company Z's sites in different countries also shifted constantly. A site outside of Austria that was described as belonging to "our team" was spoken of several minutes later as if it were part of a different company.

Company Z therefore does not always play the same role in its interactions and negotiations with collaborators, nor does it maintain constant understandings of the roles of other Company Z sites. There is a multiplicity in the understanding of Company Z as an institution. The company can play many different parts – customer, supplier, team member, rival, research partner – and it is prone to switching meanings and identities swiftly, depending on the observer and situation.

Similar fuzziness of roles and boundaries was observed inside of Company Z, particularly with regard to the technical/social division in engineering work. Project managers indicate that they are no longer "real" engineers, since they do not perform technical work and instead are responsible for organization and oversight. At the same time, they demonstrate their sophisticated technical understanding of products and problems during meetings. A systems engineer who devotes many of his working hours to communication and organization nonetheless rejects the role of communicator, labeling instead the project manager as by far the "most important" person in the team where communication is concerned.

Though the situations above represent cases of explicit role assignment or description, this process is often tacit and unspoken. Even the above examples, while they were explicitly voiced, may not have been intended by the speakers to *construct* roles and responsibilities. Instead, they were reflections of the tacit understandings of employees' roles which exist at Company Z. Employees may state that it is beneficial for engineers to work across boundaries within the company, but in their practices and their implicit statements, they indicate that this does not often occur. At the same time, they oversimplify the nature of the work that is done by most employees at the company. One does not have to take on the official role of a design engineer to be involved in the design process, and neither does a systems engineer have to become a project manager in order to communicate and organize.

Company Z is an employer of engineers who tend to believe that their roles are strictly defined, even when they are required to perform a range of tasks which may lie beyond their own understandings. The company is an institution which implicitly encourages the coexistence of a technical and a social side of engineering, while its employees simultaneously tend to condense their roles and responsibilities down to one side of this divide.

The aim of this project was to investigate the nature of Company Z as an institution of knowledge production, based on the work practices of its employees. Several answers have now been provided to the original research question, though perhaps none of them are very consequential. Company Z is something more than a "classic matrix organization". Its co-existing regimes of project-based and competence-based organization demand a complex and continual process of mutual negotiation. Company Z is also a producer of tacit, experiential knowledge as well as of technologies and technical understanding. It is an institution which recognizes that this knowledge cannot always be passed on through documents, but which persists in recording and storing data for this very purpose. It is an organization which quantifies and sorts information in an effort to control risk and uncertainty within a complicated and dynamic network of objects and organizations. These strategies, too, are recognized as insufficient, but are understood as the best available tools to use in a difficult and constantly changing situation. Most significantly, Company Z is multiple. Its name can signify different actors and entities in different situations, and definitions of "internal" and "external" may change depending on the circumstances.

With this project, I hope to have contributed something interesting and worthwhile to the fields of STS and Engineering Studies. I hope that this project will be of some use to future studies of engineering organizations and engineers' work, and that more examinations of the roles that engineers play in knowledge production will be forthcoming.

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Appendix

Appendix A: Interview Citations

Q1. *Nein, das weiß er noch nicht. Das war jetzt noch zu kurzfristig aber ich denke, wir werden da irgendeine Rolle finden und wir werden das dann irgendwie machen. Müssen wir allerdings heute noch besprechen, ich gehe aber trotzdem davon aus, dass es kein Problem sein sollte, dass Sie teilnehmen. Aber ich muss das sicher dem Kunden noch sagen, wenn wir uns intern klar geworden sind, welche Rolle Sie in dem Meeting haben werden.*

Q2. *Wir sind in der Firma in Gruppen organisiert und diese Gruppen beschicken die Projekte mit Mitarbeitern, das ist eine klassiche Matrixorganisation. Und by Proposal schon, oder dann in der, zumindest beim Start-Up des Projekts wird ein Proposal, wird ein Project Team bestimmt. Das heißt, es gibt ein Projektleiter, einen Project Engineer, das ist der Main Technical Officer so to say und es gibt immer einen PA Responsible und dann gibt es…ah…Responsibles aus den Fachgebieten Analysis, Design und AIV, also AIV, Assembly Integration Verification, das schließt auch den Punk Manufacturing.*

Q3. *Und diese Arbeitsplatzverantwortlichen, diese Gruppenleiter wie sie bei uns heißen haben halt dann die Aufgabe, das man irgendwo die Projekte befriedigen kann und ja. Da gibts natürlich Konflikte und dann muss man halt im Sinne eine Resource Coordination Runde das ganze ausdiskutieren und wenn wir nicht entscheiden können auf Interprojektebene dann müssen wir eine Ebene höher gehen und das eskaliert. Ja. Ja. Aber ich meine, es ist relativ, relativ transparent wie es bei uns läuft, ja.*

Q4. *[…] und dann haben wir uns eben die Projektstruktur überlegt, wie wir die Arbeit aufteilen im Projektstrukturplan, wo wir die Budgets, die wir in Stunden und Material haben allozieren und allozieren müssen und wer die Key-Players sind, also die Leute, die dann am Schluss beisammen gesessen sind das, war das Kern-Team, das Kern-Team im Sinne von, die Leute haben Arbeitspaketverantwortung und die haben ganze Arbeitspakete, für die sie verantwortlich sind […] ja und die haben, dieses Kern-Team haben wir eben mit der Linie ab…ausgehandelt wer mitarbeiten kann und geignet ist und im Projektstart haben wir uns diese Detailpläne irgendwie ausgearbeitet und festgeleft intern wie wir arbeiten wollen. Und dann haben wir wie gesagt begonnen diese Arbeitspakete chronologisch abzuordnen.*

Q5. *Ja ja, also wie gesagt das ist unser Hauptproblem, dass wir immer zu viel zu tun haben, Gott sei Dank. Und, dass man immer dann diesen Resourcenengpass hat, gerad bei guten erfahrenen Resourcen ist ja, ist auf Österreich gesagt a großes G'riss darum, dass man die richtigen Leute immer im eigenen Projekt sitzten hat.*

Q6. *So und, ja, dieses Projekt-Core-Team soll, wenn möglich, über das ganze Projekt stabil bleiben.*

Q7. *Und ah, beim EPPM, das ist das andere Projekt, da bin ich jetzt nicht mehr Projektingenieur. An und für sich es macht wer andere, aber das ist bei mir ein Thema und wir machen das eh gemeinsam. Es soll kein Wissen verloren gehen oder so.*

Q8. *Es gibt ein Projekt, das ist ähnlich wie dieses Projekt, da haben wir begonnen damit, vor diesem Projekt. Es hätte ja nicht so laufen sollen, dass wir dieses eine Projekt fertig machen, dann hätten wir jetzt dieses Projekt gemacht aufbauend auf dem alten Projekt. Es hat aber dieses Projekt das andere Projekt überholt. Jetzt haben wir...wobei das ist egal, ich mache beide Projekte. Also, es ist ah, jetzt haben wir quasi, die Entwicklungskosten haben wir jetzt beim Merkur mitgetragen, eben Merkur hier und ah, jetzt soll, jetzt soll das vom Merkur in das andere Projekt einfließen.*

Q9. *Das ist immer gut, wenn man von der Angebotsphase dabei ist, weil der, der anbietet, der verspricht gewisse Dinge zu einem gewissen Preis und wenn ich der bin, der das Angebot gemacht hat, dann muss ich es auch fertig machen und ich kann mich auf niemanden ausreden, dass der das schlecht oder falsch angeboten hat. Das ist total wichtig, also das ist ah, wir versuchen eigentlich immer das zu machen, dass der, der anbietet das Projekt auch weiter machen kann.*

Q10. *Leider hat bei dem Projekt, ah, auf der Kundenseite ist P glaube ich der vierte oder der fünfte, den wir haben. Das ist mühsam. Also es ist extrem mühsam, wenn das Key-Personal irgendwo gewechselt wird. Das versuchen wir zu vermeiden wo es nur geht. Der Kunde hat das irgendwie nicht geschafft.*

Q11. *Diese fünf Leute das ist das Kernteam, die natürlich auch andere Projekte zu betreuen haben, also der Prozent, das is der Herr Schwarz, das ist der Projektingenieur. Es gibt immer die Rolle Projektleiter , das bin ich in dem Projekt. Und Projektingenieur das ist immer so [...] der Projektingenieur ist technisch der Obervertantwortlicher, der Projektleiter für das Organisiatorische.*

Q12. *So, und dann gibts noch...ja, dann gibts den Projektmanager, so wie hier G. Der ist ganz wichtig, also was Kommunikation betrifft. Wenn, also wenn der gute Kommunikation betreibt, dann das ist für das Projekt sehr wichtig. Also der Projektmanager ist sicher der wichtigste im Team, was Kommunikation betrifft.*

Q13. *Wir kommen zwar die meisten aus dem Engineering, wir engineeren aber nicht mehr.*

Q14. *K: Haben Sie auch mit dem Kunden viel Kontakt oder eher nur mit anderen Leuten von der Firma?*

J: Na, schon mit dem Kunden. Also der Kunde, für den, für die technische Gruppe dort bin ich der Ansprechpartner. Ah, das ist aber so, dass, also vom Kunden gibt es auch einen Ansprechpartner, das heißt, ich hab einen Ansprechpartner dort, ich habe nicht fünf, mit denen ich die ganze Zeit oder denen erzählen muss [...] genau und...ja, also das meiste geht über, *ganz normal per Email und solche Dinge. Und wenn was schnell gehen sollte telefoniert man mit den anderen, schon ein, zwei Mal in der Woche tut man sicher telfonieren, kurz.*

K: Und Email? Jeden Tag?

J: Ja, schon. Schon fast, ja.

Q15. *Ja, es ist…als Projektingenieur, das ist eine technische Leitung und dann gibts immer einige, das sind dann die - wie sagt man? Die sind auch Systemingenieure, die helfen dann mit, weil allein kann man's ja nicht machen und dann gibts noch einen Analyseningenieur und solche Dinge also dabei.*

Q16. *Ah, das ist der Designingenieur und Zusammenbau, also der macht beides. Da haben wir, in der Phase haben wir wen genommen, der…also an und für sich macht er Design. Wir hatten ein Problem in der Fertigung, dass wir zu wenig Leute hatten und Krankheitsausfälle und, ah, wir haben gefragt, ob er das machen würde auch, ob er es ausprobieren könnte und er würde eingeschult drüben. Er ist überhaupt, also er hat HTL gemacht, also er ist technisch rasiert, er kann das grundsätzlich schon aber er ist kein typisch, kein typisches AIV Personal, das Assembly Integration und Test. Aber, das hat er gemacht und er ist jetzt vor allem mit dem Zusammenbau, nur für das Projekt, natürlich, und, ah, wird dann bei den nächsten Projekten natürlich wieder ins Design kommen. Und es ist auch sehr gut, immer so ein bisschen fachlichübergreifend zu arbeiten, weil da kriegt man wichtiges Feedback. Ah, weil ein Designer soll nicht nur sein ganzes Leben lang designen und ein Systemingenieur soll nicht das ganze Leben nur System machen.*

Q17. *Ah, das ist immer schwierig, weil zu verschiedenen Phasen verschieden viele daran arbeiten. Also es gibt immer so eine Phase wenn wir fertigen, dann ist natürlich die Fertigung dabei, die die ersten Monate überhaupt nichts damit zu tun hat. Dann gibt's eine Phase wo man das, das PCP Layout machen, das Printed Circuit Board Layout, da is halt das Layout dabei aber so, wenn ma das jetzt im Schnitt rechnet auf Vollzeitadäquat sozusagen denn wärens in etwa 3 Leut fulltime.*

Q18. *K: Wie viele Leute in Wien arbeiten jetzt daran?*

G: Derzeit arbeiten daran…Full Time Equivalent, wie man das, also ich würde sagen ich arbeite zu 30% momentan an dem Projekt, ich arbeite, ah, noch an vielen anderen Projekten. Der Systemingenieur in etwa zu 50% . Und dann gibt es, ah, derzeit vier, drei Personnen im AIV, die 100% auf diesem Projekt arbeiten. Und es gibt, ah, derzeit noch in der Elektronikabteilung einen 50% Systemingenieur, der noch die TPPAE betreut. Das wird jetzt in den nächsten Wochen noch in etwa eine Person full-time beschäftigen für die Tests. Also es ist, im Endeffekt arbeiten derzeit fünf Leute vielleicht daran im Schnitt. Es waren aber schon wesentlich mehr.

Q19. *Und da sieht man sofort, also da geht man die Projekte durch und da sieht man sofort, wenn jemand doppelt oder dreifach…doppelt oder dreifach ausgelastet ist, dann schreit er natürlich auch sofort „ach, geht sich das aber nicht aus!"*

Q20. J: [...] dann ist immer die Frage, „was ist das Risiko?" Dann sagen wir das dem Herren L, eben von der Produktsicherung, dem G und dann entscheiden wir das gemeinsam.

K: Wie schätzt man das Risiko ein?

J: Ja, in, einfach in dem wir sagen, ahm...wenn wir jetzt das Helicoil kaput machen und das auswechseln müssen, dann weiß ich ganz genau, wenn wir das Ding zerlegen müssen und wieder zusammenbauen, dann kostet das hundert Stunden, mit den Tests vielleicht dann 150 Stunden. Und das ist einfach das Risiko, wird alles in Stunden, alles in Stunden...oder, wenn wir Hardware brauchen, dann ist das Geld, aber an und für sich, ich rechne Geld auch immer auf Stunden zurück, damit ich einen Überblick habe. Interessiert mich Geld nie, sondern immer, ich tue es immer reduzieren auf Stunden.

Q21. Das dauert eine Stunde oder eineinhalbstunden, das Meeting. Das ist natürlich Arbeitszeit, die für alle verloren geht irgendwie, aber es ist trotzdem sehr wichtig.

Q22. [...] gibt's ein Analyseingenieur, ein Designingenieur, ein Systemingenieur, dann...dann, was gibts noch...Produktsicherung, die ist sowieso komplet getrennt, das ist der Herr L, der da sitzt. Der arbeitet auch überhaupt, komplet autonom, also, der steht nur dem Herrn K, das ist sowie das Gericht im Staat, dem der Politker auch nichts sagen darf.

Q23. Normalerweise nimmt sich jeder eher zu viel Arbeit und das verzögert sich dann alles ein bisschen. Und das ist eh gut, weil, also für die Workload für die Firma ist es total wichtig, dass immer alle 100% ausgelastet sind.

Q24. Also es gibt, es gibt für die Firma zwei Probleme. Das eine ist dies, wenn sie große Aufträge hat, die irgendwie nicht funktionieren, das kann ein Problem für die Firma sein. Und das andere Problem ist eben die Auslastung. Und die Auslastung ist das größte Problem eigentlich. Weil, ah, da kann man die Stunden einfach nicht verkaufen [...]und, ah, jeden, den man nicht auslasten kann, das ist wie, wenn man genau diesen Betrag verliert. Und jeder vo-...müssen Sie sich das so vorstellen, ein Projekt macht zum Bespiel, wenn's gut läuft, 10% Gewinn. Das heißt, wenn man 100% verliert bei einer Stunde, weil er nicht ausgelastet ist, dann braucht man zehnmal so viel Stunden von einem gutlaufenden Projekt, das man genau das wieder reinholt.

Q25. Natürlich macht das die Firma als ganzes ineffizienter aber ich glaube, das ist überall so. Wie würde man das sonst machen?

Q26. Was nicht immer leicht ist, was natürlich auch schwierig ist insofern wenn man auf vielen Projekten, ich meine ich hab's ganz gern bei einigen großen Projekten gemacht, wo man ein fixes Kernteam hat, die dann fünf, sechs Leute ständig 100% in diesem Projekt hat oder nah zu 100%. Da kann man natürlich sehr viel effektiver, viel effizienter arbeiten. Das Problem, das wir haben mit dieser Überauslastung, diesen ständigen Springen zwischen den Projekten und Lücken zu stopfen, macht die Organisation aus meiner Sicht als solches relative ineffizient.

Q27. *Wir haben unseren Datenpaket geliefert. Schuld daran ist die ESTEC, das Technologiezentrum der ESA in Noordwijk, da gibts das, ja das Projekt ist sehr schwach besetzt von der ESA. Ja und es gibt sehr wenig Leute, die Zeit haben dort mitzuarbeiten. Es wird sogar betont es wäre sehr wichtig für die Evolution des Copernicusprogramms aber letztendlich, ah gibt's die Ressourcen dort nicht, dass die, dass die adäquat betreuen das Projekt.*

Q28. *Das war in Vergangenheit leider nicht so. Das hat uns in der Anfangsphase sehr viel Zeit und Geld gekostet. Also wenn man, also es ist sehr wichtig, einen kompetenten Kunden zu haben.*

Q29. *Und wenn man Hardware bauen muss, dann müssen auch natürlich bestimmte interne Meilensteine gesetzt werden, bei einer, wenns eine reine Papierstudie ist dann glaubt man immer, ich meine, das kennt jeder, wenn man schon einmal irgendein Bachelor, Masterarbeit geschrieben hat, man ist eh immer optimistisch weil es sich immer ausgeht am Schluss. Aber wenn man Hardware am Tisch haben muss und das messen, testen muss, ist es relativ, ah, motivierend dass man früh fertigt.*

Q30. *Und das ist jetzt das Problem, dass wir eigentlich formal erst Hardware bauen dürfen wenn wir das CDR hinter uns haben, aufgrund des Gesamtzeitplans wir natürlich schon früher dran sind und das Risiko mit den Schweden tragen das wir schon früher Hardware bauen. Das CDR soll eigentlich schon im Februar gewesen sein.*

Q31. *Wir haben jede Woche, im Schnitt jede Woche ein Meeting, ein internes Project Meeting, ein Team Meeting, wo der Status besprochen wird, leider in den letzten Wochen einigermassen sehr oft ausgefallen aufgrund von externen Terminen oder Krankheiten aber, aber der Plan ist, oder der, ja, der Plan ist, jede Woche ein oder spätestens alle zwei Wochen ein Project Meeting zu haben, um den Status genau zu erfassen wo wir sind und Actions auszugeben. Und dann gibts, ahm, das ist sozusagen das interne Organisation, es gibt aber auch eine externe Review Organisation, die wir, die wir einhalten müssen.*

Q32. *Also das finale Negotiation Meeting ist gleich das Kick-Off Meeting mit den Kunden. Und dann sind wir formal losgekickt, dann kommts, ah, eine ATP oder gleich ein Vertrag über das ganze. [...] Wir haben dann im Herbst zu arbeiten begonnen, 2011 und haben ein internes Kick-Off einmal durchgeführt. Intern heißt, dass wir hier in Wien, und dann haben wir uns eben die Projektstruktur überlegt, wie wir die Arbeit aufteilen.*

Q33. *Die Kommunikation mit unseren Kunden ist eigentlich sehr...wie soll ich sagen...ist nicht sehr locker, aber es ist irgendwie sehr...nach allen linearen, die man zusammenarbeitet, ist es relativ, ist nicht sehr, sehr technisch streng. Also wir, im Prinzip ist man per du in so einem Projekt in der Space Industry. Weil es in, ich glaube im anglo-amerikanischen Raum einfacher ist.*

Q34. *Alles was ich jetzt aufgefasst habe arbeite ich selber ab, da schreibe ich überall meinen Namen dazu. Wenns wer andere ist, dann schreibe ich die anderen Namen dazu [...] Es gibt immer jemanden, der zuständig ist dafür und immer ein Datum, normalerweise, dazu. Und irgendwie,* *dass man, also dieses ist prinzipiell bis nächste Woche, so wöchentlichen Meetings, aber, Dinge, also auch wie die Kunden da waren, da werden auch Actions vergeben und da gibt's immer, in dem Fall gibt's dann immer eine Firma und wir vergeben das dann aber schon mit Namen von uns dazu, weil überall wo kein Name und kein Datum dabei steht, das wird sicher nicht gemacht.*

Appendix B: English Abstract

The engineering company is a particular kind of institution: not a laboratory and not a research organization, but nonetheless a site of knowledge creation and a place of innovation. The employees of an engineering company are responsible for designing and producing technologies in addition to developing their own sets of knowledge and skills to further their career development. Underlying this work is the necessity of looking out for the company's economic bottom line: as a private institution, the engineering company must make a profit in order to survive. The engineers and managers who work at a company utilize a particular combination of technical and social/communicative skills to complete their work. The combination of "hard" and "soft" skills required to work successfully as an engineer, as well as the situation of the engineering company as both an innovative institution and one that is tasked with the practical development of technologies, gives the engineering company as an organization a unique position within current discourses on innovation and new modes of knowledge production.

Using an Austrian engineering company and developer of space technologies as a case study, this project explores the nature of the engineering company as a site of knowledge production through an examination of the work practices of its employees. Semi-structured interviews and participant observation of meetings at the company were used to develop a qualitative analysis of the company employees' practices of assigning roles and responsibilities, identifying and assessing risk and collaborating with their partners and customers. A discussion of these regular work practices reveals assumptions and imaginations of the company's identity as it is understood by its employees. Conclusions are drawn about the differences and similarities of the engineering company as an institution to the sites of more traditional STS studies of knowledge creation and projectification in the life sciences and elsewhere.

Appendix C: Deutsche Zusammenfassung

Ein Ingenieursunternehmen ist eine spezielle Form von Institution: kein Labor und keine Forschungseinrichtung, und dennoch ein Ort, an dem Wissen generiert wird und Innovation einen Platz hat. Die Mitarbeiter/Mitarbeiterinnen eines Ingenieursunternehmens sind sowohl dafür verantwortlich, Technologien zu entwickeln und zu produzieren, als auch sich selbst, ihre Fertigkeiten und ihr Wissen, (weiter) zu entwickeln, um ihre eigene Karriere voranzutreiben. Nie aus dem Blick verlieren dürfen sie dabei die Profitorientierung des Unternehmens: Denn nur der Profit sichert dem privaten Ingenieursunternehmen das ökonomische Überleben. Die Ingenieure/Ingenieurinnen und Manager/Managerinnen eines solchen Unternehmens machen sich dafür eine bestimmte Kombination an technischen und sozialen/kommunikativen Fertigkeiten nutzbar, um ihre Aufgaben zu erfüllen. Diese Kombination an Fachkompetenzen („hard skills") und Sozialkompetenzen („soft skills"), die für die erfolgreiche Arbeit als Ingenieur/Ingenieurin erforderlich ist, als auch die Orientierung des Ingenieursunternehmens auf Innovation einerseits und die praktische Entwicklung von Technologien andererseits, verleihen dem Ingenieursunternehmen eine einzigartige Position inmitten gegenwärtiger Diskurse zu Innovation und neuen Formen der Wissensproduktion.

Basierend auf einer Fallstudie eines österreichischen Ingenieursunternehmens spezialisiert auf die Herstellung von Raumfahrttechnologien und, im Speziellen, auf der Analyse der Arbeitsabläufe seiner Mitarbeiter/Mitarbeiterinnen, untersucht dieses Projekt das Ingenieursunternehmen als einen speziellen Ort der Wissensproduktion. Semi-strukturierte Interviews und teilnehmende Beobachtung bei diversen Meetings im Unternehmen bilden die Grundlage für eine qualitative Analyse der verschiedenen praktischen und alltäglichen Verfahren zur Zuweisung von Rollen und Verantwortungen, zur Identifizierung und Abschätzung von Risiken sowie zur Kollaboration mit Partnern/Partnerinnen und Kunden/Kundinnen. Eine Diskussion dieser alltäglichen Arbeitspraktiken macht Annahmen und Vorstellungen über die Identität des Unternehmens sichtbar, so wie sie sich den Mitarbeitern/Mitarbeiterinnen darstellt. Daraus lassen sich Rückschlüsse ziehen auf Unterschiede und Ähnlichkeiten zwischen der Institution des Ingenieursunternehmens und den Schauplätzen klassischerer STS-Studien betreffend Wissensproduktion und Projektifizierung in den Biowissenschaften und darüber hinaus.

Appendix D: Curriculum Vitae

Kari Zacharias

Personal Information

Date of Birth:	October 9th, 1985
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Education

2011 – 2013	University of Vienna, Institute for the Social Studies of Science and Technology: Master's studies in Science, Technology and Society
2003 – 2008	University of Toronto, Faculty of Engineering: Bachelor's degree in Engineering Science, specialization in Aerospace Engineering
	Elementary and High Schools in Victoria, Canada

Work Experience

2013	Tutor for Dr. Maximilian Fochler's STS Master program seminar *Grant Writing and Project Management*, University of Vienna
2012 – 2013	Tutor for STS Master program introductory tutorial, University of Vienna
2008 – 2013	Analysis Engineer at FACC AG, Vienna
2006 – 2007	Components Engineering Intern, Honeywell Canada, Mississauga ON