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Engineering Work - On Peer Reviewing as a Method of Horizontal Control

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Engineering Work

On Peer Reviewing as a
Method of Horizontal Control

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Thank you:

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Chapter one

Introduction

Jake is a civil engineer in electrotechnics and works with development of radio hardware at General Technologies (GT), one of the world's leading producers of technology for telecommunication[1]. He arrives at work at 08.30, grabs a cup of coffee, chats for a few minutes with a colleague at the coffee machine and then goes to his office. He checks his mail and sees that he got a report from "Guido", GT's error reporting system. Getting an error report from Guido means that there is another person in the organization – typically someone who works in close cooperation with Jake's work group – who has found a problem with work that Jake has performed. This time it is a problem with a circuit that Jake has tested, and the person who found the problem works at the ASIC-department, where the circuits (ASICs) are designed.

The fact that there is a problem found after Jake has finished his tests might sound as if he failed, but at GT it is not a very big deal. It is rather considered as typical part of the dynamics of work. Problems and errors are constantly found. Most of the products that Jake produces he produces for the first time, and he – based on experience and knowledge about electrotechnical constructs – can therefore only assume how the circuit will react when it is exposed to for example new software. He can also only assume how long it will take to test it. Uncertainty characterizes the work. As one of Jake's colleagues puts it, "there's a bunch of unforeseen things that come up as work goes on". This time, for example, Jake does not know for sure what the error that causes the problem is, but he thinks the error report might be misdirected because the problem could be caused not by the circuit that he tested, but by the power supply. In order to find out more about the problem, he needs to discuss with Fred, a colleague who works with the

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[1] For reasons of confidentiality, the names of people and the company are pseudonyms.

power supply. Jake often needs to discuss problems with colleagues, partly to get advice but mainly because the engineers are interconnected by the physical pieces – or "blocks", as the pieces are referred to at GT – of the product that they work on. In this case, Jake works on the transmitter and Fred on the power amplifier (PA). If Jake feels that he needs to discuss the problem with more colleagues, and if there is time, he could also bring it up at the weekly work meeting that starts at 09.00.

Jake arrives at the work meeting a few minutes after nine. Carl, the "object leader"² who is heading the meeting has already started. He informs of some general issues, then he asks each engineer to report on his work, i.e. he does a follow-up on the past week's work and checks the engineers' work in relation to the time plan. Carl only gets into details if there are problems. When details are discussed, it is not only Carl and the engineer responsible for them who are involved, but also other engineers who either have experience in the field or work with an adjacent block. Although Carl is an experienced engineer he does not have the in-depth knowledge about the different blocks that the "operative" engineers have. He cannot direct their work on a detailed level, but he can tell them what parts are most urgent to finish for the time being – he can make priorities. As for Jake's error report from Guido, there is no time to bring it up at the meeting. The meeting ends at 11.00.

After the meeting Jake has lunch with the usual colleagues, which are the ones in his "section", who all work with radio development. They practically always have lunch together and always sit at the same table. After lunch most of them have a cup of coffee together in the space outside the area where the laboratory and their offices are.

At 13.00 Jake attends another meeting. This one is a "review" where Eddie, one of Jake's colleagues who also works with the radio but on a different block, has finalized some tests. After tests are performed they are up for a review like this one, to which people who are directly affected by the results or have valuable input or knowledge are invited. Managers may attend the review but mainly to inform themselves of the status of work. The review is a way of communicating the results, but the most important

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² At GT they use the terms "object" and "object leader". It is basically like "sub-project" and "sub-project leader", since Carl's superior is called project leader.

purpose is to discuss and decide whether the results are satisfactory or not. It is common for a piece of work to go through more than one review process. This is the case today; Eddie goes through his test results and there seems to be more work needed before they can be approved. The review meeting ends at 13.30.

After the review Jake walks back to his office and starts working on a document where he lists and explains the pros and cons of a new construction on a part of the radio, the PA (power amplifier). In the past few weeks an idea has emerged among the engineers and their immediate managers that it may be possible to improve the PA-solution, and Jake tries to figure out the consequences of a new construction (which does not exist yet) as this is his area of expertise. Jake works on the document until 15.00, then he goes out to the laboratory to make some tests.

The lab work takes quite a while, Jake needs to set up the instruments, program the computer and he also consults a colleague who is a bit more familiar with the programming part than he. He also needs to do some soldering to connect his component with another component; he wants to test how the components interact. Further, since much work is done for the first time, it is often necessary to know who has done something similar before and ask him or her for advise in order to find out a good way to proceed. Hands-on work such as testing is usually performed on an individual basis, but it tends to be preceded by a collective communication process.

Jake is finished in the lab at 18.00. When he goes back to his office and checks his mail he sees that Lars – a colleague who works mainly in the new D2-project where the next generation of products is developed – has called a meeting where possible future solutions for the radio will be discussed. Jake is thus involved not only in the implementation of existing development plans but also in the creation of the plans that will be implemented in the future. The D2-meeting is next week. Jake leaves the building at 18.15.

1.1 A surge of complex work

It has long been argued that the production of goods and services becomes ever more "knowledge intensive". Theoretical knowledge

rather than manual skills has been said to be the fundament of organizational action (Bell, 1974) and there has been a surge of academic interest in the work categories of "knowledge work" (e.g. Starbuck, 1992; Alvesson, 1995; 2004; Robertson & Swan, 2003; Blackler, 2003) and "professional work" (e.g. Abbot, 1991; Løwendahl, 1997; Covaleski et al, 1998; Anderson-Gough et al, 2000; Freidson, 2001). This interest is paralleled by the fact that the education level in the Western economies is increasing and so is the size of knowledge intensive sectors such as R&D and education[3].

Of course, one should not be too hasty characterizing the contemporary workplace as increasingly knowledge intensive and complex. It is, for example, important to keep in mind that defining the amount of people actually working in so called "knowledge jobs" is a matter of interpreting statistics (see Fleming et al, 2004), and that an increase in knowledge jobs does not exclude a simultaneous increase in less knowledge intensive jobs (Thompson et al, 2001; Nolan & Wood, 2003). But although the character of the workplace as a whole is debatable, there is reason to direct attention towards the *phenomenon*

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[3] In Sweden, according to Statistics Sweden (SCB), the number of people with university education of less than 3 years increased by 108 % between 1985 and 2005. The number of people with a university education of more than 3 years increased by 152 % during the same period. This does not have to mean that the actual work became more "complex": people with university education may very well perform "unskilled" work. The increase is considerable however, and at least some the graduates are likely to use their academic knowledge in the workplace. The likelihood of this being the case increases if we consider the fact that the industrial sector expanding most (53 %) between 1993 and 2003 was "Research and development and education" ("Forskning och utveckling och utbildning"). The second most rapidly increasing sector (36 %) was "Credit institutions, real estate management and management consultancy" ("Kreditinstitut, fastighetsförvaltning, företagstjänster"). The third was "Trade, transport and communications", but this only expanded by 9 %. As noted, exactly what is hidden behind these numbers is uncertain, but it is quite clear that jobs that require some sort of university education are tending to become more common. In broad terms, this trend is applicable to most industrial nations. Some, like Norway, the USA, Korea and Canada, have slightly more people with a university education than Sweden, while Austria, Turkey and Italy have fewer. Sweden is somewhat above the OECD average, which is about 20 % having an university education of more than 3 years (OECD (2005) *Education at a Glance*).

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that knowledge intensiveness or knowledge work and professionalism or professional work have become increasingly common in contemporary discussions of the workplace.

The categories of knowledge work and professional work have become fairly established and it is possible to identify frequently recurring definitions in the literature. Knowledge work is thought to signify work where knowledge rather than capital or labor power plays a central role in the production of goods and services, where the majority of the employees have a high education level, where esoteric expertise rather than widely shared knowledge is important, where employees are engaged in complex problem solving rather than standardized or routine tasks, and where the reliability and creativity of the employees is important to the success of the firm (Starbuck, 1992; Alvesson, 1995; 2004). Professional work also requires a high education level and complex problem solving. But above all it is associated with a tight link to an academic institution, a standardized education, a code of conduct, and control exercised by peers rather than by managers (Løwendahl, 1997; Freidson, 2001; Alvesson, 2004).

Knowledge work and professional work are not unproblematic categories. What is considered to be knowledge work or professional work is a matter of debate and politics; it is of course appealing to construct one's occupation as knowledge intensive or "a profession". Rather than being objective categories "out-there", the phenomenon of knowledge-intensity has been argued to be an example of a "system of persuasion" (Alvesson, 1993), and "profession" has been said to be the result of a power struggle over the privilege of definition rather than a representation of a type of work that significantly differs from adjacent occupations (Abbot, 1991). Nevertheless, the categories fulfill a function as analytical constructs for making sense of *at least* the phenomenon that some occupational groups *claim* to be knowledge workers or professionals (Alvesson, 2001), and perhaps that we are looking at a type of work that is fruitfully described as significantly different from capital- or labor intensive work.

The categories of knowledge- and professional work are often viewed as closely connected and both terms often occur in the same studies (e.g. Starbuck, 1992; Alvesson, 1993; Blackler, 2003). The term "knowledge- and professional work" is a bit impractical, however. As a

collective term, I shall therefore use the label "complex work" instead of referring to both categories. This relabeling is not *only* for practical reasons. First, it is illustrative to think of knowledge- and professional work as characterized by complexity. The term "complex" illustrates that work tasks are non-repetitive and not predefined in detail, which results in the need for problem solving that requires esoteric expertise and the use of a high degree of both formal and contextual knowledge[4]. Second, the empirical example of this thesis – engineering work – tends to be positioned somewhere in the gray area between knowledge- and professional work, which makes it fruitful to find an alternative to *either* knowledge work *or* professional work. Therefore, complex work will henceforth be used.

A good way of arguing for the complexity of work and discussing its nature is to use illustrations and examples, based on ethnographically inspired research. Complex work has been illustrated through the work of for example physicians (Freidson, 1975), IT-consultants (Alvesson, 1995), lawyers (Winroth, 1999), scientists (Owen-Smith, 2001), marketing specialists (Svensson, 2004) and tax consultants (Alvehus, 2006).

The introduction to this first chapter is a brief example of complex work in the form of *engineering*. Jake's workday gives us a sense of what he and his engineering colleagues do. It says something about the character of their work: its outcome and time consumption is uncertain because many tasks are performed for the first time; its environment is developing rapidly, what was cutting edge technology two years ago is standard today; it requires a high level of expertise created by both formal education and contextual knowledge; problem solving is complex and takes place between colleagues; only those working operatively comprehend the details of the work and, often, it is only these people who possess enough knowledge to understand the

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[4] The idea of complex work can be thought of as the opposite to Taylor's (1911/1998) idea of work. Taylor wanted to clearly separate the conception of work from its execution. He argued that managers should design work processes and meticulously define work tasks – both in terms of content and the means used in performing the work – whereas the workers should mechanically execute the tasks. A way of conceptualizing Taylor's idea is to say that he strived towards an elimination of all complexity in the work tasks.

consequences of new ideas and decisions, which forces the firm to rely heavily on their knowledge and creativity. In short, the work is characterized by complexity. It is this work, operative engineering work, that will be the focus of attention henceforth. Specifically, my focus will be directed on the following question: how are the operations of such work controlled? Let me therefore expand somewhat on the example of engineering, and on its consequences in terms of organizational control.

1.2 The example of engineering work

Engineering is an interesting example of complex work. It is often put forth as a highly influential category of work in the modern society (Cooley, 1980; Mellström, 1995; Pålsson, 2003)[5] and as fundamental for economic growth and improved quality of living[6]. We are frequently exposed to the products of engineering work through our extensive use of computers, mobile phones, DVD-players, cameras etc. In industry, firms are becoming increasingly dependent on engineers. As noted by Meiksins & Smith (1993): "[A]s industry has grown larger, more complex, and more technically sophisticated, it has become necessary for firms to employ a complex, diverse group of technical workers who are engaged in the labor of designing industrial processes and products [...] (p. 125)". This "technization" of society (Barley & Orr, 1997)

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[5] It is also a major occupation. In Sweden in 2003, "engineers and technicians" was the fourth largest occupation (125,952 people). Engineers with a master's degree ("civilingenjörer, arkitekter m.fl.") are not included in this figure but make up their own occupational group in the Standard for Swedish Occupational Classification, being at 19th place (62,004 people) (Yrkesregistret med yrkesstatistik, 2003A01), see homepage at:
www.scb.se/templates/Product_59071.asp).

[6] This is perhaps especially relevant in Sweden with its strong engineering tradition. See for example the Swedish government's proposition in 2004 (2004/05:80) named "Research for a better life", where technical science is one of the prioritized areas of research and seen as the foundation of a successful Swedish economy and industry: "A strong technical science is important for the supply of competence to industry and for the development of new marketable ideas and high-technology products. This is especially valid in Sweden whose economy is highly dependent upon exports and where a large part of these exports consists of high-tech products or originates from high-tech processes" (p. 81, my translation from Swedish).

means that the products of engineering work increasingly guide our behavior. This calls for exploration of what guides the behavior of the engineers.

Engineering is also interesting because of its multi-faceted nature. Take the introductory case of Jake's work as an example. His work is "mental" when he needs to use his technical knowledge to figure out how to proceed in the laboratory, but it is also "manual" when he does the soldering. Jake started at GT immediately after finishing his university studies. He could already perform rather complex tasks but he, a bit like an apprentice of a craft, needed to be taught by the other engineers how they do things at GT before he could work independently. Jake has no management responsibilities; he is at the bottom of the formal hierarchy, works with production and operates machines and instruments, a bit like a factory worker. But his tasks are more complex than those of a factory worker. Operating the instruments, for example, is not a matter of turning them on and off and observing them operate, but rather of understanding their potential and programming them to execute the tasks needed. It is also a matter of understanding, producing and manipulating symbols – i.e. the numbers that result from the tests made with the instruments – which is a feature of knowledge work (e.g. Alvesson, 2004) and professional work[7] (e.g. Freidson, 2001). Or as plainly put by Pentland (1997: 114): "technical work is knowledge work". But it is not *only* knowledge-work. It is quite diverse. Jake's work shows similarities with craft-workers, knowledge-workers as well as professionals.

The nature of engineering work and its consequences for the way in which work is controlled has not been the main focus of attention among scholars, however. Much research on engineering has focused on positioning it into traditional categories of work (such as manual vs. mental, blue collar vs. white collar, unskilled vs. professional, craft vs. science). Broadly, there can be said to be a "craft perspective" and a "professional-scientific perspective", the former focusing on engineers

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[7] Take for example lawyers who work mainly in the symbolic realm of the law, or management consultants who work mainly in the symbolic realm of management vocabulary using words like "downsizing" or "teamwork" which are thought to symbolize actions and behavior that are taking place in the organization.

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as wage laborers and their commonalities with other workers, and the latter on engineers as professionals, managers and designers of production systems, legitimized by their university training (Smith, 1996: 190 f.)[8]. Within the professional-scientific perspective, engineers have thus been portrayed as managers and producers of management control systems on the one hand (Braverman, 1974; Cooley, 1980), and on the other as professional workers who work largely independently of management control and develop their own occupation-based methods of control (Whalley, 1986; Crawford, 1989).

Another large body of studies takes a managerial perspective and aims at making engineering work more effective. Examples of topics and arguments in the managerialist genre are the need of improving the management skills of engineers (Batley, 1998), the dissatisfaction and demotivation among engineers which calls for improved motivational tools in engineering companies (Petroni, 2000), and the vertical polarization between technical and managerial roles as a cause of under-utilization of engineers in product development and an obstacle for knowledge sharing in the organization (Lam, 1996)[9]. In a Swedish setting, Adler (1999) makes the argument that there is a discrepancy between the project management techniques in use (which focus on planning) and the nature of complex product development and calls for

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[8] To a large extent, the debate has been conducted from a Marxist perspective, portraying engineers on the one hand as a "new working class" (Mallet, 1975) that will affiliate with manual workers and add technology to muscle power as a working class resource for reducing capitalist power over the means of production, but on the other hand as victims of "deskilling" (Braverman, 1974) through tightened management control and commodification of engineering expertise, which would place the power over technical knowledge in the hands of managers (Smith, 1987). The quest of "knowledge management" to make tacit knowledge explicit and thereby manageable testifies that there is reason to be attentive to deskilling tendencies (cf. Sewell, 2005). Still, whether "proletarians" is a fruitful way of labeling engineers is questionable, or at least remains an empirical question.

[9] There are also journals directing their interest specifically towards the management systems of engineering work, such as *Engineering Management* that covers "management methods, techniques and processes relevant to engineers" (See journal homepage at:
http://www.iee.org/Publish/Journals/MagsNews/Mags/Em.cfm).

new management techniques that focus more on integration and synchronization of the processes.

These studies indeed deal with organizations where engineers work. But a problem with the categorization attempts, as I see it, is that they focus more on engineers as a social category than on their work. Such categories may be helpful for making sense of the position of an occupation in the relations of production, but say little about the dynamics of everyday work. And they tend to fall apart when confronted with observations of everyday work. Similarly, the managerialist writings fail to offer understanding of what guides the engineers on an everyday level because the overarching issue is how to increase organizational effectiveness, asking questions about how to train, motivate and utilize the engineers, or how to optimize the project management techniques.

The limited efforts to offer rich descriptions of engineering work have been noted by others, for example by Whalley (1986: 15) who says that "… descriptions of technical work in high-tech companies have been largely anecdotal …", or by Barley & Orr (1997)[10] who point out that "science and engineering have attracted considerable attention over the years, but only recently have researchers begun to examine what scientists and engineers actually do and how their work is organized" (p. vii).

If categorization attempts and managerialist writings do not make justice to engineering work, how, then, might we describe it? One way of offering a more relevant description of engineering is thus to focus on what engineers do rather than what they are. Put differently, I believe that focus on *characterization* by use of adjectives rather than categorization by use of nouns gives a richer picture of how engineers (or other employees) work and what guides their behavior. In addition to this, I believe leaving the idea of dichotomies will produce more useful descriptions, exchanging "either-or-categories" for "more or less-characterization", and allowing a specific type of work to be "both … and" if that proves more fruitful.

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[10] See also Barley (2004).

Studies have been conducted that aim to describe the very work of engineers, to describe what they do. In particular, there are a number of ethnographically inspired studies – especially Whalley (1986); Crawford (1989); Mellström (1995); Barley (1996); Orr (1996) and Barley & Orr (1997, eds.)[11] – which provide valuable insights into the nature of engineering. Using these in combination with my own study, I shall offer 1) a definition that clarifies what type of engineering work I have studied, and 2) an outline of aspects that I argue are central to the practice of engineering as defined here, and aspects that make engineering work into an example of complex work.

Central aspects of engineering work

Berner (1981: 115) has described engineering work as a social activity consisting of the "development and use of new technology". She also exemplifies this work as "solving technical problems in production, constructing new products and processes, [and] leading technology firms" (ibid.)[12]. Barley & Orr (1997) – based on a number of ethnographic studies of both technicians and engineers – argue that "technical workers" have the following characteristics in common[13]:

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[11] Of these, Whalley, Crawford and Mellström focus specifically on engineers whereas the others use the term "technicians", which includes a wider range of work activities. Orr (1996), for example, studied the work of technicians repairing photocopiers, work that shares features with but in many ways is different to that of the product development engineers at GT.

[12] My translation from Swedish.

[13] Barley & Orr (1997) point out how both the work of engineers and technicians blur traditional categories of work. It is a bit difficult to separate between engineering and technical work and when those categories are discussed, the terms engineer and technician are sometimes used synonymously. I view engineering as a subcategory of technical work. Whalley & Barley (1997: 47) make a point of the difference and argue that engineers to a larger extent than technicians are represented among managers, engaged in the control strategies of the firm and have responsibility for people. The engineering work focused upon in this thesis, however, is most of the time performed from a non-managerial position. When management positions are involved, it is the perspective of the managed engineers and not the manager that is taken. Therefore, the work of the engineers focused upon at GT shares many features of the technicians studied by Whalley & Barley.

> (a) the centrality of complex technology to the work, (b) the importance of contextual knowledge and skill, (c) the importance of theories or abstract representations of phenomena, and (d) the existence of a community of practice that serves as a distributed repository for knowledge of relevance to practitioners (Barley & Orr, 1997: 12).

In characterizing engineering work, I shall use these two descriptions of what engineers do (Berner) and what is characteristic of their work (Barley & Orr) as a point of departure. I have little to object to the descriptions – they describe rather well in general terms what the engineers at GT are doing and what is characteristic of their work – but a few things can be added to clarify the empirical focus of this study.

One clarification is that my study concerns engineers and not technicians. Although technicians and engineers are likely to have much in common, there is a point in separating between them. One way of separating that is useful in this book is to stress the line "development and use of new technology" in Berner's definition, where the *development* of new technology can largely be reserved for the engineering occupation, whereas engineers as well as technicians *use* new technology. Jake and his colleagues at GT work with development of high-tech telecommunications technology and their work results in a physical object, a product that will be used in mobile phones. This makes them not only engineers, but more precisely *product development engineers* within the field of *electrical engineering*. Henceforth, however, I will refer to them only as "engineers" and to their work as "engineering work".

A second clarification is that the work I have studied is performed on a "hands-on" level: the engineers have little or no managerial responsibilities[14] and are positioned at the lowest level of the formal hierarchy. (This position does not prevent them from being highly educated however; the majority of them have a master's degree in engineering – typically electrical engineering – which corresponds to 4 ½ years of university education.) Returning to Berner's definition above, it is thus not the "leading technology firms"-part of engineering

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[14] When people are not "just" engineers but managers of some kind, it will be indicated.

work – at least not in terms of an emphasis on strategic issues or management work – that is focused upon here[15]. Instead, I focus on the operative level of engineering work, the level that emphasizes the *"development and use of new technology"*, which includes the *"solving of technical problems"*.

Berner's (1981) and Barley & Orr's (1997) definitions are both fruitful for making sense of what engineering work is all about. But although I hope the reader will learn something about "the nature of engineering work" after having read this book, the primary focus is not on engineering work per se, but on the *control* of engineering work in its capacity as an example of complex work. Therefore, taking departure in the definitions offered by Berner and Barley & Orr, I will suggest aspects that are central to engineering work, but that are *particularly* interesting because they tend to make the work complex. They are also particularly interesting because they set the context within which the operative control of engineering work takes place, and because they are used and/or dealt with by engineers and managers in their attempts to control work. These aspects are:

- Uncertainty
- Knowledge intensiveness
- Deadline focus
- Idea intensiveness

While developing technology and solving technological problems, engineers are faced with *uncertainty*. In particular, it is difficult to predict how much time an activity will take and it is unclear exactly what needs to be done (Stinchcombe, 1985; Adler, 1999; Westling, 2002). In the introduction we see how Jake is faced with uncertainty in a number of ways: problems and errors show up almost randomly, what Jake does is usually done for the first time, and it is uncertain how long it will take to perform his work. Such uncertainty tends to complicate the nature of the work.

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[15] For a good account of attempts of "leading technology firms" through the use of normative control, see Kunda (1992).

Another aspect of engineering work is its *knowledge intensive* character. This is partly connected to the uncertainty aspect in the sense that performing uncertain work can be said to require more knowledge than performing certain work (Cooley, 1980). Somewhat surprisingly perhaps, the term "knowledge intensive" is seldom used when engineering work is accounted for. But knowledge plays a central role when engineering work is discussed, not least in Barley & Orr's (1997) definition quoted above (see also Crawford, 1989; Whalley & Barley, 1997). Special attention is paid to the separation between and integration of *formal (theoretical)* and *contextual* knowledge (Crawford, 1989; Whalley & Barley, 1997). Engineers are highly educated theoretically, but they also need much on-the-job training and thus "contextual knowledge" in order to perform their work. I will not attempt to find out here whether engineering knowledge is more theoretical or contextual, suffice it to point out that a large portion of both types of knowledge is used in operative engineering work and that the combination produces a complex and specific body of knowledge – engineering knowledge.

Jake's work in the laboratory in the introductory case can serve as a micro-example, indicating that lab-work requires a number of different types of skills and knowledges: manual skills (e.g. soldering), contextual/practical knowledge of machines, and theoretical knowledge of the programming language as well as the functioning of machines. Being able to combine contextual and formal knowledge means being able to understand the connection between the language of programming and the functioning of the machine in a certain context, which in turn enables engineering work. Pertaining to the specificity of engineering knowledge, it is perhaps best understood as being characterized by *impenetrability*, or as Whalley & Barley (1997) note regarding technicians and engineers: "few outsiders can claim to possess their skills or knowledge" (p. 41).

While the aspects of uncertainty and knowledge can be seen as paraphrases of Berner's and Barley & Orr's definitions of engineering work, the third aspect – *deadline focus* – is rather to be seen as an addition. The centrality of time limits in engineering work (Mellström, 1995) to a large extent stems from the fact that engineers often work in projects and projects have deadlines that have to be kept, or at least

"dealt with" (see chapter seven). The work is thus to a large extent organized around deadlines. In the introduction, the deadline focus comes forth most clearly at the work meeting that Jake attends at 9 AM. Work meetings are held on a weekly basis and one of their more important functions is to check if the engineers are on track in terms of time. If they are not on track, something needs to be done. If it is an important deadline it cannot be moved, and the engineers must find out how to deal with the deadline in one way or another.

Working in projects and having deadlines is hardly exclusive of engineering work. Neither does on it alone make work complex. But it becomes interesting in combination with the uncertainty-aspect since deadlines become more complex to deal with when the efforts needed are uncertain: a tight deadline in repetitive work (such as cleaning offices or loading containers onto a ship) will require an employee to either work faster or work overtime, whereas it may require the employees of complex work to change more profound aspects of work such as method and structure, or bring in new people or new machines. Deadline focus is also particularly interesting in combination with uncertainty *and* knowledge intensiveness, because when work is uncertain and specific knowledge is required to deal with it, the deadline is suggested to be one of the few devices that can be used to control work (Mellström, 1995).

The fourth aspect, the centrality of *ideas*, should also be considered as an addition to Berner's and Barley & Orr's definitions. It is an aspect that – in line with what has been said above regarding the difference between technicians and engineers – indicates that the employees at GT are engineers rather than technicians. They develop technology, and that includes the management of ideas; it is a part of their work to think of new solutions that can improve the product and to give feedback on the quality of other people's ideas. Ideas also give rise to work in the sense that an adopted idea tends to become a project with a time plan. In this way, the ones who are in control of the ideas are also in control of what work shall be performed. The aspect of idea development is touched upon in the introduction when Jake tries to figure out the consequences of the idea to construct a new PA-solution (which will be discussed in depth in chapter eight).

In sum then, engineering work is referred to in this study as the *development and use of new technology through technical problem solving* that takes place in a context characterized by *uncertainty, knowledge-intensiveness, deadline focus and idea-intensiveness*. This character makes engineering work particularly interesting in terms of organizational control, an argument to which I shall turn next.

1.3 Complex work – problematic control

In the light of the characterization of the example of engineering, possible implications for organizational control emerge. A problem in the shape of a discrepancy, I argue, arises when we combine the characteristics of engineering work with organization theory's dominant concepts of organizational control.

Suggestions of control methods that are thought to guide operative work are manifold. Some of the most common and influential are *direct supervision* where a manager directly supervises the behavior of the employees (e.g. Taylor, 1911/1998), *technical control* where the technology used (e.g. the assembly line) plays a central role in the control of work (e.g. Edwards, 1979), *bureaucratic control* where standardization and rules are thought to control employees' behavior (e.g. Weber, 1922/1947; Edwards, 1979; Ouchi, 1979; Mintzberg, 1979), *normative* or *clan control* where the employees' norms and beliefs are targeted by managers in order to create a common direction among the work force (e.g. Etzioni, 1961/1975; Ouchi, 1979; Kunda, 1992; Alvesson, 2004), and *professional control* where the institutional conditions surrounding the profession are thought to guide the behavior of the professionals (e.g. Wilensky, 1964; Simpson, 1985; Abbot, 1991; Freidson, 2001).

The major methods of organizational control have mainly (with the exception of professional control) focused upon managers and managerial action. There is a vast literature concentrating on "management control", thus explicitly delimiting itself from control exerted by other organizational members than managers (e.g. Oatley, Berry & Anthony, 1995; Anthony & Govindarajan, 1965/1998). Here control is defined as "the process by which managers influence other

members of the organization to implement the organization's strategies" (Anthony & Govindarajan, 1965/1998: 6). Similarly, most literatures on "leadership" explicitly exclude any control but the one exerted by managers, from Stogdill's (1948) discussion on leadership traits to Senge's (2004) argument that the contemporary leader should take on the role of a teacher and steward rather than supervisor.

But also the broader literature on organizational control generally pays attention only to how organizations can be designed and steered by managers (e.g. Etzioni, 1961/1975; Ouchi 1979, 1980; Mintzberg, 1989). For example, Ouchi asks in his search for an understanding of organizational control: "What are the mechanisms through which as organization can be managed so that it moves towards its objectives? How can the design of these mechanisms be improved, and what are the limits of each basic design?" (1979: 833). It is quite clear in Ouchi's analysis that the designers of the control mechanisms are managers. As a way of designing the "clan-organization" – Ouchi's main contribution to the theory of organizational control – managers are thought to direct socialization and recruitment practices towards the employees, "socializing them to accept the company's goals as their own" (1980: 132).

There are of course authors of organizational control who are less certain than Ouchi about the extent to which managers intentionally and strategically can "design" organizations, and especially about the extent to which they can exert influence upon the employees' values and beliefs. Instead of taking for granted the possibility of intentionally controlling people, these authors can be said to more or less explicitly discuss control in terms of what managers *attempt to do* (e.g. Czarniawska-Joerges, 1992), pointing out that normative management or leadership is a matter of attempting to "frame and define the reality of others" (Smircich & Morgan, 1982: 258), or similarly, to "enact a particular form of organizational experience" (Kärreman & Alvesson, 2004: 152). But despite the skepticism to the possibilities of affecting people's norms, values and beliefs, focus is still placed upon managers as the agents of control attempts: understanding of organizational control is pursued by studying managerial action.

A few words should also be said regarding the somewhat misleading use in the literature of the notion of "self-management". The concept tends to convey the impression that no managerial intervention is needed and therefore control would have its origin in the actions of the employees. But that is not so. Instead, managers have been given a different task: to exercise normative control. For example, Manz & Sims (1980: 366) contend that "when a task is largely creative, analytical, or intellectual in nature, greater self-management would be appropriate". In order for "self-management" to be exercised it must be a norm, something that the employee believes is the right thing to do. Manz & Sims therefore argue that "it is a useful and legitimate role of the supervisor to develop and encourage self-management capabilities" (ibid). Hence, it becomes the task of the manager to convince the employees of the advantages of managing themselves, which makes him/her remain the origin of control also when self-management is wanted, it is just that the method of control has been transformed into a normative kind.

The assumption that managers are the origin of control should be considered in the light of the argument that engineers – much as a result of the complex character of their trade discussed earlier – tend to work quite independently of managerial influences, an observation made in this thesis and by others such as Whalley (1986: 38) who notes that "a distinctive characteristic of [engineers'] jobs is that they are expected to perform them responsibly without supervision" and Crawford (1989: 103) who states that "engineers often develop specialized expertise that supervisors lack [which] makes it difficult for their supervisors to tell them how to do a particular job"[16]. Jake – our engineer in the introductory example – has little contact with managers. He talks to Carl, his object leader, only at the work meeting once a week. When Jake needs advice in technical matters he more often asks a colleague, as when he works in the laboratory and asks a colleague who is a more experienced programmer. To a large extent, Jake must be trusted to do a good job for the organization because managers cannot wholly comprehend the complexity of his work.

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[16] See also Adler (1999) who notes that project managers of complex product development play "an administrative role" and that "the responsibility for technical matters […] is outside their control" (p. 261)

Because of this distance between management and engineering work it has been suggested to characterize engineers as "trusted workers" (Whalley, 1986). In a similar but more general vein, indicating the need for managers to simply trust the employees, Weick (1985: 115) has suggested a tendency towards, "See what you can do and do your best" as a job-description for decision makers in complex organizations. Meiksins & Smith (1993) likewise point out that a consequence of the increased need for highly skilled technical workers is "the dependence of management on a 'class' of qualified technical workers; managers cannot any longer perform this labor themselves or rely on relatively untrained workers to design products and production systems" (p. 125).

This tendency towards a work situation where workers need to be trusted to do a good job calls for an approach to organizational control where more attention is paid to non-managerial activity. Instead of formulating organizational control as a managerial practice, I follow Johnson & Gill (1993: x) and define it broader as "*the processes and methods by which an organization's members determine what things get done and how they are done*". In this light, management control makes up a part, but not the whole, of organizational control. In simplified terms, it is possible to talk about *vertical* control, which is control that has its origin in managerial action and is directed towards their subordinates, and *horizontal* control, which is control that is exerted between people on the same formal hierarchical level. Such separation will be used in this book.

It is in the light of the discussion above that I suggest we ask the question: how is work controlled when it is uncertain how long it will take to perform the tasks, when a high degree of both formal and contextual knowledge is required to perform the tasks and as a result the employees to a large extent must be trusted to do a good job, and when the organization to a large extent depends on the people at the lowest level of the hierarchy to come up with ideas of how to improve the product?

1.4 A strategy for understanding the control of engineering work

Sometimes it is argued that the field of organization studies in general needs to "bring work back in" and not mainly focus on strategy, structure, the environment and performance (Barley & Kunda, 2001). This call for detailed studies of work is particularly relevant for the study of control of complex work such as engineering. The concepts of organizational control that have been briefly mentioned thus far are fruitful in many ways, but they, as I see it, leave a blank space that this study can hopefully contribute to filling. The "blank space" can be divided into two connected parts.

The first part is made up by the fact that traditional and highly influential studies of organizational control such as Edwards (1979), Etzioni (1961/1975) and Ouchi (1979) have only studied the methods (or systems) of control and not their targets. Put differently, they have not studied work but instead focused upon over-arching structures and environmental conditions, which leaves us with little information of how control appears from the perspective of those who are supposed to be controlled: the employees of the organization. The limited number of studies that focus upon work has been stressed in this introduction. It seems to be a general trend in organization studies (Barley & Kunda, 2001), including studies of engineering work. As Barley (2004) argues: "Grappling with the role of engineers and other technical workers in contemporary society will [...] require sociologists of work to examine what technical workers actually do *in situ* (p. 388)".[17]

The second part of the space is created by questioning the assumption among many authors that control has its origin in the actions of managers and that it is possible for managers to intentionally control the employees of the organization. The assumption that organizational control is something that managers impose on employees seems to be a common denominator of traditional and highly influential studies such

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[17] See also Latour & Woolgar (1979) who – in their study of scientists and the way they construct scientific facts – advocate and employ an "in situ"-approach for understanding the contents of work.

as Etzioni (1961/1975), Edwards (1979)[18], and Ouchi (1979; 1980). It is argued that *managers* should align the mode of control with the "compliance structure" of the organization in order to make control more effective (Etzioni, 1961/1975), that *capitalists* develop different methods of control in order to gain maximum labor out of the labor power they buy from workers (Edwards, 1979) and that *managers* should design organizations in order to maximize the effectiveness of the control mechanisms (Ouchi, 1979). More recent studies of control have argued that *managers* attempt to define the reality of the employees (Smircich & Morgan, 1982; Kärreman & Alvesson, 2004), for example by regulating their identities (Alvesson & Willmott, 2002) or by influencing the culture of the organization (Kunda, 1992).

These, and I wish to emphasize this, are all interesting and insightful arguments that have contributed much to our understanding of organizational control. But in addition to being insightful they have in common a strategy of inquiry where focus is placed upon the owners or the managers/foremen of the organization, and where organizational control is assumed to have its origin in their actions. The character of complex work, as it has been outlined above through the example of engineering, suggests that such focus on managerial work[19] has a hampering effect upon the interpretative possibilities regarding the control of work. It is my contention that our understanding of how complex work is controlled would gain from widening the strategy of

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[18] In Edwards' (1979) analysis, it is the capitalists who are the actual architects behind the control systems, and managers are seen as instruments in their hands, i.e. as the executors but not designers of control.

[19] For the sake of clarity I would like to point out that the authors mentioned above do not necessarily take a "management perspective" in the sense that they set out to aid managers in their pursuit to control employees. They differ quite strongly in this regard. Etzioni and Ouchi are interested in how the organizational effectiveness can be increased, whereas Edwards, Kunda and Alvesson & Willmott take a perspective where focus is placed more upon description and the consequences of managerial action. Further, Kunda and Alvesson & Willmott focus on control *attempts* rather than assuming that control has intended effects. Thus, I do not wish to bundle them together into one category of studies. What I wish to point out, however, is that they all focus on managerial action – be it in the shape of control attempts with ambiguous effects or "real" control with intended effects – in their attempts to make sense of organizational control.

inquiry towards a stronger focus on operative, everyday and non-managerial work.

To sum up my strategy for understanding the operative control of engineering work, I shall do two things: 1) bring work into the study of organizational control, 2) leave the focus on managers as the apparent origin of control and, as a result, make place for horizontal forms of control.

The aim and argument of the study

In the light of the above said – by bringing in everyday engineering work, leaving the managerial focus and making space for horizontal forms of control – I shall in this study problematize the idea that managers are the origin of organizational control and open up, develop and argue for an alternative understanding of how complex work is controlled. Specifically, I shall argue for an understanding of control as exerted horizontally.

Recalling the characterization of engineering work, there are thus two main arguments running through this book, let us call them the aspect-argument (1) and the control-argument (2):

- Uncertainty, knowledge intensiveness, deadline focus and idea intensiveness are central aspects of engineering work.
- These aspects in turn have consequences for the way work is controlled, and it is argued here that operative engineering work can be understood as controlled mainly by horizontal control.

As an exit from this chapter and an intro to the next, where organizational control will be discussed more in depth, I offer a very short version of the book.

Disposition

The next chapter deals more in detail with the concept of organizational control. Methods of managerial (vertical) control that have been put forth as central for controlling complex work will be

discussed, as will some popular concepts of horizontal forms of control. Last, I will briefly outline suggestions of how engineering work is controlled.

The third chapter is a methods chapter where I give the reader an insight into how this study was conducted and how it developed into a study of operative control. I also discuss the reason why I have chosen an interpretative, ethnographically inspired approach.

In chapter four, an introduction to the general context within which the engineers at GT work is offered. Attention is paid to themes such as industrial demands on the product as well as the socialization of the engineers. I also present a managerial perspective of how work at GT is controlled.

Chapters five to eight make up my study of engineering *work*. They also contain the aspects: uncertainty, knowledge intensiveness, deadline focus and idea intensiveness. Although there are overlaps (particularly the central position of knowledge turns up in all chapters), each chapter emphasizes a particular aspect.

Chapter five problematizes the use of vertical controls by presenting control attempts at a work meeting and through the use of an error reporting system. The chapter stresses the aspects of *uncertainty* and *knowledge* in an attempt to illustrate how the uncertain and knowledge intensive character of engineering work makes it problematic to control by rational managerial methods.

Chapter six focuses mainly on *knowledge* and to some extent on *ideas* as central aspects of engineering work. The episode presented is based on one week's shadowing of an engineer. It is suggested that engineering work can be seen as guided by two types of control: self-control and horizontal control. Knowledge, both contextual and formal, is put forth as a prerequisite of carrying out as well as controlling engineering work.

Chapter seven focuses on the aspect of *deadline focus*, but also, and again, on *knowledge*. The episode of engineering work presented is based on a work meeting as in chapter five, but in a different group of engineers. One point with the chapter – based on a comparison

between two work meetings – is to nuance the picture of the absence of management control and point out possibilities for a manager to exert control over the engineers. Another point of the chapter is to show the reciprocal control relationship between the engineers and their deadlines: the deadlines seem to control the engineers, but the engineers also seem to control the deadlines.

Chapter eight focuses on the aspect of *ideas*, how they evolve and how they are managed before they become a part of a time plan. It is argued that the ideas play an important role in the work of the engineers as the ideas control what they can and will do. The chapter is an attempt to illustrate how an idea is managed in a largely horizontal process, and argue that the ideas that make up the foundation upon which the time plans stand to a significant extent are a product of the engineers' own work.

In chapter nine, the final chapter, I develop an understanding of the horizontal control as a process of *peer reviewing* in order to gain an alternative and in my view better understanding of how engineering work is controlled. I also relate the notion of peer reviewing to the suggested control methods of complex work outlined in chapter two.

Chapter two

On the control of complex work

In the introductory chapter I argued that the complexity of work makes organizational control problematic, especially in its dominating form where managers are seen as the major source of control. In this chapter I shall review a number of control methods that are to be seen as well established in the literature on organizational control. What the methods have in common is that they are argued to be used when work is too complex for managers to understand its details, when work is complex enough for direct supervision or heavily rule laden control methods to become ineffective or even impossible. I shall also outline forms of control that have been put forth as particularly relevant when it comes to engineering work. In line with the emphasis in this thesis, the review – except for the outline of the engineering studies – is organized based on a separation between vertical and horizontal controls.[20]

A note regarding the separation between horizontal and vertical controls

The separation I make between horizontal and vertical controls is based on the extent to which the methods emphasize the horizontal dimension of control. Such separation is not self-evident, of course. For example, teamwork is thought of as horizontal because of its emphasis on cooperation, empowerment and on the non-hierarchical distribution of the positions within the team. On the other hand, most scholars of teamwork view it as a management tool, which stresses the vertical dimension. From a managerial perspective, all methods of control become vertical methods: mutual adjustment and teamwork as well as norms and values are thought of as created and controlled by managers.

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[20] For a broader review of the organizational control literature, see e.g. Johnson & Gill (1993); Gabriel (1999) or Mir, Mir & Upadhyaya (2003).

I do not take a managerial perspective, however. That enables an *analytical* separation and the argument that, as we shall see below, the horizontal dimension is less salient in management by objectives, standardization of skills and normative control than in mutual adjustment, teamwork and professional control.

2.1 Vertical methods

The following methods of controlling complex work are "vertical", i.e. they emphasize managers as the origin of organizational control.

Management by Objectives (Output control)

When it is difficult to control the behavior of employees through direct supervision or detailed instructions for how to perform various tasks, it is often argued that the focus of control should be directed towards the output of work rather than towards the behavior of the workers (Ouchi & Maguire, 1975; Eisenhardt, 1985). Under output control, goals are put up and tasks are defined, and when the tasks have been executed the output is measured. Output can be controlled quantitatively as in piecework, basing wages on the amount of work performed (e.g. picking strawberries or distributing advertising brochures to households), or as in the use of budgets. A problem with an exclusive focus on quantity is that the control of quality is neglected. When products are complex, output control is more of a qualitative kind since the product needs to fulfill certain qualitative requirements. Quality needs to be controlled on a more continuous basis by putting up intermediate goals. In such cases, a version of output control becomes more relevant: so called "Management by Objecitves" (MBO).

The common denominator among the descriptions of MBO, as Rombach (1991) who has reviewed the MBO-literature puts it, is that

> clear goals shall be formulated by the management of the organization, that staff on different hierarchical levels shall be engaged in the formulation and breaking down of goals, that it is up to the people responsible for a certain activity to choose the means for achieving the

defined goals and that the goals shall be followed up, which means measurement of quantity (p. 19-20)[21].

Formulating, breaking down and following up goals are thus the key activities of MBO. Peter Drucker (1954) – by many seen as the "father" of MBO (Greenwood, 1981) – emphasizes how company goals should be broken down onto lower levels and how "the objectives of every manager should spell out his contribution to the attainment of company goals" (p. 157). As I read him, he views the organization as a system of goals that hang together and each goal is seen as a derivative of the common goal of the organization. This view has been very influential, so influential that it almost feels like a cliché when we say that "an organization is a number of people who work towards a common goal". Cliché or not, the people of an organization *do* in some sense contribute to a common objective – otherwise the work at Volvo would not result in Volvo-cars and the work at a hospital would not result in treatment of patients.

A central task for scholars of organizational control, as I see it, is to suggest explanations of how it can be that work results in concertive efforts such as for example Volvo-cars. Although the existence and management of objectives may point out the direction of work and explain why we don't do just whatever comes to our minds, and although it is descriptive of managers' activities, it does not tell us much about how work processes are controlled on an operative level. How is work guided towards the goal? The very goal in and of itself cannot make a person attain it if s/he does not know how to go about, can it? Drucker (1954) offers some explanation by stressing the close connection between MBO and *self-control*. Hence, in addition to suggesting that company goals be formulated and then broken down onto lower levels so that every level has a "relevant" and "clear, simple and rational" goal (p. 162), he suggests that goals be attained through the exercise of self-control:

> ... every manager should be held strictly accountable for the results of his performance. But what he does to reach these results he – and only he – should control (p. 164).

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[21] My translation from Swedish.

And:

> What the business enterprise needs is a principle of management that will give full scope to individual strength and responsibility, and at the same time give common direction of vision and effort, establish team work and harmonize the goals of the individual with the common weal. The only principle that can do this is management by objectives and self-control. (p. 167)

MBO thus builds on the idea that goals be formulated, broken down and followed up by managers, an activity that is thought to implant the goals in the employees so that they themselves figure out how to attain those goals (see also Covaleski et al, 1998). Thus, the employees are expected to control themselves in their quest of attaining the goals.

MBO is a management philosophy that builds on a view of the organization as a system with a general goal. It is a modernist theory in so far as the system is seen as something that can be identified and managed. Management of the system is performed by formulating a general objective for the whole system and then breaking down the system into smaller components, which in their turn are given a goal that contributes in its own way to the general goal. By bringing in the notion of self-control the theory sort of acknowledges the difficulty of managing work; the "how" of work is left to the employees themselves to figure out.

The fairly simple philosophy of MBO with its focus on goals shares many features with normative and control-oriented versions[22] of "project management" (cf. Larson, 2003). In the project management literature, projects are often defined as having a clear beginning and a clear end (Kerzner, 1992). As a result of this "temporary" nature of projects (Packendorff, 1993; Söderlund, 2000), *goals* or *objectives* are often put forth as central to project management activities. For example:

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[22] The project management literature can be divided into a normative and control-oriented and a descriptive and sense making-oriented branch (Thomas, 2000). Since this study focuses on engineering work and control and does not attempt to describe and make sense of the project per se, it is mainly the normative and control-oriented branch that is relevant and, accordingly, will be described here.

A project can be considered to be any series of activities and tasks that have a specific *objective* to be completed within certain specifications. [...] Project management, on the other hand, involves project planning and project monitoring. [...] Successful project management can then be defined as having achieved the project *objectives* (Kerzner, 1992: 2-3, my italics)

Very few theories of project evaluation exist. Evaluation is typically operationalized as degree of goal fulfillment (Thomas, 2000: 31)

Goals shall, as in MBO, be clear, specific, measurable, realistic, attainable and common to the project members (Kerzner, 1992: 410; Blomberg, 2003: 39) and they are often related to time, quality and cost (e.g. Kerzner, 1992; Maylor, 2003).

An activity linked to the formulation of goals is *planning*. The dominant approach to project management focuses much on planning (Adler, 1999)[23], which is often referred to as a matter of dealing with goals. As for example Kerzner (1992) puts it:

The most important responsibilities of a project manager are planning, integrating and executing plans. [...] Planning, in general, can best be described as the function of selecting the enterprise objectives and establishing the policies, procedures, and programs necessary for achieving them. (p. 584).

It is not only the importance of *having* (clear) goals that is a central feature in both the project management and MBO-literature. This also goes for the idea of *breaking down* goals onto operative levels – e.g. Thomas (2000) who writes that "project management entails planning work in small measurable tasks and tracking effort against outcomes" (p. 29) – and the idea of *following up* the goals – e.g. Kerzner (1992) above who talks about "project monitoring".

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[23] Also see Adler (1999) for a managerialist outline and critique of the idea that planning is the most efficient way of managing complex product development. Adler contends that instead of focusing so much on planning, efficient project management is accomplished by focusing on what he calls "integration-driven development" (managers focusing on integration rather than direction of sub-units) and "dynamic synchronization" (managers focusing on communicating the "wholeness" of the project).

Some readers may find my way of summarizing project management as some modern version of MBO a bit unfair and for example argue that there have been planning techniques developed that should be brought up. There are planning techniques such as the "Gantt-chart" or the "Critical Path Method" that prescribe how to go about when planning[24]. I think such techniques fit under the umbrella of MBO because the activities of formulating goals and breaking down goals (which are MBO-activities) onto lower levels are largely a matter of planning (which is a project management activity). Further, planning techniques shall be seen as *tools* used in the follow-up practice (which is an MBO-activity). I agree with Larson (2003) who argues that "management by objectives is [...] the key-term in the traditional project management literature"[25], and for my purposes – which are descriptive and interpretive rather than prescriptive and normative – MBO functions as a management philosophy that also catches the gist of project management.

There are three comments that I wish to make regarding the idea of MBO. First, the notion of self-control is dealt with in too vague a manner to be accepted as an explanation of how goals are attained. It is introduced as a black box rather than as an explanation of how work is controlled. We cannot just expect people to work towards organizational goals because there is a goal put up in front of them. Self-control may be a *prerequisite* for MBO to function, but it does not help us understand how work is controlled on its way towards the goal. The question of how goals are attained is thus lingering. Second, the bias is strong towards managers as the agents of control in their capacity as "managers of objectives". Drucker consistently takes a management perspective, discussing only managers as the developers of objectives and taking for granted that employees follow these goals, presumably

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[24] The Gantt-chart is a way of visualizing what should be done and when it should be finished. The Critical Path Method (CPM) is a way of producing a network that illustrates the shortest and longest estimated time of different project activities and how these activities are connected. Some activities are executed in parallel and the one that takes the longest time belongs to the "Critical Path", and the activities not belonging to the Critical Path thus have "slack". CPM is basically about finding the "bottleneck" of a process and using that as a point of departure in the planning. (see for example Kerzner, 1992, or Maylor, 2003)

[25] My translation from Swedish.

under self-control. This management perspective is also expressed by Odiorne (1965), another advocate of MBO who defines it as

> a process whereby the superior and subordinate managers of an organization jointly identify its common goals, define each individual's major areas of responsibility in terms of the results expected of him, and use these measures as guides for operating the unit and assessing the contribution of each of its members (p. 55-56).

Third, MBO makes the somewhat optimistic assumption that the constituencies of an organization can be identified and given goals that actually hang together and make up a controllable whole. The view builds on the metaphor of the organization as a machine or possibly an organism (Morgan, 1986), a view that is especially problematic when applied to complex work.

Standardization of skills

Another vertical method that is suggested for controlling complex work is to standardize the skills of the workers (Mintzberg, 1979; 1989). The method is often associated with the control of professionals and contains explicit bureaucratic elements because of its focus on standardization and rules.

The standardization of complex work takes place mainly through higher education. A typical example is physicians. They have all learned at the medical school the standard way of diagnosing and treating otitis, appendicitis, pneumonia or other common diseases. In a similar manner, engineers learn standard methods of solving technical problems. Berner (1981: 85 ff.) points out that the work of engineers builds mainly upon two methods: systematic variation of parameters and the use of scale models. Systematic variation of parameters means keeping one variable constant and changing others in order to find the optimal solution, and the use of scale models means using modifiable models of the actual product, which enables the engineer to test – by trial and error and/or systematic variation of parameters – what happens when various changes are made.

Standardization of skills controls work on a very general and abstract level. Complex work tends to be of a problem solving character,

something that is particularly apparent when it comes to engineering (Berner, 1981)[26]. Engineers struggle to find solutions to technical problems and their education has only given them knowledge to use certain methods for problem solving, not ready-made cures. They are engaged in activities such as "sophisticated" trial and error, which builds upon experience but still involves much uncertainty, as pointed out by an engineer at GT:

> ... much [of the work] builds upon experience and knowledge. It's hard to explain without getting into too much detail, but for example: if you're building something on a circuit, then it might disturb something else. This is impossible to predict so you have to see [what happens] when you get the circuit back [after it has been manufactured]. And then when you get the circuit, then it either works or it doesn't work and then you sort of have to find out what was wrong and do it again.

Usually, the engineer has a hunch about what will happen – which is where "experience" comes into the picture, as pointed out by the engineer's statement above – but s/he does not *know*. This is because the solution of the problem is *new*. It is because they cannot teach at technical universities in detail how to develop a product, only the theory and methods necessary to perform the qualified use of trial and error, systematic variation of parameters, scale models, computer simulations and other methods. But the solution of a problem can seldom be found in a book.

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[26] It is appropriate to note that "complex work" is a broad term and all types of work in the category are not focused on "problem solving" in the same way. Product development work, such as the engineering at GT, is for example likely to be more focused on finding solutions to readymade problems, whereas the work of physicians is more focused on identifying the problem to which a readymade cure is applied. The cure is normally standardized. For example, when a physician knows that the patient suffers from tonsillitis s/he also knows that antibiotics will (probably) cure it, and when s/he knows that a patient suffers from mononucleosis (which may show symptoms similar to those of tonsillitis) she knows that medication will do no good and can therefore tell the patient to rest until the illness yields. The work of product development engineers is a bit different. There, the problem is known, and instead of trial and error to find the problem, they are engaged in trial and error and systematic variation of parameters to find a solution. Both activities, however, are characterized by problem solving.

It is apparent that there is an element of standardization of skills in the complex work of for example engineers, physicians or lawyers. But skills are not standardized to the extent that it is learned at school how to work in a product development project or in a hospital. There is no standard for that sort of activity. The standardization of skills is thus partly relevant but insufficient for explaining the way operative work is controlled. Perhaps this is especially valid when it comes to engineering work. First because of the fact that that much work is done for the first time, something that makes the idea of standardization a little misplaced: the solving of new problems can hardly be standardized. And second, the idea of standardized skills does not tell us much about how work is controlled on an everyday level – be it medical work or engineering work. The idea that a system of standards would actually provide us with satisfactory knowledge about how control operates in everyday work appears to me, quoting Freidson (1975: 11), as "rather bizarre".

Normative control

A third plausible method that is put forth as relevant for controlling complex work is *normative control* (Etzioni, 1961/1975; Kunda, 1992). It is often put forth as the main method of control in organizations where bureaucratic methods fall short of guiding behavior (e.g. Ouchi, 1979), or when "[h]ierarchical and technical means cannot prescribe behaviour in detail due to the complexity and organic nature of the work tasks" (Alvesson, 2000: 1102). Normative control is directed not towards the behavior of the employees (as is the case with for example bureaucratic methods), but towards their thoughts, beliefs, norms, interpretations and emotions (Barley & Kunda, 1992; Alvesson & Kärreman, 2004). Or as stated by Czarniawska-Joerges (1988: 10), the control "targets the organizational members' perception of reality".

Influential control theorists such as Etzioni (1961/1975) and Ouchi (1979; 1980) put forth *socialization* and *recruitment strategies* as the main methods of normative control[27]. In more recent studies there have been attempts to discuss and suggest other (although related) methods

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[27] For accounts of socialization into a complex work environment, see e.g. Anderson-Gough et al. (2000) or Eriksson (2000).

by which normative consensus is (or is to be) brought about. Control over the employees' identification[28] is one such normative method that has gained much attention (e.g. Ashforth & Mael, 1989; Pratt, 2000). It is seen as increasingly important to manage the "organizational identity" in order to create "an internalized cognitive structure of what the organization stands for and where it intends to go" because "the environment becomes ever more dynamic and complex" and "[a] sense of identity serves as a rudder for navigating difficult waters" (Albert, Ashforth & Dutton, 2000: 13). The idea is thus to align the identity of the employees with the identity of the organization by directing control towards the employees' sense of self.

Alvesson & Willmott (2002) label this idea *identity regulation*, and they suggest various ways in which this may be attempted by managers. One way is by constructing knowledge and skills, for example constructing technical knowledge as a prerequisite for being able to manage an organization that produces technical products. This knowledge is then thought to work as an important element in the identity work of the individual, i.e. in his/her work with creating a sense of self. Another way suggested is by providing organization members with a specific vocabulary of motives; for example implying what the preferred values of the members should be – e.g. teamplayership, commitment, empowerment or customer orientation – which in turn is thought to influence their identity work in a for the company desirable manner. Similarly, putting forth the significance of "the client" may be used for

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[28] Identification, defined as "the perception of oneness with or belongingness to some human aggregate" (Ashforth & Mael, 1989: 21), is thought of as the process of creating a "social identity". Social identity is a part of the self (the other part of the self is said to be personal identity, which refers to features that are unique to every individual such as bodily constitution, abilities etc.) and it is constructed through identification with a group. Henri Tajfel, who was one of the first to use the notion of social identity, says that it is "that part of the individuals' self-concept which derives from their knowledge of their membership of a social group (or groups) together with the value and emotional significance attached to that membership" (Tajfel, 1982: 2). For the process of identification to occur there must, reasonably, exist a group in the mind of the individual that is subject to identification. Social identity theory thus assumes that people tend to classify themselves and others into social categories (Ashforth & Mael, 1989). These categories then work as objects of identification in the process of creating a self, an idea of who one is.

identity regulating purposes, constructing customer needs as a guideline for behavior, making certain behavior legitimate and other behavior illegitimate For example, Anderson-Gough et al. (2000) have shown how it, "in the name of the client", is constructed as a part of the professional identity of accountants to work late hours and to downplay the importance of family and friends.

Vertical normative control may indeed have impact on the operative work of engineers. But there is reason to be somewhat skeptical not of the argument that managers engage in normative control *attempts*, but of the argument that those attempts would actually have controlling effects. Can we assume that the actions of managers, what they do and what they say, have effects on the employees that they are aimed at? For example, how do we know that a managerially initiated culture change attempt actually changes the culture? Kunda's (1992) insightful study of normative control at "Tech", an engineering company, is highly relevant for this question. Although saying little explicitly about the effects of the normative control attempts, Kunda's book, as I read it, does leave the reader with the impression that managerially initiated normative control is the dominating method of control at Tech. There is no direct discrepancy between my study and Kunda's regarding the prevalence of managerially initiated normative control attempts; managers at both GT and Tech are engaged in the exercise of normative control (although the attempts appear to be more common and widespread at Tech). There is an important difference, however, in terms of focus: Kunda focused upon *managerial work* in terms of normative control, whereas this study focuses on everyday *operative work*. Kunda is convincing in his account of normative control attempts, but there is little testimony of how this method of control has effects on that which is Tech's main activity: production of hi-tech products.

In this thesis, it is argued that there is reason to nuance the idea that the dominant method of control in complex organizations is vertical normative control. This does not mean that complex workers are not exposed to such attempts, nor does it mean that such attempts lack controlling effects. What I argue, instead, is that the dominant form of organizational control cannot be derived from the observation that managers are engaged in normative control activities, and neither from

the observation that work is too complex to be guided by direct supervision or bureaucratic rules. There is no reason to jettison the idea that control of complex work takes the shape of norms and values inculcated on the employees' minds by management. But since the target of control is the work of the employees of the organization there is reason to focus upon this very work, and not only on managerial work, in the study of organizational control.

To sum up this section of vertical control methods, MBO, the standardization of skills and normative control may indeed have controlling effects on complex work such as engineering, but they are all general concepts that do not in and of themselves explain how control operates in everyday work. Their value for explaining how operative complex work is controlled remains a lingering empirical question.

2.2 A note regarding the scope of control

As a reflection upon the outline of vertical controls above and an intro to the horizontal controls that will be discussed below, I shall briefly address the question of how far control reaches. Are we always controlled in some way or is there space for autonomous action? When it comes to control in a wider sense – control as that which influences us to do A and not B – I find it hard to imagine completely uncontrolled areas. Some form of control is necessary for purposeful action to take place: for example, individuals do not automatically come together and work in line with organizational interests, i.e. create maximum value for the organization as a whole, without guidance (e.g. Braverman, 1974; Thompson, 1989; Galbraith & Lawler, 1993 Ezzamel & Willmott, 1998). As Czarniawska-Joerges (1988) contends: "Without control, organization is invaded by chaos and deadly entropy. Without control, individuals are exposed to too much pressure from existential anxiety" (p. 2). On the other hand, I would argue – again with Czarniawska-Joerges (1988) – that there is no such thing as total control, i.e. a situation where there is no space whatsoever for autonomous action. Thus, control and autonomy always coexist, but there will be more or less of the one or the other.

This implies that there are places in companies where organizational controls have little influence. For example, people may be influenced by a phone call from their mother, or by a documentary on TV revealing how the top-managers of their corporation have doubled their own salaries despite the fact that the business is going bad and the employees have had to do without pay raises. In such cases, organizational control is not the most fruitful conceptualization of that which influences the actions of an individual. In the same vein, vertical control – i.e. control exerted by formally appointed managers – does not reach out to all areas of the organization; there is likely to exist "non-managed areas" (Gabriel, 1999). Particularly questionable is the argument that vertical control reaches out to complex or knowledge intensive areas, which is the assumption behind "knowledge management". Knowledge management has been portrayed as a somewhat paradoxical concept (Alvesson & Kärreman, 2001) because of the tacit dimension often ascribed to knowledge: is it possible to control the tacit, the implicit, the unspeakable? Knowledge management builds on the assumption that the means by which (tacit) knowledge is acquired can be made explicit, an assumption that has been questioned in itself and instead critically put forth as a means for "managers to come to believe that they can exercise control over what were previously considered to be matters of subjective personal experience" (Sewell, 2005). In short, some areas are unlikely to be controlled by managers, they may be influenced by phone calls from mothers or documentaries on TV, but more relevant for this ethnography of complex work, these areas may be influenced by horizontal controls.

2.3 Horizontal controls

As a result of the strong focus on management control, or vertical control, as *the* form of control taking place in organizations, little direct attention has been paid to horizontal forms of control. When horizontal forms are brought to the surface they – rather than being discussed in terms of content and character[29] – tend to either be *assumed*

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[29] The literature on "resistance" (e.g. Burawoy, 1979; Kondo, 1990; Jermier, Knights & Nord, 1994) in a sense deals with horizontal control. But the metaphor of resistance creates an explanation of employee behavior as a *reaction* to the initial force of management control attempts (see Sörgärde (2006) for a

to exist or to be *necessary* in our times of swift change and high demands on flexibility. An example of the former is the idea of management by objectives, which assumes some sort of control to take place among the employees in their quest for attaining the managerially formulated goals. An example of the latter is the emphasis on the necessity of self-management, worker involvement and empowerment as a result of the increasing complexity at the workplace (see e.g. Galbraith & Lawler, 1993). As Stohl & Cheney (2001: 350) put it: "Worker participation, in many forms, has moved from the periphery to the center of corporate philosophies and organizational restructurings". A short version of these statements goes: it is argued that workers need to control themselves and each other to a larger extent when the complexity of work increases. Hence, horizontal controls are indeed seen as important for controlling complex work, but the conceptual development for describing how this works is less established than its vertical counterpart.

In the following, I shall present three methods that are put forth as relevant for controlling complex work. They are "horizontal" in the sense that the horizontal dimension of control is more salient than in the methods previously presented.

Horizontal control in teamwork

The perhaps most widespread concept that can be said to assume some form of horizontal control is *teamwork*, whose gist, as Thompson & McHugh (2002) put it, is that "team members can be persuaded to think like managers by delegating responsibilities that were once the preserve of management" (p. 325). Or as put by Galbraith & Lawler, 1993):

> The development of self-managing work teams and employee involvement turns an organization away from formal bureaucratic control. More control activities are performed by team members themselves. (p. 9)

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discussion), and not as something that may emerge beyond its reach. Thus, the impression remains that managers are the origin of control. This makes the concept of resistance misleading if one wants to pursue a purpose such as mine.

Teamwork has become a very popular concept that is thought to be useful in many types of work; from so called self-managing work teams in traditional manufacturing industry (e.g. Wall et al, 1986; Berggren, 1989) to software development teams (e.g. Cusumano, 1997). It is hence not a form of control that is dedicated exclusively to complex work. Rather, it is thought to be applicable to this type of work *in addition* to a large number of other types (although the need for horizontal cooperation and communication, which is strongly associated with teamwork, is often said to increase with the complexity of work (e.g. Cohen, 1993; Galbraith & Lawler, 1993)).

Despite its clear horizontal dimension, teamwork tends to be turned into a managerial form of control and studied as such. Scholars of teamwork are mainly interested in how teams can be made more effective[30] and discuss managerial issues such as: why is there resistance to teamwork and how can it be managed (Kirkman & Shapiro, 1997)?; how can we increase team effectiveness by taking process and the fact that different teams use different processes into account (Marks, Mathieu & Zaccaro, 2001)?; or what type of team is appropriate under what circumstances (Lind & Skärvad, 2004)? Hence, in favor of a managerial approach, there is little attention paid to the horizontal dimension and to the ways in which control operates within the team.

The attempts to conceptualize the control that operates in teams have generally been made by critical researchers stressing relationships of domination, such as Ezzamel & Willmott (1998) or Sewell (1998). The latter stresses how "horizontal surveillance" is performed among equals in the team where "[t]hose who stand out from the crowd […] will

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[30] Cohen & Bailey (1997) did a review over the research on teams and groups in organization settings published from January 1990 to April 1996, and the conclusions they draw concerning what we have learned about team during this period of time only refer to team effectiveness (which is clearly indicated by the heading of their conclusions-part: "What have we learned about team effectiveness?" (p. 281)). What we have learned is that "the type of team matters for the determinants of effectiveness", that "group cohesiveness is positively related to performance", that "autonomy is associated with higher performance for work teams" (but not for all types of teams), that "the factors associated with success vary based on who is rating the team's performance" etc. (p. 281). For additional examples of studies that focus on team effectiveness see for example Bolman & Deal (1992) or Katzenbach & Smith (1993).

receive the scrutiny of their peers and then be subjected to sanction or reward and any other forces of normalization determined by the team" (p. 411). The perhaps most fruitful attempt to conceptualize control in teams has been made by Barker (1993; 1999). He did an ethnographic study of the introduction of teamwork in a manufacturing firm and observed how employees in the teams developed norms for controlling their own behavior. In order to create an understanding of how this form of horizontal control operates he developed the concept of *concertive control*. Concertive control tones down the role of management and shows instead how the employees are highly active in the production of control in the shape of rules of behavior. Control is seen as the result of the group members' own negotiation about what constitutes good work; the members of the group "act in *concert* with each other to create a mechanism for controlling their own behavior" (Barker, 1999: 35). Concertive control is to be seen as belonging to the normative methods of control as it is the norms and beliefs regarding what is right and wrong or good and bad work that make up the target. Thus, it is a normative but horizontal method of control.

The extent to which the studies of horizontal control in teams are relevant to this study is somewhat ambiguous. They, and Barker in particular, aim to describe what I want to describe: how horizontal control operates. The organizational context is quite different however. Ezzamel & Willmott, Sewell, and Barker alike studied the manufacturing industry: manufacturing of garments (Ezzamel & Willmott) and assembly of electronics equipment (Sewell, and Barker). The context is thus not "complex work" as defined in this thesis. I still want to point out these studies for the reason that they discuss methods of control that origin not among managers but among the employees, which nuances my critique that the teamwork literature assumes but does not discuss horizontal forms of control.

In sum, the idea of teamwork per se does not tell us much about how horizontal control operates but rather assumes that horizontal control of some form takes place. However, there are scholars who have studied the introduction of teamwork and attempted to make sense of this horizontal control. Particularly relevant for my purposes – albeit developed based on a study of manufacturing work and not complex work such as the work at GT – is the concept of concertive control.

Mutual adjustment

Another concept that touches upon the notion of horizontal control is *mutual adjustment* (Thompson, 1967; Mintzberg 1979; 1989). The idea of mutual adjustment is that reciprocally interdependent employees – rather than being controlled by a manager – take one another's work into consideration and adjust to each other through informal communication. The need for mutual adjustment is thought to increase as work and the situation in which work takes place get more complex and variable (Thompson, 1967). In my view, teamwork and mutual adjustment are closely related. Most team researchers would probably agree that a team where the members do not mutually adjust to each other is simply no team, or perhaps a very "bad" one.

In this light, mutual adjustment is a concept that explains how "unmanageable" work is controlled. But the explanatory value of mutual adjustment is rather limited. What is being said is that mutual adjustment is *necessary* when work cannot be controlled by other means. That is a good point that helps us understand that it is important in terms of organizational effectiveness that people under complex work conditions take each other's work into consideration (and work "as a team"), but it does not help us understand how and why it works. The vocabulary and the "metaphorical power" of mutual adjustment are rather poor. "Mutual adjustment" is too close to the phenomenon that it tries to say something about, and therefore gives rise to few additional associations than the literal one: that we have to adjust to each other.

Professional control

A central feature of professional control – i.e. the control that is thought to guide professional work – is that it is exercised by peers rather than by managers (Løwendahl, 1997; Alvesson, 2004). As Freidson (1975) notes, "the professional model of control" stresses that "instead of being controlled and directed by superiors who are not trained to perform the basic productive work, it [work] is directed and controlled by the workers themselves" (Freidson, 1975: 9; see also

Mintzberg, 1979)[31]. The conceptualization of this professional self-control is primarily made on an institutional (rather than interpersonal) level[32], emphasizing as methods of control the development of "professional associations" (Abbot, 1991), which give rise to "professional norms" (Wilensky, 1964), "restrictive licensing, formal training and educational requirements" (Freidson, 1975). It is thus mainly through indirect forms of control, or "institutional circumstances" (Freidson, 2001: 12), that professionals are thought to control themselves, not through forms that require direct interaction between individuals.

But professional self-control must not necessarily be discussed on an institutional level. A way of opening up for a discussion of professional control beyond that which is produced by institutional circumstances is to separate between indirect (institutional) and direct methods of professional controls. Freidson (1975) argues that the distinction between indirect and direct forms of control is that the former "consist in administrative structures that constitute a framework of limiting constraints and rewards around the possibilities for behavior" and the latter "involve the mutual influences of human beings in everyday settings" (p. 7)[33]. There is no need to restrict professional controls to

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[31] This is an ideal type of professional control. In practice, it has been shown that other characteristics are associated with professionalism. For example, professionalism may be created based on the degree to which one puts the client first, which constructs the client and not the profession the dominant source of control (Anderson-Gough et al., 2000).

[32] On this level, the "standardization of skills" can be seen as a type of professional control. I have chosen to separate them for two reasons. First, although often associated as the coordinating mechanism of the "professional bureaucracy", it is not *necessarily* professional skills that are to be standardized, it is more general. As Mintzberg (1979: 6) notes: "Skills (and knowledge) are standardized when the kind of training required to perform the work is specified". He exemplifies with both potters and physicians. The method thus expands outside the borders of professional control. Second, standardization of skills is put forth as a vertical method of control; the skills are thought to be standardized by someone who does not appear to be a peer. For example, Mintzberg gives the example of how kings were to control the activities of their governors in distant colonies.

[33] This distinction is not unique of course. For example, Briand & Bellemare (2006) draw upon Giddens' theory of structuration and separate between systemic and social integration practices. The former create integration (or

the institutional level; also professionals must be exposed to control directly in their operative work. For example, professional norms may be used in direct, everyday horizontal interaction in order to determine what to do and how to do it. On such direct level, as we shall see in the final chapter of this book, professional control is a category that can be used for making sense of the horizontal control of complex work.

2.4 Organizational control in earlier studies of engineering work

After this outline of three vertical and three horizontal methods that are argued to be used for controlling complex work, I shall finish the chapter by a brief outline of what studies focusing particularly on engineering have put forth in terms of control.

Organizational control in studies of engineering work is generally put forth as a vertical problem, rooted in a conflict between the goals and ends of technology and those of bureaucracy and capital. In the light of such a conflict, the task of management/vertical control becomes to make the engineers consent to: 1) "managerial authority rooted in bureaucratic position rather than technical expertise", and 2) "the subordination of technical goals per se to capital's goal of profit maximization" (Whalley, 1986b: 223; 1986). This may be seen as the problem of control in all kinds of work, but it is accentuated in complex work such as engineering, where the firm to a larger extent than in other types of work is dependent on the knowledge (and not labor) of its employees, a dependence that complicates the aim of management to be in control of the production process.

As indicated in the introduction, it is often stressed that engineering work is difficult to control by authoritarian means and direct supervision (e.g. Whalley, 1986; Smith, 1987; Crawford, 1989; Barley, 1996; Zabusky, 1997). The assumption that work can be controlled through a vertical division of labor where managers possess expertise is questioned because the work of engineers "decouple[s] the authority of

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control) via some form of instrument (e.g. a budget, or a rule) whereas the latter require a physical meeting between individuals.

position from the authority of expertise" (Barley, 1996: 434). Thus, higher position does not mean higher level of expertise or knowledge, and as a consequence, a superior position may no longer work as a legitimate base for the exertion of management control. Under such circumstances the controllers of work are said to turn to other, less direct methods. For example, Whalley (1986) who studied ethnographically the engineers at two British companies, one high-tech company and one traditional manufacturing company, argues:

> Professional technical staff are socialized and selected from the beginning to accept the legitimacy of both bureaucratic authority and the dominance of business values. […] This selection and socialization process does not end at recruitment but continues through the early years of employment. Promotion to more autonomous positions is only available to those judged 'responsible', i.e. those whom management feels are trustworthy". (Whalley, 1986b: 225-226)

Similarly, Crawford (1989) who did an ethnography based on the study of two French companies – one manufacturing pipes and other metal products and one producing electronics and telecommunications products – makes the following note regarding the necessary management control methods of the companies:

> It is for work that is both difficult to supervise or evaluate individually, and for which the consequences of errors are expensive, that management seeks – must seek – trustworthy workers […] who have indicated their reliability by making it through an *école* and investing in a job whose key feature is the long-term career rewards offered in exchange for the faithful discharge of responsibility (Crawford, 1989: 94-95).

Thus, the methods used as a substitute for authoritarian control are classical normative methods – socialization and recruitment strategies (Etzioni, 1961/1975; Ouchi, 1979) – directed towards the minds, thoughts and believes of the employees rather than directly towards their behavior (e.g. Alvesson & Kärreman, 2004). An interesting account of socialization is Kunda's (1992) study of how managers attempt to align the engineers' interests with those of the organization by engaging in various attempts of controlling the organizational culture.

An additional suggested solution to the control problem has been to create a career path for engineers. Often, this has been done by linking engineering to management, offering the engineers a managerial career and thereby connecting the engineers stronger to the corporation and less to the occupation (Perlow & Bailyn, 1997; Whalley & Barley, 1997).

But the problem of control is not considered to be solved solely by selection and socialization procedures. In attempts to solve the conflict between technical expertise and organizational constraints, Whalley (1986) suggests that the control is maintained through "insulated involvement" of the engineers, which means that they are granted "a high degree of technical involvement and a low degree of organisational constraint" (p. 73). In other words, the engineers are free to practice their work and use their knowledge (which makes them "involved") at the same time as they are "insulated" against that which is thought to be the two major sources of constraint: authoritarian control and market requirements. In a sense, the solution to the problem of controlling engineers offered by insulated involvement can be formulated as "let them do what they wanna do". In the same vein, Barley (1996) points out that in engineering work "[c]oordination occurs not through a chain of command but through the collaboration of members of different groups working conjointly: a form of coordination in which practitioners retain authority over their own work" (p. 435). And Crawford (1989) argues that "a source of freedom from direct supervision is the predominantly lateral flow of communications among technical workers" (p. 194). Thus, what is argued is that a horizontal rather than vertical division of labor matters for the control of work and transfer of knowledge (see also Whalley & Barley, 1997; Zabusky, 1997).

The importance of horizontal relationships as a site where control takes place is connected with the complex, knowledge-intensive nature of engineering work. As was noted earlier, engineering knowledge is often divided into a formal and a contextual kind, and the central place ascribed to contextual knowledge further stresses the importance of horizontal relationships. The reason is that contextual knowledge is more difficult to formalize or rationalize (Barley, 1996), more difficult to make explicit and manageable (cf. Sewell, 2005). Although most

engineering managers have the same formal education as their subordinates, they do not understand the details of work because "knowledge is preserved and transmitted through extended training within a community of practice, rather than through rules and procedures" (Barley, 1996: 435). A good example of this is Orr (1996) who studied technicians repairing photocopiers and showed how stories told by and circulated among the technicians functioned as vehicles for disseminating knowledge and establishers of membership in a community of practice.

Hence, engineering work is argued to be controlled by use of classical vertical normative methods such as socialization and recruitment strategies, but also within the firm by granting the engineers a relatively large degree of freedom through "insulated involvement" that is through to give rise to fruitful collaboration and a lateral flow of communication. The statements above about the control of engineering work point at the necessity of horizontal control to take place, but do not quite develop any understanding of how it works.

The one that comes closest to a conceptual development that aims at describing how the horizontal relationships give rise to control is Orr (1996) in his convincing argument that the telling of stories has controlling effects on the copier repair technicians. The work of copier repair technicians is quite different to that of the engineers in this study however. The most important difference is that which I have pointed out earlier, that technicians use technology but engineers use *and* develop the same. Orr's technicians only use technology. In addition, there is a rather large difference in terms of education level: among Orr's technicians only 5 percent have bachelor's degrees, among the engineers I studies basically everyone has a master's. Nevertheless, they have in common that the content of their work is hard for outsiders to understand because of its technical orientation, and I wish to build upon Orr's and the other's emphasis on the importance of horizontal relationships for understanding the control of engineering work. I shall do this in an attempt to answer the question that still lingers: how can the control that is assumed to take place inside the "insulation", in the "collaboration" or in the "lateral flow of communication" be described and understood?

In sum, the "engineering studies" largely adopt the argument that complex work such as engineering is controlled by normative means, thus joining the proponents of normative controls. They also – joining teamwork, mutual adjustment and professional controls – strongly emphasize the importance of horizontal relations for understanding how engineering work is controlled, and offer some labels to signify the relatively independent working situation of the engineers. Except for Orr's (1996) ideas of story telling, they do not, however, engage much in conceptual development that suggests how horizontal control operates.

2.5 Conclusion

Although potentially relevant, the methods presented here are in my view unsatisfactory for creating an understanding of how operative complex work is controlled. The problem with the vertical methods has been noted earlier: basically, they are disproportionately dominating explanations of how work with an unusually strong horizontal dimension is controlled. The problem with the horizontal methods is generally that they suggest the necessity of horizontal control rather than develop concepts that aim at explaining how this control operates. A number of teamwork-studies have indeed contributed with conceptual development – particularly fruitful is Barker's concept of concertive control – although they are based on studies of work that cannot be categorized as "complex".

A problem with the majority of studies of both teamwork and mutual adjustment is that they take a managerial perspective, assuming that horizontal controls, after all, are controlled by managers. Another way to put this is that the concepts have been used for a different purpose than understanding. Drawing upon Habermas' notion of knowledge interests (cf. Willmott, 2003), the concepts have been used for technical purposes: that is, they have been used with the aim to control, predict and master organizations and individuals. That is not the purpose of this thesis; the purpose here is *understanding*, not in order to control or predict, but for the sake of understanding[34], which is connected to what

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[34] See chapter three for further discussion of what is meant by this focus on understanding.

Habermas calls a practical knowledge interest. I am making this point partly to position this study and partly to clarify and nuance the critique I have directed towards the concepts discussed above. It is thus not necessarily the case that the concepts of teamwork and mutual adjustment are "unsatisfactory" per se for producing understanding (although, as noted, I find the explanatory power of "mutual adjustment" rather limited …). But it is the case that they have been used in a managerialist and modernist tradition with a highly dominant technical knowledge interest. This makes them "unsatisfactory", in their present shape, for creating an understanding of the horizontal control of work, but not necessarily for creating a management tool and arguing that certain forms of control are *necessary* under certain conditions.

In the light of the characterization of engineering work made in chapter one and the strategy in this thesis to leave the assumption that managers are the origin of control, "professional controls" makes up a category with large explanatory potential. Similarly, the emphasis among the engineering studies on the importance of horizontal relationships is in line with the argument that I wish to make in this book. However, neither "professional controls" nor the concepts offered by the engineering studies offer conceptual development describing how the "necessary" horizontal control operates and how we are to understand it. It is with such description and such understanding that I wish to contribute.

Chapter three

Methodological considerations and work in the field

There are two purposes with this chapter. One is to explain the method used and argue for its relevance for the research question asked. The other is to convey an understanding of how this study came about, i.e. how it was initiated, how it changed and how it developed into a study of engineering work and control. The point with doing this, as I see it, is to create *transparency*. It gives the reader increased possibility to direct relevant critique towards the claims made in the study because s/he gets to know some things about what happened "backstage" (cf. Kunda, 1992).

3.1 In vindication of the choice of method

A few words should be said defending the choice of method. Why have I chosen to interview and observe people rather than to send out a questionnaire? Why do the interviews resemble discussions rather than verbally conducted polls? And why have I decided to present certain pieces of empirical material, certain episodes of engineering work?

The purpose of this study implies that I shall attempt to create an "understanding" of organizational control in a local context, i.e. at the company that I am studying. A way of paraphrasing this is to say that I shall "interpret" the way organizational control operates, for the creation of understanding, as Schwandt (2000: 194) puts it, "*is* interpretation". Understanding is a complicated notion, however, and I do not believe that it is possible to understand in a correct or false way. But it is possible to understand in an interesting and fruitful way. For example, when I argue that uncertainty and knowledge intensiveness

are central aspects of engineering work I do not claim to have found an absolute characterization, but a characterization that I believe will support a fruitful understanding. And by fruitful I mean that the understanding serves the purpose that it is thought to be used for (Watson, 1997). That is: to open up for, develop and argue for an alternative way of describing how complex work is controlled.

Understanding is not an isolated activity that a "knower" performs in order to objectively make a statement about an object that is located outside of him or her. Understanding is always about understanding differently; it is "participative, conversational, and dialogic" and it is "something that is *produced* in [the] dialogue, not something *reproduced* by an interpreter through an analysis of that which he or she seeks to understand" (Schwandt, 2000: 194). Understanding, or even thinking, is thus to be seen as an intersubjective and not solitary activity (Asplund, 2002). As a consequence, it is in interaction with the empirical world – interviewees, participants of meetings and other practices, documents – that I present an alternative understanding.

An attempt to create understanding calls for in-depth, face-to-face *interviews* rather than a search for quantifiable answers to readymade questions through the use of questionnaires (Bryman, 1989; Fontana & Frey, 2000). Interviews have the advantage that they enable a greater openness towards the object of study. Discussion-based interviews allow the interviewee to develop his/her thoughts more freely and the interviewer to ask follow-up questions and "drill" for new aspects of the phenomenon studied (Alvesson & Deetz, 2000). Interviews only, however, bring with them certain limitations for exploring the dynamics and control of work. If I want to create an understanding of engineering work it appears to me insufficient only to *talk* to engineers. In order to grasp the practice of work it is advisable also to observe them while working.

Observations have the same advantage as discussion-based interviews regarding the goal of "understanding", but they have the additional advantage of capturing the "natural" setting better than interviews. The interview is an artificial situation that would not take place if the researcher were not there, whereas observations can be conducted without any major interference with the way work is normally carried

out. "Where interviewers *construct* data, observers *find* it", argues Robert Dingwall, who is an advocate of observations, and adds that the difference between interviews and observations is "the difference between the experiment on the laboratory animal and the animal in the wild" (1997: 60). Dingwall captures the advantage of observations, but in my view he is overly optimistic. There is an element of intrusion even in a "non-participatory" observation (Angrosino & Kimberly, 2000) which makes it impossible to "find data". But the intrusion is of lesser magnitude in observations than in an interview situation and the researcher gets closer to the phenomenon studied. For my purposes of understanding the practice of everyday work, observation is of course a highly relevant tool (cf. Bryman, 1989; Silverman, 1993).

Hence, the methods of interviewing and observing have not been chosen based on the assumption that they will let us know how it "really" is, but rather based on the assumption that it is helpful for answering "how-questions", for creating an understanding of how something works.

Inspiration from the ethnographic tradition

Creating an understanding of a work practice to a certain extent requires understanding of a culture[35], and research that aims at developing such understanding is often labeled *ethnographic* (Van Maanen, 1988; Schwartzman, 1993; Prasad, 2005). This study is inspired by that type of research. Ethnographies typically use a vocabulary of "cultural practice" – such as rituals, ceremonies, myths, legends and taboos – to create a conceptual framework for analyzing their object of study (Prasad, 2005: 81). I do not use this conceptual framework, i.e. I do not discuss engineering work in terms of rituals, ceremonies etc. Although I expose the culture by presenting the way the engineers do things (cf. Watson, 1994) and the knowledge they share (cf. Van Maanen, 1988), more explicit references to culture have been placed in the background in favor of references to control. Also, a

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[35] For a detailed discussion on organizational culture, see Hatch (1993) or Alvesson (2002). Alvesson contends that the abstract notion of culture can be seen as a system of shared meanings. Hatch argues that culture consists of assumptions, values, artifacts and symbols, and suggests that studies of culture should focus on understanding the processes through which these elements are constructed.

traditional ethnography would probably focus more on the general environment and belief systems of the "natives" (Latour & Woolgar, 1979). I *do* consider these conditions as a way of contextualizing the work of the engineers, but my *focus* lies not on the general conditions of their work but on their particular work practices. Thus, ethnographic "inspiration" means that although the ethnographic tradition has not dictated the way this study has been constructed, some ethnographic features and assumptions about how knowledge can be created have been influential. These features will be discussed below.

The ethnographic features that have influenced this study most are *empirical openness* and *empirical proximity*. Ethnography can be said to be the method of cultural anthropology, a discipline that developed out of Western researchers' curiosity about and subsequently travels to other cultures (Schwartzman, 1993; Prasad, 2005). As the anthropologists were traveling to unknown lands, they had very little knowledge in terms of what to expect of the other culture and needed to be open to what the new empirical world had to offer. Although engineering culture was not as unknown to me when I started my study as, for example, was the culture of the Trobriands to the anthropologist Bronislaw Malinowski when he first arrived at the Trobriand Islands in 1915, I have been inspired by the open approach towards the field that characterizes an "explorer". One example of this empirical openness is the fact that the object of study was not decided beforehand but emerged as the study proceeded. Another example is the openness that has characterized the interviews: interview questions have been open and based on discussion, which tends to offer rich descriptions rather than short affirmative or negative answers and increase the possibility for the respondents to answer in a way that they feel comfortable with (Schwartzman, 1993).

The possibilities of being open should not be exaggerated however. It is possible to be more or less, but not completely open. Hence, I am not arguing that I was like a *tabula rasa* when I entered the field. Apart from being biologically and socially constituted in a certain way that distinguishes each individual from others, every researcher is theoretically "programmed". For example, a student of culture theory is likely to be more sensitive to ritualistic behavior, which will probably make her find expressions of this. Furthermore, in order to create focus,

the amount of openness must diminish as the study proceeds. That has been the case in this study. I chose at a certain point to follow episodes of engineering work that I *expected* would tell me something about how work is controlled.

Empirical proximity is the other feature of the ethnographic approach that has inspired this study. Prasad (2005) notes that "ethnography [...] has always stressed the importance of getting close to the natives being studied" (p. 81), and in a similar vein Schwartzman (1993) points out that "[e]thnographers go into the field to learn about a culture from the inside out" (p. 3-4). This is in line with my aim of bringing operative work into the study of organizational control, an aim that calls for proximity to the practice of working. Following Orr (1996) who states that "[a]n important point about the ethnographic study of work practice is that it must be done in the situation in which the work normally occurs" (p. 10), I argue that without being close to the engineers and their operative work, without getting "inside", it would be more difficult to develop an understanding of what they do and how this "doing" is controlled.

There is a limit to my proximity to the field, however. Ethnographic fieldwork may be understood as "living with and living like those who are studied" (Van Maanen, 1988: 2; see also Tedlock, 2000). I have not gone that far, my proximity to the field is limited to the notion of having *been among them* rather than having *lived with* them. One reason for this is the fact that I am not an engineer, which prevents me from participating in their activities. Practical experience of the field tends to bring with it both advantages and disadvantages. Orr (1996), who studied technicians who repair photo copiers, had practical experience which he felt was "both a boon and a curse" because, he says, "it made my presence in the field less obtrusive, since I needed fewer explanations [but] I also found that I had a tendency to regard certain phenomena as unremarkable which are not really so to outsiders" (p. 7).

I feel the same way as Orr, but the other way around. Lacking practical and theoretical experience from the field of engineering, I needed explanations for even the most basic things, which may have had an obtrusive effect on the engineers. On the other hand, my portrayal of

the field is probably basic enough for a layperson to understand which may not have been the case if I were an engineer. Also, and as Orr notes, I may have paid attention to phenomena that a former engineer would not see. With Latour & Woolgar (1979: 29), I do not view practical experience, "prior cognition" or "prior socialization" as a prerequisite for understanding engineering work (or any other kind of work). In fact, as the aim of this thesis is to offer an *alternative* understanding, I believe it is rather an advantage that I have not had the possibility of becoming totally immersed in the engineering culture. In the language of ethnography, I have not run a very great risk of "going native" (e.g. Tedlock, 2000). Thus, my type of empirical proximity has created a description of engineering work that is not the result of an insider accounting for his practice, but the result of an outsider observing and interpreting a different culture at a near distance.

To conclude, I am inspired more by the ethnographic *method* than of the ethnographic vocabulary of culture and the traditional ethnographic epistemology. The latter, stemming from the work of the early anthropologists, assumed the possibility of taking, representing and interpreting the perspective of the "natives" in order to gain a deeper understanding where there was a definite bottom of the deep. Where the bottom of understanding resides, I believe, is in itself a matter of interpretation. Hence, instead of assuming that I can take the perspective of the engineers, I draw upon their discourses and practices in order to create an understanding of control that differs from the dominating one. In this sense, I am looking for a broader rather than deeper understanding.

Asking questions and hanging out

In practical terms, the ethnographic method is dominated by the activities of "asking questions" and "hanging out" (Dingwall, 1997). This describes my approach well. I have asked managers on different levels, people working with human resources, but primarily engineers working with technology and product development. And I have been hanging out with the engineers in various work contexts.

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Many questions have been asked within the formal framework of "the interview". The interviews have taken the shape of discussions. It may be objected that the fact that the agenda is set by the researcher, it is questionable whether an interview can be said to be like a discussion (see Dingwall, 1997). What I mean is that the development of the interview depends partly on the replies of the respondent. Furthermore, answers that are followed up by improvised questions in order to delve deeper into the topic often develop into rewarding accounts. When this happens, I think the discussion metaphor is descriptive. Discussion-based interviews were used throughout the study – however to a larger extent in the earlier phase – and have served well to increase my understanding for the engineers' work, but they do not serve very well to create good descriptions. For that, "hanging out" is more appropriate.

I have basically been hanging out in two ways. The first should perhaps be labeled "sitting in" rather than hanging out, since I have been sitting in at different meetings. The second way of hanging out is more a matter of "real" hanging out, which means that I had lunch together with the engineers, joined them at coffee breaks, and sat in the lab watching them working. During a couple of weeks I was positioned near the coffee machine with my laptop, which proved rewarding since people tended to stop by, grab a cup of coffee and on occasions chat informally about all kinds of things. Getting up for a cup of coffee was a natural way for me to join their conversations. My view over the laboratory also enabled me to observe how they worked, interacted, asked each other questions, made jokes or just stopped for a while to talk. In addition, I shadowed one engineer for a week, which was an intense way of hanging out, albeit only with one person. All this will be outlined in more detail below.

3.2 How the study came about

After this discussion of the methodological inspiration I shall outline the background to the production of the empirical material. The study can be divided into two phases: one where a general understanding of the organization was gained, and another with a stronger focus on operative work. Let us call them phase one and phase two.

Phase one

In phase one, which started in February 2002, I studied GT as a part of a larger research project that set out to study a management attempt to change the corporate culture[36]. Except for myself, there was one senior researcher and another PhD-student involved in the study. To begin with, the interviews and observations conducted mainly revolved around the culture change attempt. At this time, I was interested in teamwork and group-based organization as a means of controlling work, and in order to create some material for studying this I started to observe the object meetings of a group of engineers (the radio-group) that we had interviewed regarding the culture change attempt. Despite the quite extensive empirical material it was difficult to use it for the purpose of studying group-based organization and control. The material did not lend itself to such analysis, at least not in my hands. The study at GT in phase one was designed to investigate the initiatives behind, practices for, interpretations of and reactions upon the culture change attempt. The material gave me a general understanding of the organization and the engineers' view of their work, but it did not say enough about the very work itself and how it is controlled.

But the study of the culture change attempt opened up for control related questions. The culture program was ambitious: a lot of money was spent; workshops where held in most sections where section managers were asked to inform about the "new" culture and discuss how each individual and each group could contribute to the new culture; the CEO urged everybody to "contribute to create a strong company culture by participating in our 'new target culture program'"; fancy brochures were produced and experts hired. But according to my observations among the engineers, nobody seemed to care much about the culture program. Nobody talked about it unless I brought it up. And when I interviewed the engineers about a year after the program was initiated, some engineers said they had "suppressed" it, others that it had no effects on their work, and yet others did not remember that they had had the culture workshop at all. This indicated to me that if I wanted to find an answer to how operative engineering work is

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[36] For a detailed analysis of the culture change attempt, see Alvesson & Sveningsson (2007)

controlled, I should perhaps search elsewhere than in initiated normative management control attempts.

Letting go of the culture program as well as the group-organization focus which I could not come to terms with, but sticking to the control perspective in which I saw potential, I designed a new study at GT whose realization gave rise to a second phase of my work in the field.

Phase two

Phase two started in February 2004. Now I focused more clearly on the object meetings and the relationship between the engineers and the object leader[37]. I observed six consecutive object meetings in the "radio-object"[38] (they are held on a weekly basis) and interviewed the object leader and the engineers about the meeting and issues connected to it. I asked about their view of the meetings, of situations at the meetings when they receive instructions of some kind, their view of top management, but also about the way they are working, what they think is characteristic of the organization and the group they are working in.

Except for the radio object, I exposed two other objects to this "treatment" in order to make comparisons possible. I chose objects that are connected to the radio object: another object in the same department because they are related by having the same project leader, and an ASIC-object because they work close to but at a different department than the radio object. In this way some synergies were created since I learned some more about the environment of the radio object at the same time as I gained understanding of the work in the other objects. In addition to observing and interviewing the members of the objects, I observed the object leaders' meetings with their project leaders. I also interviewed these project leaders. This material makes up the empirical basis of chapter five (the ASIC-object) and seven (the radio-object).

I started to see that the work was rather loosely coupled to the instructions that came "from above". The control, in simplified terms,

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[37] As you may recall from chapter one, they use the term "object leader" at GT, which is like a "sub-project leader" whose superior is called project leader.
[38] This is the object where Jake, whose workday introduced this book, works.

seemed to consist of establishing the features that a product must support and the time frame of the project, then it was up to the engineers to find out how that was to become reality. I got this impression from the object meetings and from spending many days in their laboratory, noticing that people seemed to know what to do and very seldom asked for instructions from their manager. Neither did I ever see anybody from higher management levels visit their department. This impression was strengthened by Harry, the section manager of the radio-group that I paid most attention to, who pointed out that there is nobody who tells them what to do. There were also some other people with long experience in the organization painting a similar picture of their work, saying that initiatives come "from below".

The talk about their work as being very independent from top-management – or that there is nobody telling them what to do – made me wonder where work "comes from", how it emerges. If nobody tells them what to do, how do they know what to do? In an interview with an engineer I got to know that they were discussing the idea to develop and exchange of a part of the product, the power amplifier (PA). As a supplement to the object meeting observation, I decided to follow this idea to exchange the PA. My intention was that following the idea would help me understand better where work comes from and what it is that controls its emergence. In terms of my work, following the idea meant observation of six meetings where the PA was discussed and interviews with the people involved. Studying this emergence of an idea thus became another part of phase two of my fieldwork, and it makes up the foundation of chapter eight.

The observations of object meetings and the following of the idea helped me getting a grasp of their work and its control environment. What I had not done, however, was to follow the work of a person in order to get close to everyday work on a more continuous basis and to a greater extent "via the eyes of an engineer". With a certain degree of inspiration from Barley & Kunda's (2001) call for bringing work back into organization studies I asked an engineer – one who seemed fairly interested in what I do and with whom I had talked quite much at lunches and coffee breaks – what he thought about the idea of being "shadowed". I explained that shadowing means that I follow him in his work. He first seemed to find the method unproblematic but when he

realized that I meant following him wherever he goes and whatever he does he, partly on my advice, decided to think about it until the next day. On the following day the idea still sounded interesting, or perhaps endurable, to him and we decided a week when I would be his shadow.

One general purpose of the shadowing was to get a closer and more coherent view of what they do when they work. Another and more specific purpose was to get a more profound understanding of activities that are referred to at object meetings. For example, what does it mean to "make measurements"? I had spent quite some time sitting in the lab observing that they tap on computers, solder, turn knobs on instruments, look at monitors and get a colleague to look at it too, mess with cables and wires etc. These activities could probably be part of "making measurements", but I could not place them into a context. I hoped to remedy this lack of context by shadowing Jake for a week. So I did. I sat in his office when he sat there, I sat in the laboratory when he sat there, I stood in his colleague's office listening when Jake stood there talking, I sat in meetings listening when Jake sat there participating, I went for lunch when Jake did and I went for a cup of coffee when he did. I got many new insights about the general content of their work (the *detailed* technical content remains unknown and mysterious to me) and after the week in the shadow I understood to a larger extent the meaning of that which is talked about at the object meetings. In addition, Jake was very accommodating and, when possible, described to me what he was doing which gave me insight into things that are not talked about much at the object meetings and that do not come out in interviews. The material from the shadowing is mainly presented in chapter six.

In terms of time, the shadowing of Jake was finished in the beginning of April 2004. In parallel of studying the radio-group, I observed the object meetings of another object at the same department and interviewed its members. After April, I focused upon the ASIC-object for about two months, and that work was finished in June. Phase two thus lasted from February until June 2004, and the three major activities performed during phase two – observing the object meetings and interviewing the participants (in the radio-group as well as the ASIC-group), following the PA-idea and shadowing Jake (both in the

radio-group) – make up the bulk of the empirical material presented in this thesis.[39]

Later, I came to see the study as an example of how the operations of complex work are controlled.

3.3 The presentation of the argument

As outlined in the introduction, there are two main arguments that run through this book:

1) Uncertainty, knowledge intensiveness, deadline focus and idea intensiveness are central aspects of engineering work.

2) These aspects in turn have consequences for the way work is controlled, and it is argued here that operative engineering work can be understood as controlled mainly by horizontal control.

In an attempt to describe how the argument is constructed I will discuss four themes below. First, my choice of using episodes; second, the way in which the episodes have been chosen; third, the relationship between the episodes and last, the status that I give the episodes as empirical material.

The use of episodes

I have chosen to run my argument by presenting a number of episodes of engineering work. An episode is presented in order to gain a deeper or broader understanding about the object of study, i.e. about the control of operative engineering work. There are two characteristics of the episodes that I wish to point out here: 1) they set the boundaries for the study (Svensson, 2004), and 2) they are "one among others" (Stake, 2000: 436).

Regarding the *boundedness*, the presentation of each episode sets, although somewhat blurry, boundaries for what can be talked about. For example, the presentation of the initiative to exchange a part of the

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[39] See appendix for a quantification of the empirical material.

product in chapter eight limits me to talk about things directly or indirectly connected to that very initiative. The boundedness is both a strength and a weakness: a strength because it creates focus and a weakness because it excludes the possibility to talk about other things relevant to the object of study. This weakness can be dealt with, however, by presenting different types of episodes, a strategy pursued in this thesis.

Each episode being *one among others* means that there are many initiatives, work meetings/object meetings[40] and workdays at GT but I have chosen to present only one of each (with the exception of the object meeting, which there are two of and I will comment on that below). One reason for presenting a great number of episodes of the same kind would be if the researcher had ambitions to make empirical generalizations. I do not have such ambitions, however. My study is focused upon interpretation and prioritizes analytical depth, complexity and detail before possibilities of (empirical) generalization.

A modification must be added to the focus on "one" among others, for I *do* pursue the strategy of presenting more than one episode of the same kind. This is not for the purpose of generalizing, however, but for the purpose of *making comparisons*. Comparisons, in turn, can be vehicles for grasping additional layers of meaning, for creating a "thicker" narrative (Geertz, 1973)[41]. The episodes that enable comparisons are the object meetings presented in chapters five and seven which are of the same kind (in the sense that they are object meetings) but they also differ in a way that makes it interesting to present both and compare them.

The simultaneous likeness and difference between the episodes can be used to make two arguments. First, the likeness supports the contention

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[40] At GT, the weekly or semi-weekly meetings where the ongoing operative work is followed up are called object meetings. I will therefore henceforth refer to them as object meetings.

[41] When Geertz is talking about thickening the description he refers to the description of one single situation. I am using two situations to thicken the description of one phenomenon: holding object meetings. I have thus allowed myself to slightly deviate from the original meaning of creating thick descriptions.

that holding object meetings according to a certain, say, semi-structured pattern is a *typical* activity at GT and not something that just happened to take place in one particular group. That argument is also supported by the fact that I studied a third group that also held object meetings, following a similar pattern. (The empirical material from that third group is not presented in the thesis, however, as there is no reason to make the same point twice.) The second reason for presenting two episodes of the same kind is that the difference between them supports the contention that the dynamics of the object meetings is dependent not so much on the formal set-up with an object leader following up the work of the engineers, but rather on the knowledge possessed by this object leader.

The choice of episodes – omission and selection

A lot of potential empirical material on engineering work has been left out. For example, I have observed "section meetings" where the section manager (who is in the line organization) informs and discusses with the engineers what is going on in the organization. I have observed "department meetings" where the department manager (the section managers' manager in the line) informs of and discusses with his section managers what is going on in the organization. I have also observed and followed up management attempts to change the culture of the organization. All of these observations are episodes of engineering work in the sense that it is performed by engineers in an engineering organization, but none of them fit the purpose of this study as well as the selected episodes do, and therefore they have been omitted.

So what about the criteria guiding the selection among the episodes? An episode should enhance (deepen or broadening) our understanding of the object of study; of the operative control of engineering work. Therefore, and in the first place, the episodes must say something about engineering work. This criterion is easy to fulfill since my method of observing engineers at work by definition produces episodes of engineering work. But it is not just any kind of engineering work that is the object of study, but the complex operative work that engages the engineers in the development of new technology/products and the solving of technical problems. The episodes must thus illustrate the engineers when they are engaged in this kind of activities, and the

selection has been based upon three criteria – particularity, proximity and typicality.

The reason for the omission is that the episodes are not in line with my strategy of bringing work in and leaving the managerial focus. First, the omitted episodes do not serve very well to illustrate the *particularity* of operative engineering work as it has been outlined in the introductory chapter. They do not to the same extent as the selected episodes "blur" the conventional concepts of work and control. For example, they do not serve to illustrate very well how engineering work is both manual and mental or how it is difficult to organize with traditional means of control. This is because they are not particular episodes of engineering work, but general episodes of line activities. Instead of being classified as engineering work, the work performed at the section meetings and department meetings may just as well be classified as "managerial work" or "administrative work" and its kind may be found in almost any organization. Along the same line of reasoning, the work performed when the culture was to be changed may just as well be classified as "change management", which is also an activity that is not particular to engineering work. Second – and in line with the ethnographic method as presented above – the omitted episodes fail to offer the sense of *proximity* that the selected episodes offer. Section meetings, department meetings and (especially) the culture change initiative only indirectly deal with the operational work that is the focus of this study.

On the same basis as some episodes have been omitted, others have been chosen. Thus, the chosen episodes are argued to be close-up examples of the particular activity of product development engineering work. Regarding the episodes chosen there is one more criterion that has influenced the selection and that is *typicality*: the episodes may be particular of engineering work and they may be close to the production process, but they are also typical. In the matter of deciding upon the degree of typicality I wish to refer partly to my own observations during my time at GT and partly to the statements of the engineers. Both indicate that taking initiative to changes in the product (chapter eight) and holding object meetings to follow up the implementation of existing time plans (chapters five and seven) are typical activities of product development engineering work.

It was not hard to realize that object meetings are typical and central features of their work; after a few weeks at GT I noticed that they meet up on a weekly basis in order to follow up and discuss work. As I touched upon above when the merits of comparisons where discussed, I observed three different groups and they all held object meetings of a similar kind. It was harder to observe the dynamics behind the initiation of new ideas, however, and the argument for the typicality of that activity relies more upon the engineers' own statements. Those statements are presented in chapter eight and I prefer to refer to that chapter rather than presenting empirical material here, suffice it to point out that the engineers say that initiative to make changes and develop new ideas often comes from themselves. Concerning the work day presented in chapter six, I wish to refer to my ethnographic credibility and contend that, based on my observations at GT, the work day that I present includes typical product development activities such as laboratory work, review work and meeting up with colleagues to follow up and discuss both past, present and future work on the product.

As the reader may realize at this point I do not mean by "typical" that I have measured exactly the number of instances of initiatives, object meetings or laboratory work at GT. Closer to my point is to say that my own observations as well as the statements of the engineers indicate strongly – to turn the issue of typicality upside-down – that there is little reason to suspect the episodes to be *a*typical.

It has been pointed out the importance of the episodes' illustrative power in terms of creating an understanding of the object of study, which is not just engineering work but the *control* of engineering work. Thus, the episodes should not only say something about engineering work but also about how it is controlled. There is a difference between the episodes in terms of their power to create an understanding of control. Holding object meetings (chapters five and seven) and developing ideas (chapter eight) are not only episodes of engineering work but also, as I see it, *controlling activities*. That is why they are presented as episodes saying something about how engineering work is controlled – they are episodes where I expect attempts to exert control to become "observable". The episode presented in chapter six, a work day, is not a controlling activity of course. Instead, that episode fills a

clarifying function. It illustrates how pieces of engineering work – such as developing ideas and meeting up, but also other types of work such as laboratory work and review work – fit into the concept of "everyday work" by means of following an engineer rather than following a particular work practice. It is the engineer who works and it is the engineer's work that is exposed to control, which makes "the work day"-episode a source for deepened understanding of the ways in which control operates on an everyday level.

The relationship between the episodes

Now let us turn back to the two arguments of this thesis: there is the aspect-argument and there is the control-argument. These arguments are constructed by presenting the episodes in a certain order and I wish to say a few words of this order and how it is connected to the ethnographic method.

As was noted in the introduction, the emphasized aspects – uncertainty, knowledge intensiveness, deadline focus, and idea intensiveness – are the result partly of previous studies of engineering work and partly of my observations in the field, and they fill the function of setting the scene, as it were, for the exertion of operational control. In metaphorical terms one could liken the relationship between the two arguments with the relationship between the insulation and the wires of a cable: like the insulation creates the environment of the wires of a cable, the aspects of engineering work create the environment of operational control. In a cable, it is through the wires and not the insulation that something (current) is "running". Likewise, it is the argument of control and not that of the aspects that is "running" through the thesis. This means that in terms of the aspect-argument, the chapters do not build upon each other to the same extent as in terms of the control-argument. That is, it is not necessary to know from chapter five that uncertainty permeates engineering work in order to understand in chapter eight that the management of ideas is central. The argument of control, on the other hand, is "run", and in brief, it runs like this:

- In chapter five it is argued that vertical methods are decoupled from engineering work and unsatisfactory for explaining how it is controlled.
- In chapter six I bring in work in the shape of a typical workday and argue that engineering work is controlled mainly through self-control and horizontal control.

After these two chapters, it may still be objected that managers *do* play a central role in the control of the operative work. First, they may exert control by telling people *when* to finish a certain piece of work. Second, they may control the ideas (i.e. *what* shall be produced) that the engineers work with.

- In chapter seven, then, it is shown and argued that managers' possibilities of controlling by the use of deadlines are limited. The extent to which the deadlines control the engineers or the engineers control the deadlines is ambiguous.
- In chapter eight, it is shown and argued that the ideas to a large extent are the result of the engineers' own work, and not of managerial work.
- In chapter nine, the final chapter, the argument of this study is expanded upon by developing the concept of "peer reviewing" as a way of understanding horizontal control in complex work.

The strategy of presentation outlined above is in line with the ethnographic focus on contextualization, assuming that by describing the contextual factors that shape the scene where action takes place, we will gain a better understanding of this very action (Tedlock, 2000; Prasad, 2005). In this thesis, the "action" is control. Contextualization – here made up by the focus on a number of aspects of operative work – is thus a way of making the control-argument credible, a way of making it understandable to the reader. It can similarly be argued, again, that new layers of understanding the object of study are added in the chapters with the purpose of creating a "thicker" description (Geertz, 1973).

Contextualization, however, is not only a way of *making* the argument, but also a way of *delimiting* it. In line with the cable-metaphor, the

contextualization insulates the argument and creates a certain *kind* of environment. It is thus not a matter of bringing the "total context" into the study; it is not possible to take *everything* into consideration that could have controlling effects on engineering work. In this study, it is a local and operational context that is constructed, which means that for example institutional circumstances such as education or the role of trade unions are placed in the background in favor of operational circumstances such as the interaction with colleagues or materials. In sum, the relationship between the arguments is that one (the aspect-argument) is there in order to enable but also delimit the other (the control-argument).

The status given to the episodes as empirical material

By asking questions in interviews and other less formal situations, and by hanging out with the engineers in various work situations – production- as well as non-production situations (such as lunches and coffee breaks) – I have constructed the episodes that are presented in this thesis. Aiming to give the reader an insight into the dynamics of the work of the engineers at GT, this is a text containing a quite large amount of empirical material. Still, and of course, the major part of the material is left on my hard drive. As with all texts, there has been a lot of editing of the raw material: choosing quotes, interpreting quotes, choosing observations and shortening down observations etc. Thus, I could hardly claim to transfer to the reader what I have seen and heard, but only a version that is quite strongly edited by myself. So what is the status of the material if it is not a mirror of "work at GT"?

Manuel Castells (1996) writes in a methods note to his work on the information age:

> the data, observations, and references presented in this book do not really aim at demonstrating but at suggesting hypotheses while constraining the ideas within a corpus of observation, admittedly selected with my research questions in mind but certainly not organized around preconceived answers (p. 26).

He thus presents the role of the "corpus of observation" (i.e. the empirical material) as the one to constrain the ideas and interpretations of the researcher. I find that idea sympathetic. The status I give the

empirical material is that of an advisor and inspiration source. It serves to create ideas but also to constrain them, both when the text is produced and when it is reviewed or consumed by a reader who is given some insight into it and the possibility to criticize the interpretations or claims made. Although the author is free to edit the material – which is often a prerequisite for making it readable and "interesting" – it still prevents her from writing just anything that comes to her. The text presented to the reader, I think, should convey that the author has been influenced but also constrained by what he or she has experienced in the field.

In this vein, I believe that the producers of flow charts or organization structures as representations of organizational control have been little constrained by empirical observations and therefore produced abstract images based on ideals or perhaps "wild" imagination rather than fieldwork. Although imagination is an important feature of all social research, the lack of research where empirical observation functions as the basis for those imaginations calls for studies of what people do at work. Therefore, it is good advise that we bring work back into our texts (Barley & Kunda, 2001) for the purpose of criticizing, balancing and broadening our understanding of organizational control, and let that which is experienced in the field inspire but also constrain our texts.

After this presentation of the role of method and emergence of the study, I shall now turn to a presentation of the place where I have studied. In the next chapter I shall outline the context and the structure in which the engineers work.

Chapter four

GT – The industrial and organizational context

The aim of this chapter is to set the scene for the object of study. In order to create an understanding for how engineering work is controlled on an operative level – and in line with the ethnographic tradition (Tedlock, 2000; Prasad, 2005) – it is necessary to outline the more general context in which work is carried out. For analytical purposes, "context" is here divided into three levels: industry level, organizational level and everyday work level. This chapter will be devoted to the first two levels, whereas the remaining empirical chapters will focus primarily on the operative level.

4.1 Industry level – control through international standards

GT – the organization in which I have studied – is a fairly large (about 800 employees) producer of high-end software and hardware for the telecommunications industry. The telecommunications industry has developed very rapidly during the past twenty years or so. A mobile phone today, for example, is much smaller, much faster, much cheaper and still consumes much less energy than it did ten years ago. Innovation is central in the industry and innovation has brought about this rapid development.

In line with the focus on control in this study, let me start by pointing out that the innovators of the telecommunications industry cannot innovate in just any way they like. The standards of telecom-

munications are controlled by the *3GPP*[42], an international partnership between a number of officially recognized standardization organizations whose purpose is to "prepare, approve and maintain globally applicable Technical Specifications [...] for a 3rd Generation Mobile System"[43]. GT is owned by a larger conglomerate called "Global", and GT and Global are members of the 3GPP and have thereby subscribed to its standards. However, the standards worked out are based on the technological development that GT is directly involved in, and Global was one of the founders of the 3GPP. Thus, as members of the 3GPP, Global and GT are not only subordinated to, but also play actives roles in the creation of the standards.

An important objective of the 3GPP is thus to standardize requirements and specifications for mobile telecommunication. The radio frequency that can be used by a telecom device is regulated, and the device must not "leak" signals to such an extent that it disturbs other devices that use the atmosphere for communication. When telecommunications technology is developed, it must thus follow the rules of the 3GPP. Harry, a department manager at GT, points out how the 3GPP influences their work when he talks about his view of the core competence of GT:

> GT's strength is that we can break down the requirements from the 3GPP, which standardizes the whole system. [...] We can read the specification and then make a construction that fulfils the requirements, the system requirements. We can take the system requirements and break them down into a suitable architecture; [find out] how to proceed to make it consume less energy, be cost efficient, as simple as possible to produce, how to measure performance. Above all it needs to be as simple as possible, but still fulfill the requirements. That is our core competence. Then our work is also to transform this internal construction that we have produced into something that corresponds with what the customer wants.

The 3GPP thus sets the scene on which GT acts. The major question for GT is how to, within the framework of rules set by the 3GPP,

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[42] "The 3rd Generation Partnership Project". For more information on the 3GPP, visit the homepage: www.3gpp.org

[43] *Third Generation Partnership Project Agreement*: www.3gpp.org/About/3gppagre.pdf

develop technology that is as small, cheap, power saving and simple to produce as possible. This is what they are best at, argues Harry. Then they need to be good at aligning their constructions to customer needs too. The latter, as we shall see below, is what the managers at GT think they must be better at.

APA – 3GPP-imprints on operative work

The most concrete imprint of the international 3GPP-standards on the operative work of the engineers is *APA* (Application approval), a test of the electronic parts carried out to make sure the parts fulfill the requirements of 3GPP. The test is formalized to a certain extent, as explained by an object leader at GT:

> For us, the concrete meaning of the tests is that we we're supposed to have tested about 20 phones, at least, it can be forty, we define it ourselves depending on what we find reasonable, but somewhere between 20 and 40 phones shall when it comes to RF [Radio Frequency]-performance be measured in all conditions in accordance to the laws of 3GPP. That means different voltage, different temperature. And the purpose is make sure, based on this small number on phones, that we are within specification on practically all critical radio parameters in 3GPP. So it's a large, extensive test.

The formalization is thus made up by the general 3GPP-requirements and a loose directive regarding the required number of phones tested. APA is something that is done when the engineers consider their development work to be more or less finished. Prior to the APA, a lot of both conceptual work and laboratory work (testing and measuring of components) is performed (see chapter six), and the APA is therefore done rather late in the life of a project.

The APA does not prescribe specific actions; it is not a written down step-by-step process that the engineers keep in front of them when working. For example, in a document describing of one of the larger projects at GT the requirements are that "[e]ach object and project member is responsible to have fully documented, tested and verified deliveries". "Fully documented, tested and verified" means little to an outsider, but it means much to the engineers. The controlling effects of APA therefore lie in its capacity as a "label" that indicates certain actions to the engineers, given that they possess specific engineering

knowledge (cf. Weick, 1985; Czarniawska-Joerges, 1993). For example, the engineers know that APA is about, as one engineer tells me, "doing environmental tests, making sure that the requirements of the producer correspond with GT's requirements and to test the prototype phone together with the signaling software". He also knows that "fully documented", among other things, means that he is expected to create links in the document to the test documents he has produced in order for other engineers to access the details behind the document. The actual approval of the work is then made in a review process by the engineers themselves. In this way, the international requirements find their way to the operative work of the engineers at GT.

4.2 Organizational level

Now let us move from the demands of the telecom industry as a whole to the organization that I have given the pseudonym "GT". The organization was formally created as a legal entity in 2001. Before 2001, GT was a part of Global, a global actor in the telecom industry. Global still owns GT, however. The reason for creating GT – say top managers of GT – was that Global wanted to concentrate its core competence in a separate organization that focuses only on technology development and sells its products as an independent actor in the international market.

Management's dual focus – technology and customer orientation

The major consequence of the stronger market focus is that GT now needs to serve and build relationships with external customers. Market and customer orientation are put forth by top-management as an important part of the company's strategy. The main driving force behind the perceived need for a stronger customer focus is the fact that GT was in a financially pretty bad shape by 2001 and the customer orientation is seen, by top-management, as a way to get on the right track again. Managers talk about the importance of a change of "mind-set" that needs to take place in the organization, where the main focus is on switching from being engineering-minded to being business- or customer-minded.

But despite the talk about customer orientation, technology still carries great weight at GT. Most of the employees working in the company are engineers, both among managers and operative personnel. The "engineering culture" is often said to be strong and the organization has a reputation of being technologically- rather than customer oriented. This is expressed by top managers, e.g. the Head of Technology Development:

> [...] at Global, the engineering culture is honored [...]

> On the whole, Global is a company that is run by engineers, everything is kind of done on the engineers' terms.

And the CFO:

> The predominant attitude from outside is that this was an arrogant, technology-oriented organization that was blowing its own trumpet and said that we're the best in the world when it comes to technology.

On an operative level the new situation of the company seems to make a difference mainly in the parts of the organization that actually *have* customer contact, which is far from all. The others may get customer related questions, but are seldom or never exposed directly to customers. Most of the engineers still work only with technology development and the fact that business orientation is more important now does not mean that the people in the organization have automatically changed to being "business minded". It would therefore be wrong to argue that the organization is customer focused. Instead, suffice it to point out the fact that the organization has contact with external customers, that management points out the importance of serving them, and that this has consequences for the engineers' work. One such consequence is increased *delivery focus*.

"Customer orientation" can mean many things, but at GT it tends to mean delivery focus. This is pointed out by the CEO, for example, at a meeting in 2002 to which all employees were invited. The CEO talks about the importance of delivering on time, that their minds have to be set on meeting committed dates, and, as he exclaims: "*not* on delaying deliveries only because we cannot recruit more people … of course not!" To the engineers, this basically means that they must make sure to keep their *deadlines*. Although this has always been important, it is

perceived as essential now when they have external customers. The delivery focus was also a central message in a culture change initiative that I followed in the first phase of this study. There, "delivery accuracy" was emphasized as one of GT's three "drivers for success".

In sum, the traditional conflict between the goals of technology and the goals of the firm (Whalley, 1986b), with the engineers representing the former and the (higher) managers the latter, seems to exist at GT. Most engineers at GT are still very focused on product and technology development. The "engineering culture" is strong. There has been a change after the company was created in 2001 however, and since then top-management explicitly points out the importance of customer orientation. This has brought with it a slight change of focus. Above all, it is more important now to keep deadlines.

Organization structure

The organization structure is best described as a matrix, with a line that is responsible for issues such as work processes, recruitment, retention, allocation of recourses (people), working conditions etc., and a project organization that deals with the actual product development on a hands-on basis. It is the work in the project organization that I am interested in because that is where the operative product development goes on. The line indirectly affects the work in the projects, however, and will therefore be described in brief.

The line organization

The line organization is divided into six levels according to Figure 1 ("Sales & marketing" are outside the focus of this study and included only to illustrate that there are other functions than technology development):

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                           ┌─────────────────────────┐
                           │           CEO           │
                           └─────────────────────────┘
        ┌──────────────────────────────────┬──────────────────────────────────────────────┐
┌─────────────────────┐      ┌────────────────────────────────────────┐
│  Sales & Marketing  │      │         "Technology development"        │
└─────────────────────┘      │ Head = "Head of technology development" │
                             └────────────────────────────────────────┘
┌─────────────────────┐      ┌────────────────────────────────────────┐
│                     │      │                 Sector                  │
└─────────────────────┘      │          Head = Sector manager          │
                             └────────────────────────────────────────┘
┌─────────────────────┐      ┌────────────────────────────────────────┐
│                     │      │               Department                │
└─────────────────────┘      │ Head = Department manager (e.g. Harry)  │
                             └────────────────────────────────────────┘
                             ┌────────────────────────────────────────┐
                             │              Radio Section              │
                             │ Head = Section manager (e.g.Victor)     │
                             └────────────────────────────────────────┘
                                        ┌─────────────┐
                                        │  Engineers  │
                                        └─────────────┘
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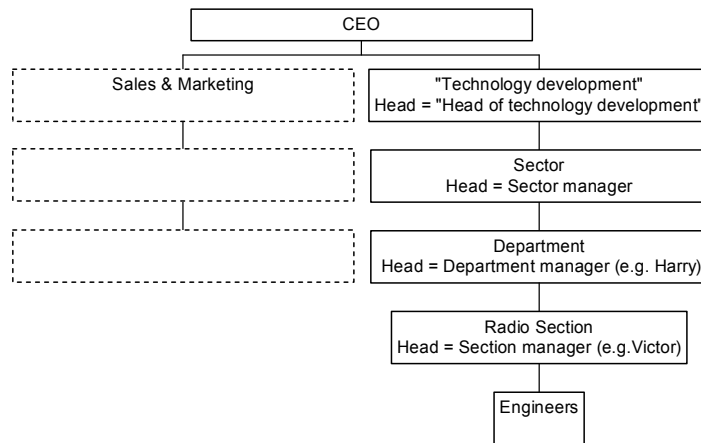
Figure 1 The line organization

The figure gives a rough view of the functional hierarchy. As you can see, there are five management positions: CEO $\Rightarrow$ Head of technology development $\Rightarrow$ Sector manager $\Rightarrow$ Department manager $\Rightarrow$ Section manager.

If you walk around in the building, it is not until you get to the department level that this structure becomes discernible. The employees are physically divided into *departments* and those who belong to the same department are located in one "wing" of the building ("Harry" is the department manager in the department that I focused most on). The *sections* then make up a part of the wing. Sections constitute the base of the line organization. They consist of 5-20 people and each section is populated by people who specialize on a certain part of the final product. There are more than 50 sections and each one works on a different part. The grouping into sections is thus a way to horizontally divide the employees according to their function. The sections make up the resource base for the projects in the sense that people are allocated from the sections to different projects. The head of the section is called a *section manager* ("Victor" is the section manager in the section that I focused most on) and it is his or her task to manage this allocation.

Departments and sections seem to be what matters to the engineers. I have never heard anyone talking about their sector manager, whereas the department and section managers are mentioned every now and then. The section manager is the line manager interacting most frequently with the engineers. There are variations within the company of course, but in the section that I have focused upon the section

manager was more or less the only "line-contact" of the engineers. The section manager had, or at least intended to have, weekly section meetings where he informed the engineers of what was going on in the organization. In between the section meetings the engineers talked spontaneously to the section manager every now and then, but there was no frequent contact. In terms of influence over the everyday work, the section manager seems to play a rather peripheral role. As pointed out by one engineer:

> You know ... I don't have that much contact with the section manager really. I mean we have section meetings every week and that's mostly info. [...]
>
> JR: You don't have much contact with him you say...
>
> Not in my daily work. It's very little. Of course, some bullshitting and things like that sometimes ... but in the daily work it's the object leader who's in charge.

The line organization should be seen not as disconnected from, but at least loosely coupled (Weick, 1976) to the engineers' daily work. There are connections, but line activities mainly influence work on a "maintenance level". The section manager allocates the engineers to projects, has "development talks" with them, informs them about what is going on in the organization, is supposed to make sure everything is alright and, within quite limited frames, sets their salaries. In short, the section manager "maintains the resources".

The project organization

"The object", the lowest level in the project organization, is the focus of the main part of my study and therefore it is mentioned first here. When the section manager allocates resources, s/he allocates them to objects. The object is headed by an *object leader* and it is responsible for the development of a certain part of the product. The object leader has a manager who is called a project leader, who in turn reports to program management, which is the top level in the project organization. Transformed into a chart, it looks like this:
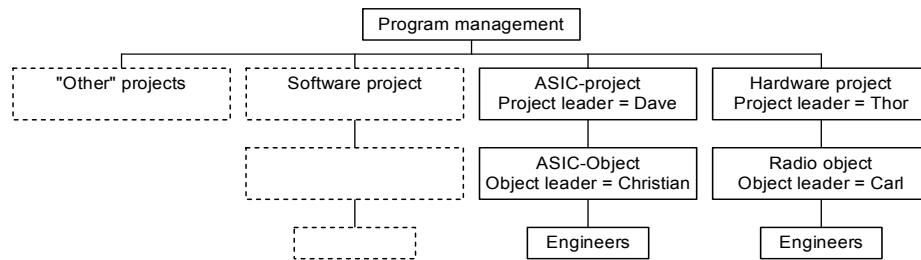
Figure 2 The project organization

The "ASIC[44]-project" and the "Hardware project" are outlined in detail in the chart because that is where this study has been conducted. Most focus has been placed on the object-level, and I shall briefly explain below what an object is by outlining what it is a part of.

Program management, headed by the program manager, decides on an overall level which main projects, or "designs" as they are often called, are to be pursued. This is also where the time frame of the project is set. A concrete way in which "delivery accuracy" is controlled is thus through the formulation of goals in the shape of time plans.

After the general content of the design has been decided upon it is divided into *projects*. A rough division is to say that there are hardware and software projects. I have studied a hardware project, where the project leader is called Thor (see Figure 2). Under Thor, there are six object leaders who are responsible for different parts of the hardware.

This is where the *object* enters the picture. The radio is one part of the hardware. There can be several radio objects, the major reason for this being that the design comes in different versions. During the time of my study there has been one major radio object consisting of between 6 and 12 people (depending on the object's stage in the production life cycle), and one minor consisting of only two or three people, including the object leader. I have focused upon the major radio object, which has been run in different constellations during the time of my study, and where Carl is object leader (see Figure 2).

Running the risk of hitting the molecular level, now let's divide the radio into its components, which are called *"blocks"* at GT. The radio

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[44] An ASIC (pronounced *ay-sik*, and stands for Application-Specific Integrated Circuit) is a circuit (a chip) that can be designed to execute various actions.

basically consists of seven blocks that are developed separately but in parallel. An image of a radio may help illustrate this:
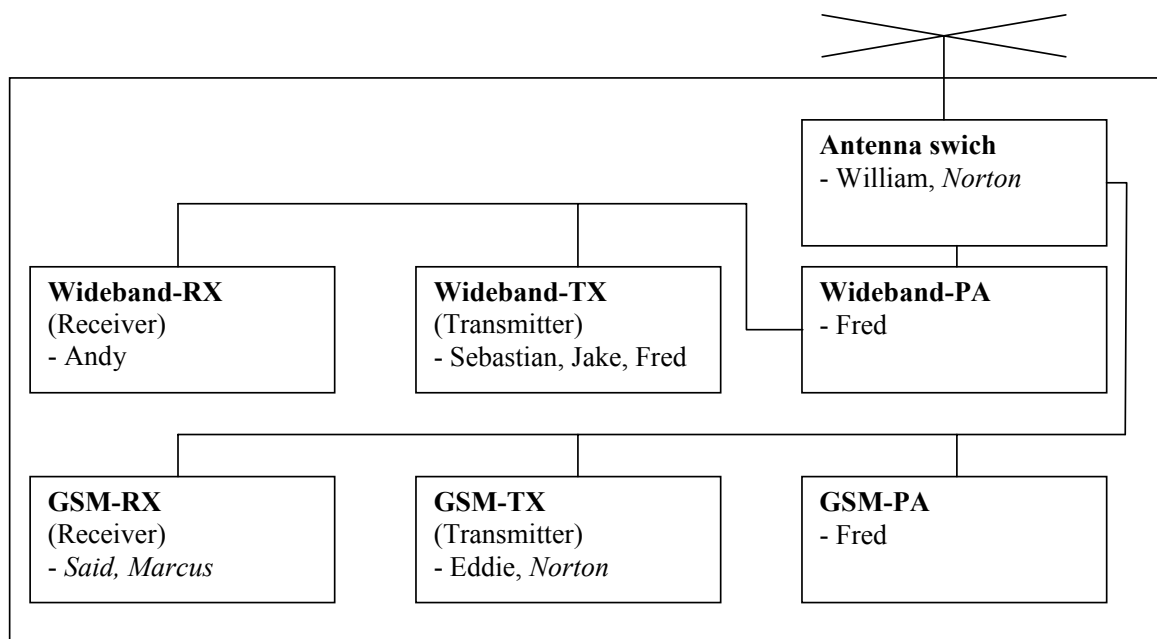
Figure 3 The Radio Object

The "R" in "RX" stands for "receiver", and the "T" in "TX" stands for "transmitter, as indicated in the figure, but "RX" and "TX" are the labels used at GT. (Somebody probably knows what the "X" stands for but after asking two people about it without getting an answer I gave up the project of finding out.) PA stands for "power amplifier". Then there is the antenna switch that leads the reception to the right "band". There are two bands: wideband and GSM. As you can see in Figure 3 there are two versions of the receiver, transmitter and PA. This is because the radio of a modern mobile phone must be able to handle both wideband signals (which is the high-speed communication band that allows for transmission of vast amounts of data within a short time period) and GSM-signals (which is the older and slower but widely used way of mobile communication). The image above is simplified, but it gives an overview of the different components of the radio and how each engineer is attached to one or more components.

One of the main tasks of the radio group is to make sure the blocks work together as a whole. They thus do not design the content of, or the components included in, the blocks. This is instead done at GT's ASIC-department, with which the engineers in the radio group

frequently interact. In simple terms, each block is connected with one ASIC[45]. For example, Jake who is responsible for the Wideband-TX block gets a Wideband-TX ASIC from the ASIC-department and works on it. In broad terms, there is thus one Wideband-RX ASIC, one Wideband-TX ASIC, one GSM-RX ASIC and one GSM-TX ASIC. The ASICs are usually given a name, typically a woman's name. We will for example observe an object meeting in chapter seven where they talk about "Isabel", "Winona", "Wendy" and "Tina". Those are ASICs on which the radio group engineers work in order to make them operate together with other functions included in their product.

As you can see in Figure 3, there are 2-3 engineers working on each block[46]. Each engineer is thus attached to and responsible for a physical block of the radio, which makes "the block" an important source of positioning the engineers organizationally. The detailed knowledge of the block that the engineers develop enhances this positioning. Within a reasonably short time each engineer becomes the "expert" on his block – for example, there is nobody at GT who knows more about the present state and possibilities of the Wideband TX than Jake – and thereby they become more firmly attached to the physical material they work with.

The blocks are not like watertight compartments, however. The engineers are attached to their blocks in terms of responsibility, but there are overlaps between the blocks and the engineers often need to ask each other for help and advice. They talk much about the importance of helping each other and sometimes that means doing each other's work, and sometimes stepping in for each other for different reasons. A reason may be that somebody has lagged behind and needs help, or that they want to have vacations in times when the workload within their area is high.

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[45] In reality one large ASIC may covers two blocks, a solution that is more complex but saves space.

[46] Most of the persons mentioned in the model will be central to the proceedings in the coming chapters. Some names are written in italics. That is because they only worked in the project for about a year and I have not interviewed them.

The hierarchy of the "ASIC-project" (see Figure 2) follows the same logic as the "Hardware project". The work of the ASIC-group will be further described in chapter five.

Related out-groups

The radio group and the ASIC-group both work with hardware. But there are other projects not working with hardware that are connected to the hardware engineers' work. The most important ones are those engaged in software development. The projects with the dotted lines illustrate this. "Software" is a general name for the programs that command the hardware to exert certain operations.

"Software guys" and "hardware guys" (as they often call each other) seem to have a rather vague idea of each other's work. As pointed out by one engineer in the radio object:

> When software people describe the product, they usually draw a cloud, which makes up the hardware, and then they start talking in detail about the software. Hardware people do the same. They draw hardware, talk in detail about that, and then draw an arrow into a cloud which makes up the software.

Although there is relatively little individual interaction between the "software guys" and the "hardware guys" and although their knowledge about each other's work is a bit "cloudy", they are connected in the production process. For example, if the software engineers do not have any hardware to work on, they cannot develop any software. And in the case of the radio group that works with testing how different components work together, the status of the software development is important because if they do not have the final version of the software, their measurements can be nothing but preliminary.

As noted, my object of study is not the relationship between software- and hardware-engineers. But it should be kept in mind that the hardware engineers do not work in isolation, but are dependent on and must coordinate their activities with the development status of other groups in the organization.

After this focus on organizational context in terms of the formal social structure, I shall turn to the context in terms of control of a more

institutional and normative kind, control that is not directed towards any specific piece of engineering work but towards basically all engineers at GT.

Recruitment and socialization

At GT there is a tradition of recruiting young – and probably talented since GT/Global always scores high on the students' list of favorite employers – engineers directly from the technical universities, and in particular from the nearby university in Southtown. It is also common that the engineers start their career at GT already before finishing university, writing their examination paper at the company. As one senior manager points out:

> [T]here is great knowledge of wireless technology here in Southtown, which has to do with Global's early investment in the technical university here. There have been radio courses, which made cooperation possible. [...] We were the only ones at that time and we got the best people from the university, often through exam papers and contacts with university teachers and so on. So you can say without exaggerating that we've got very competent people in Southtown.

Thor, the project leader of the hardware project, gives a good example of the socialization as well as the "cooperation" with the technical universities when describing his background in the organization:

> I started in 1988 at Global in Northtown. It was right after I completed my last high-school engineering course. I only worked for half a year then there were some people encouraging me to go to college. I didn't really plan to go to college at that time, but it was quite good because I could take leave from my work at Global but still work there during the summer and Christmas and so on during my studies. That was good; I was keeping up in the salary adjustments and things like that. Then I wrote my exam paper [at Global] during the summer. So I finished in 1992, as a Master of Engineering in electrotechnics, and then continued working in Northtown. Then in 1994 I wanted to move ahead, develop. I applied for and got a job in Easttown [also Global], but then they wanted me to stay and work with construction in Northtown so we started a construction department in Northtown [instead]. I worked a couple of years and we also started up cooperation with the university, where I did some labs and some teaching. But then in 1998 I was a bit tired of it and my wife was also ready for moving, so we checked this region out and we thought it was ... we knew people

here, so we moved. So I started to work as a constructor, did the receiver at first. In 2000 I started to work as a technical manager. Then GT was created and [shortly thereafter] I was asked if I could stand in only for a few months as main hardware project leader, then it's been rolling on ...

Many of the engineers in the radio group share Thor's background in terms of writing their exam paper at GT and then starting to work there directly after graduating form the university. The engineers working with the radio (see Figure 3) thus make up a quite homogenous crowd. As William notes:

> [...] here people are from the same, they have the same background, almost the same age, and almost everybody has studied electro at the [local university]. So in a way it's better [than at another Global-site where he has worked] because when you start talking about things, if you're to explain something, then you don't need to explain everything from the start. It goes faster this way, but on the other hand, you might not reflect upon why you're doing certain things. (William)

The homogeneity is also noted by a human resources person working with recruitment. He is a bit more critical of the strategy of recruiting people directly from the university, noting that homogeneity is often gained at the expense of diversity and people who "stand out a bit more and question things". He uses the metaphor of a "duck-pond"[47] to illustrate that most people at GT have been formed in the same communities: first at the technical university, then at GT.

> If you have been a volunteer worker in South America, then I find that positive because then you understand that the world is not just about moving from duck-pond to duck-pond, so to speak. [The local university] is a duck-pond. This is a duck-pond. It's sort of ... it's the elite in both places. [...] Many people here are cast in the same mould.

In addition to being a homogenous crowd in terms of educational background and the fact that many of them have started their work career at GT, it should be pointed out that the *level* of education is high. Most of them have a Master's degree in electrical engineering; if

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[47] The Swedish term used is "ankdamm", which is used to signify a safe-haven, a motionless and very limited community which, however, is conceived of by its inhabitants as the whole world. Thinking of ducks in a duck-pond is thought to be illustrative of this phenomenon.

you want a higher education level in Sweden you must go for a licentiate[48] or a PhD. In addition to this they are about the same age – most of them are around 30. At the time of the major part of my study they should all be considered to be fairly experienced. Most of the engineers in the radio group started working at GT around 2000, some earlier and one started in 2002. When I conducted the second phase of my study in spring 2004 all except one of them had thus been at GT for more than four years.

There is thus a process of *socialization* that most of the engineers have gone through, which has been put forth also in earlier studies as a way of controlling engineers (e.g. Whalley, 1986; Crawford, 1989; Mellström, 1995). The university education that is required to gain a Master's degree in engineering gives the engineers access to a common background and experiences[49] as well as common formal knowledge. The education can also be said to be an entrance ticket to an "occupational community" which consists of people who do the same type of work, who identify with this work and who share a certain set of values and norms (Van Maanen & Barley, 1984).

Recruitment practices and socialization at the university are relevant factors for understanding how engineering work is controlled. But it is about understanding control on an institutional level. On an organizational and operative level the engineers are exposed to a different dynamics, to which I shall turn next.

The vertical control of the projects

Once the engineers have finished the technical university and been recruited to GT, they are exposed to the production process. In this part of the contextual framing I will portray the way this process is organized and managed as it is described by those who are thought to manage it: project leaders and object leaders.

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[48] A "licentiate" degree in Sweden is an education level between a Master and a PhD.

[49] See the prologue in Mellström (1995) for an account of socialization activities at a technical university.

As has been noted, there are influential actors outside of the organization who have to be taken into consideration before deciding upon the features and functions of new technology. The 3GPP is one of them and the other external actors with major influence are operators and customers. On a general level, it is the task of "program management" – i.e. the highest level of the project organization (see Figure 2) – to stay informed about external requirements and requests, and then incorporate these into GT's product development process. As expressed by Thor, a project leader, when asked where the requirements come from:

> It's actually program management that try to look into the future and see ... and there they have analyses and things like that ... and our largest operators have much influence [on] what requirements the products are going to fulfill. And they are often very aggressive. So program management breaks down the requirements, what it is that we're going to do, and what we will have inside our reference phones.

Carl, who is object leader and subordinate to Thor, gives a similar picture, arguing that "program management, to a certain extent together with us, decide which different tracks, which different reference designs, that will be produced". The requirements of program management are then formulated in a specification. Thor exemplifies what the requirements may look like:

> We're going to make a reference product that contains this type of display with these colors and that resolution and that camera, we're going to have that MMC, we're going to have a USB-port, we're going to have a certain number of Megabits RAM-memory, flash memory [...] and we're going to have a radio.

These requirements, however, are too general and too many to be applicable to all of the development processes at GT. As Thor notes, the requirements from the product requirement specification need to be "broken down". Thus, Thor says that there is a process of breaking an overall goal down into relevant parts: program management breaks down external requirements and Thor in his turn and in his role as project leader of the hardware project breaks down the requirements of program management. Breaking down the requirements is described as a process where

[y]ou simply write a project specification where you draw up the time plans, which circuits that will be made and how we believe in this. And then they are iterated with the rest of the program, with the planning of software and everything in order to make sure that there's a fit. (Thor)

And once Thor has made his time plan, it is the object leaders' turn to break it down onto the object level, as noted by Carl: "so once it has been decided what platforms to produce, then we [Thor, Carl and the other object leaders] make the detailed time plan." Christian, another object leader, puts it similarly, also stressing the importance of the breaking down process:

You've got to break down the work. You can't just have a start and finish, because then you won't reach the goal on time, but you break it down onto different measurable points.

The process of breaking down requirements is thus thought to filter down through the project hierarchy.

The *importance* of having goals or requirements is also emphasized. Thor often returns to the importance of clear goals:

I try to have one [plan] in Excel in order to get clear, simple goals.

[...] what we're trying to do is to draw it so you get a clear goal, so that everybody can see, and knows where to run.

What I find most important, absolutely, [...] something that I have observed during the years I have worked and it is valid today too, is to make people understand the importance of having clear goals in terms of what to do.

Dave, another project leader, similarly points out how important it is that that people understand what has been specified and what is required:

The requirement specification needs to be clear and comprehensible. I mean, the requirements must be identifiable and measurable, identifiable and unique.

Goals regarding the functions and features of the technology are not enough, however, but it is also put forth as imperative to make people realize the importance of finishing on time.

> What I am trying to do most is to make people understand that it [to finish on time] is important. That's step one. And, "is it ok with you to help out and work this weekend?", sort of. (Thor)

> Times are important; to be on time for meetings and to be on time in the projects. (Dave)

> Yeah, this company is controlled by times to a large extent. That's the way it is in the IT-business, that if you miss the launch date with a week, then it's impossible to regain that volume you know. Then you rather back off a bit on the specification, in order to release the product. So most often it's a matter of times. (Dave)

> This company makes time plans. There are different ways of doing time plans. You can make a very aggressive time plan, and then you put up a risk list: "*this* can happen; what do we do if it happens?" Or you can make a time plan that includes some margins. […] But I think that what we are doing here is probably the most common way to work; to have a rather aggressive time plan, and then a risk list on the side. (Dave)

Dave thus points out the importance of being on time, and tries to practice what he preaches. He says he is always on time at meetings and often points out: "if the management is not on time, why should the project be on time?" Asked how he is working with this, i.e. how he works with setting a good example he says:

> [I] tell them: "hey, now we're late again." I think it's in the walls. It's culture. [...] Or else I go and talk to people face to face. "Where are we today?" "That which we said we would do, are we finished? What has happened?" (Dave)

This activity that Dave is talking about is frequently conceptualized as "follow-up", something that is regarded as a central part of being a project leader.

> I do a lot of follow-up, finding out where we stand, and ...

> JR: So how do you do that then?

> How to do it ... well, you talk to people, you communicate. You can have formal follow-up meetings, like the ones you sat in at, and you

can have informal follow-up meetings, you can have informal follow-up by calling people, walking by people, management by walking around. [...] Checking things out, seeing how people are feeling and so on, how things are going. (Dave)

Yeah, leadership to me is to put up goals and to follow them up. And to have plans that you're following. Thus, putting up goals, having plans that follow up the goals, that's leadership to me. (Dave)

Also Thor points out the importance of following up goals, when asked:

JR: ... so it [leading the project] is about putting up clear goals?

Yeah, I think that's absolutely the most important thing, and then to follow up what happens.

And Christian:

It's about following up. Understanding if we're on track or not. And as support for this I have this tracking list [shows a list on the computer that illustrates how the different blocks are doing] in order to make the designers[50] consider: "What is my status?" [...] A very mean rule is that the interval you've got between the follow-ups, that's the time you'll lag behind.

In sum, the importance of goals is stressed, both in terms of *what* needs to be done (although this "what" is quite general) and *when* it is to be finished. Project management is a matter of formulating, breaking down, and following up goals. The latter is said to be done by checking out how people are doing and trying to convince them of the importance of finishing on time.

Examples of goals tend to become rather technical. On an overarching level there are some general goals – or as the project leader Thor puts it: "they are truths" – which can be summarized as *smaller, less power consuming* and *cheaper*. If we want more detailed goals we may look into the project specification. For example, some of the "top goals" of the project that Thor was leading during the most intense part of my study were:

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[50] Christian calls the engineers "designers". "His" engineers are designing ASICs.

- "[The project] shall deliver a [...] reference design, including the new circuit [called] Steven2 and the new GSM RF ASIC [called] Tina."
- "The reference design should also be based on a modular radio concept. It should have a cost-improved GSM radio and an updated WCDMA radio."

Goals as they are formulated in the project specification are not very specific. The first goal basically says that they shall make sure the *new circuit works* in the design, and the second goal says that they shall make the design *based on a modular radio concept*, and make sure it has a *cheaper* GSM-radio and an *updated* WCDMA-radio. The "breaking down" of goals that Thor talks about is much a matter of making a time plan that points out *when* they shall start and finish different stages in the development process.

4.3 Summary

This chapter has outlined the *general context* in which the GT-engineers work. I have pointed out that the industry of telecommunication has certain standards and requirements – produced within the framework of the cooperation organization called 3GPP – that have to be taken into account when producing telecom devices, and that these standards control the work of the engineers on an overall level. In terms of *organizational context*, I have highlighted management's dual focus upon qualitative and cutting-edge technology on the one hand and customer orientation on the other. The *organization structure* has been described as a matrix with a line- and a project organization, with organizational positions strongly attached to the parts of the product. I have also emphasized that the engineers make up a rather *homogenous crowd*. They share the same educational background and many of them have been recruited directly from the technical university and therefore have no experience from other work organizations but have been socialized into work life only at GT.

In terms of the formal vertical control of the projects, there is said to be a process of formulating goals and time plans that takes place mainly on program management level. These goals are then broken down onto

lower levels. Once broken down, the goals and time plans are followed up by project leaders and object leaders in order to make sure that the planned work is finished on time.

Chapter five

Decoupling vertical control

When the previous chapter focused on the general conditions under which work is performed, the following empirically based chapters (chapters five, six, seven and eight) will shift the focus from the general to the particular; from the context of engineering work on an organizational level to its specifics on an everyday and operative level. I shall thus zoom in the four aspects of engineering work that were brought up in chapter one: uncertainty, knowledge intensiveness, deadline focus and idea intensiveness. This chapter focuses mainly on the aspect of *uncertainty*[51], particularly how uncertainty limits the effects of vertical control and how it is drawn upon to *decouple* vertical control attempts from the practice of engineering work.

The activity of decoupling is understood here not as stopping two systems or logics[52] from being coupled to each other which would mean that vertical control attempts have no relevance whatsoever to the work of the engineers (after having been decoupled). Instead, decoupling is related to the notion of "loose coupling" as referred to by Weick (1976), who notes that two loosely coupled systems are "somewhat attached, but [...] their attachment may be circumscribed, infrequent, weak in its mutual affects, unimportant, and/or slow to respond" (p. 3).

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[51] As noted in chapter one, however, the aspects are not like watertight compartments and more than one will appear in each chapter. The aspect of knowledge appears in all chapters, and in this chapter, the aspect of deadline focus is dealt with indirectly since the follow up is a matter of relating work to the time plan.

[52] By logic I mean a certain version of reality, of how things are related. A logic can be expressed through a rhetoric.

Decoupling is therefore referred to here as the activity of making the coupling between two systems or logics loose[53].

I shall illustrate this decoupling by presenting two at GT typical vertical control attempts. The first and most extensively outlined one revolves around the follow-up-activity at an "object meeting" in the ASIC[54]-group. The other is a presentation and discussion of the error-reporting system at GT.

5.1 Vertical control attempt I – MBO at the object meeting

Background: a rhetoric of management by objectives

In the previous chapter I outlined the formal vertical control of the projects based on interviews with project- and object leaders. In simple and summarizing terms, the vertical control process was described as follows:

1) Program management analyses the external environment, formulates organizational goals based on the analysis and sets a time frame. Goals are continuously followed up at program meetings.

2) Project leader analyses the goals of program management, breaks them down onto project level and sets a time frame. Goals are continuously followed up at project meetings.

3) Object leader analyses the goals of the project leader, breaks them down onto object level and sets a time frame. Goals are continuously followed up at object meetings.

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[53] See also the Oxford English Dictionary that defines the verb decouple as "to make the coupling between [two oscillatory systems] very loose", or as "to muffle the sound or shock of [a nuclear explosion] ...". These definitions also indicate limitation and loose coupling rather than total disconnection.

[54] As a reminder: An ASIC (pronounced *ay-sik*, and stands for Application-Specific Integrated Circuit) is a circuit (a chip) that can be designed to execute various actions.

This description can be seen as informed by a certain rhetoric – i.e. a vocabulary that is used to promote a specific version of reality, of how things are related to each other – that I shall refer to as *the rhetoric of management by objectives* (MBO). As was noted in chapter two, the "common core" of the descriptions of MBO consists of the idea that managers formulate, break down and follow up goals (e.g. Drucker, 1954; Odiorne, 1965; Greenwood, 1981; Rombach, 1991). This is in line with the picture provided by the project- and object leaders regarding the way the projects are managed. MBO can therefore be said to capture the gist of the formal vertical control of the projects.

The vertical control exercised in this first example revolves around the follow-up process. Follow-up of goals is said to play a central role in the vertical control activities. Or as Christian, the object leader performing in this example, put it in the previous chapter: "It [project management] is about following up; understanding if we're on track or not".

The context

The object presented is in the early phase of developing an ASIC that they call "Katla", which will be used in the company's future products. Katla, which is not only the name of the ASIC but also of the object, is part of a larger project called D2[55]. The major improvement that Katla brings about is that it can execute the same actions that in the old design required two ASICs. Katla is an ASIC that controls the radio communication, and when it is finished, it will function as a combined transmitter and receiver of radio signals (see Figure 3 for a review of the parts of the radio). The advantage with Katla is thus related to size but also to money: Katla requires less material and is therefore smaller, and less material is cheaper than more material.

The follow-up activity takes place mainly at "object meetings" which are held on a weekly basis and where the engineers are expected to account for their work status. The object has a place in the formal project organization according to Figure 4.

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[55] "Design 2". "Design" refers to the construction of the entire product, which will be used in mobile phones.
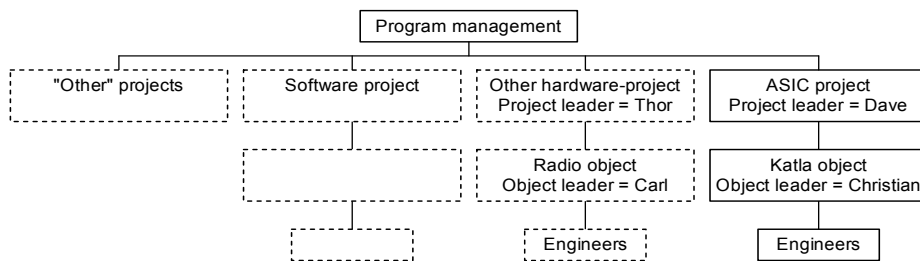
Figure 4. The project organization of the Katla-object.

The figure is like Figure 2 presented in the previous chapter, but with focus on the ASIC-project instead of the other hardware project in which the radio-group works. The two groups are connected in the sense that it is the ASIC-group's products (ASICs) that are later put together, tested and verified by the radio-group.

The formal objective of the Katla-object is described in a "project specification" where the goals, the plan and the organization of the project are written down. The information is rather scarce, however. The goals are to "deliver Katla to the D2-program", to have "fully functional samples" week 42 and to have "final samples available" week 15 next year. Further goals are that the area of Katla must be less than $6mm^2$, the power consumption of the transmitter part must be between 60 and 85 mA and it must be less than 78 mA on the receiver part[56]. In brief, thus, the goal is to deliver Katla at a certain time, it cannot be too big, and it cannot consume too much power. The goal in the project specification is well in accordance with the general goals – the "truths" as they were conceptualized by Thor in the previous chapter – towards which most development of telecommunications is directed: smaller, less power consuming and cheaper.

General characteristics of the object meetings[57]

Object meetings are held on a weekly basis. With few exceptions, it is the same people who take part in the meetings. In the ASIC-group they are:

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[56] Fake figures.

[57] Methodological note: No whole meeting but instead parts of different meetings will be presented in order to illustrate dynamics that are relevant in terms of the operative control of the work process.

Christian – object leader
Alex – specialist engineer, to a certain extent the "brain" behind Katla
Isac – specialist engineer (20 years of experience)
Simon – engineer (2 years of experience)
Nils – engineer (5-10 years of experience)
Marcus – engineer (2-5 years of experience)
Edgar – engineer (2-5 years of experience)

There are some elements that are characteristic of the object meeting. First, there is the explicit presence of a *time plan* that has to be followed and, as we shall see, dealt with. Second, the structure is rather tight and there is an apparent element of *evaluation*. The object meeting is a work meeting that is held on a weekly basis and, in brief, it follows a certain pattern that consists of two parts:

1. *General information*: this is where the object leader presents the information that he has received from his project manager or from other external sources of information, and
2. *Tracking*: this is where the work of the engineers is followed-up/evaluated by the object leader.

The tracking is the most extensive part and where the evaluative elements stand out most. Third, the formal hierarchy is rather conspicuous at the meetings. It is clear and decided beforehand who is the formal leader. Christian (the object leader) is the one who has the agenda and keeps track of the work in relation to the time plan. In sum, the object meeting is understood here as a relatively structured social situation with the purpose to inform the engineers about relevant activities in the organization and to keep track of their work.

Regarding the two parts of the meeting, I will focus here on the tracking part because it contains more interaction between the object leader and the engineers and more features relevant for the study of operative control. The tracking part is of particular importance because it is a process where the MBO-rhetoric is put into practice.

Tracking – checkin' what's up'n askin' for a date

In this part of the meeting Christian follows up the work that has been performed during the week. He uses two lists as tools to support the follow-up: the "action list" and the "block-tracking list". The action list is a document where the "actions" of the engineers are listed. An action is basically a task. An engineer can for example get the action to check up the consequences of a change, and going through the action list is a way of checking how the engineer is doing in the matter. "Block-tracking", then, is more directly related to the time plan, i.e. this list is used to keep track of how the engineers are doing in terms of the planned development work. There are overlaps between the lists of course, but the action list is a bit more of an ad hoc nature, or as one engineer says:

> We've got this action list. We go through it at every meeting and make sure that the issues that have come up ... that somebody is working on them, so that we don't forget anything. [...] Then block-tracking, it is more related to the time plan. We have to deliver a block at a certain time. (Simon)

The longer-term block-tracking list reaches from the beginning of the work process until the "tape-out". The tape-out is like a deadline[58]. It is the time when the databases are ready for delivery; either to "factory" to be manufactured, or to the radio-group that tests the way Katla interacts with other radio components. The block-tracking list looks approximately like this:

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[58] They call it a tape-out because before the time of CDs and DVDs, they stored information on tapes, and when they were finished they took out a tape with the stored information and sent it to the factory. Today they send a data file stored on a disc. What they do, in simple terms, is thus not to construct the actual ASIC, but to construct a database with information that tells the technicians at the production site (factory) in detail how to go about when manufacturing the ASIC.

Block name	Responsible	Work process A	Work process B	Work process C	Work process D	Work process E	Work process F	Work process G	Work process H	Tape-out checks done
Latest delivery date		Week 10	Week 17	Week 19	Week 23	Week 23	Week 24	Week 24	Week 27	Week 29
Vco	Isac	Done	Done							
TX buffer	Nils	Done								
etc ..	etc ..	etc ..								

Table 1. The block-tracking document

As an example of the logic of the document, Isac works on the block named "Vco" and he has finalized work process A (which is due week 10) and B[59]. Isac is thus connected to a physical part of the product, the "Vco", just as Nils is connected to the "TX buffer".

The tracking is often a rather mechanical activity where the object leader only mentions the name of the engineer and the area focused upon, whereby the engineer responsible for the area gives his[60] report – a report that tends to be very brief and technical. In general, Christian just mentions the name of the engineer and the work process on which he works. The information exchange is incomprehensible for an outsider, for example: "Isac. Oscillation TX-out, VCO, specify and block specification ... calculate the sensitivity of [inaudible] and input". The reply is likewise technical, Isac's reply to the question above is: "1,4 Megaherz per 5 FRA in sensitivity".

The brief reports indicate that the engineers seem to know well what is expected of them and they know who is doing what. Their name is sufficient to trigger a report, a report mainly in terms of *what* they are doing, and not so much in terms of *how* they are doing and *when* they think they will finish. But what Christian wants to follow up is less what they are doing and more if they think they are going to finish on time, as he notes: "I have the tracking list in order to make the designers consider, 'what is my status?' [...] They have to consider and then actually report and tell *where* they are, so to speak." These

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[59] The work processes have to an outsider rather obscure names. I refer to them here simply as "Work process A", "B" … etc.

[60] There are no "hers" in the group.

attempts to make the engineers commit to a date are central in Christian's follow-up practice.

Decoupling by infusion of uncertainty

When Christian pushes the engineers a bit, asking them to commit to a date, they tend to reply by stressing the uncertain nature of the work. Below are some examples of this. In the first, we enter the meeting where they have just established the fact that RadioOne, the company they cooperate with in the design of the ASIC, is late.

> Christian points out that the delay of RadioOne gives them some extra time, which they should use. He asks Isac how much time it would take to design a more advanced version of a component called "VCO". "Well, that depends how different it is", says Isac, mumbling. Christian asks if he can estimate: "I mean if you take a guess?" "Well ... a month", Isac replies. "Is it gonna get bigger or...?", Christian asks. Isac says that it will get bigger. Christian then asks cautiously: "How much is it size-wise ... you don't know ... yet...?" "No idea", says Isac. Marcus chimes in with a joke, "Don't you *know* that?", ironically pointing out the difficulty of knowing such thing. Christian tries to get an approximate answer, asking if they are talking 50 % bigger or more, but Isac says that he doesn't "have the slightest clue". "No ...", says Christian, a bit resigned. The conversation is rather slow. Isac mumbles something, and then explains what it looks like technically. Christian wonders, cautiously, about the differences between the old and the new one. Isac explains. It is technical. Alex also chimes in. Christian then says that they have to consider how uncertain the additional work would be and the risk it brings with it.

Another example of the engineers stressing uncertainty is below where we enter the meeting during the tracking round. Christian is following up Nils' work, asking him how the work on the "TX-buffer" is going.

> "Nils. TX-buffer has to be finished next week", says Christian. "I hope...", replies Nils. "Hope ... does that mean that it's possible?", asks Christian. "Yes", says Nils. Christian tries to get a more useful answer, asking if that means that is will probably be finished. "It's on the limit, but I hope I'll be able to finish it", says Nils. Christian seems to be satisfied with that and goes on following up Alex' work. "I have a lot left to do. I'll have to see ... with a bit of luck...", says Alex when asked about his status.

This dynamics is common. They answer vaguely and evasively and make jokes when Christian wants to know something that according to them is unknowable. Another example of mocking the search for definite dates is an engineer who said he can have an "approximate estimate" next week, whereby Alex adds: "plus minus fifty percent".

This stress of the uncertainty of work can be contrasted with the rationalism inherent in the project management process, or MBO. MBO assumes that work is controlled in a rational process. There is an assumption of the possibility to calculate and plan what is necessary to do and to break down and transmit these plans to those who are to fulfill them, and the plans can allegedly be followed up in a "tracking" process where the object leader can inform himself whether everything is running according to plan and whether the goals are fulfilled. This is the logic, and it can be expressed in rhetoric or practice.

The observations offer some examples of MBO put into practice. The use of tracking lists at the object meetings – i.e. on a weekly basis listing the engineers' activities and the time they are thought to be finished – can be seen as an example of the follow-up part of MBO. Christian's activity at the meeting mainly revolves around the lists: he keeps them projected on the screen throughout the meeting, he compares the engineers' status with the progress suggested by the lists and he asks them to commit to a date defining when they will be finished. The lists are tools for putting MBO into practice. It is in the light of the lists that Christian checks what's up, often simply by saying the name of the engineer responsible for the area discussed, and attempts to draw out a commitment to a date from the engineers, often simply by asking when they can be finished.

When this logic of MBO is put into practice at the object meetings, it is confronted by a different logic: that of engineering work. Instead of going along with the MBO-practice, the engineers, as we have seen, stress the uncertain nature of work. They can be said to reply to Christian's follow-up attempts by *infusing uncertainty* into the process. For example, Isac replies to Christian's question about the possibilities of using a new VCO by mumbling: "Well that depends how different it is". And when Christian asks how much bigger the new VCO would be, Isac replies: "I don't have the slightest clue". Christian thus searches

for answers whereas Isac implies that there are none. Instead Christian gets statements such as "I hope [I'll finish]" or "with a bit of luck" [I'll finish]. The uncertainty of work is also implied by the jokes made by the engineers, e.g. Marcus ironically saying "don't you *know* that" to Isac, implying that it is rather evident that it is impossible to know how big it will be.

The logic of engineering work, as it is expressed here, assumes that work is uncertain and complex, that it is impossible to predict the exact outcome of technical solutions and that there are new issues turning up all the time. And as the logic of MBO is expressed in the rhetoric (and practice) of the project managers, the logic of engineering work is expressed in the rhetoric of the engineers (e.g. by saying "I hope" or "it depends" etc.). It can be said that the logic of engineering work is employed by the engineers to infuse uncertainty into the process of developing Katla, a process that may look quite straight-forward and rational if one looks at the time plans and tracking lists or listens to the rhetoric put forth by project managers, but that appears to be much more complex and uncertain if one observes the discussions at the object meeting.

Mutual understanding as enhancer of the engineering logic

Controlling engineering work by rational means such as MBO seems to be a difficult task. The rhetoric of engineering work that the engineers draw upon when confronted with the MBO-rhetoric appears to be highly effective because they seldom really commit to a date, but usually communicate that "it depends" on this and that. One fact that enhances the effectiveness of the engineering logic is the fact that Christian is well aware of the complexity of the work; there is thus a common understanding among object leaders and engineers regarding the logic of engineering work. It would thus be a mistake to assume that only the engineers advocate this logic. Christian too – although in-depth knowledge about the intimacies of engineering work seems to be required to get full access – gives expression to it:

> We're dealing with advanced stuff. It's not like building a house. That's the first thing you've got to learn when you come here, that it is not like building a house. You don't make a gigantic project plan and then do everything and everything falls into place and then you're finished.

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There's such an *incredible* amount of things that cause trouble on the way, because that's a part of the technology.

"It is not like building a house", or in other words, it is not possible to plan and calculate in advance exactly how to go about and it is not possible to expect people to work in line with the plan all the time. The rational process of MBO, of managing work by checking what's up and asking for a date, does not correspond very well with the way the nature of engineering work is conceived of, neither by the engineers nor by their object leader. This common understanding of the complexity makes Christian's role not one of *making sure that* they finish on time, but rather one of *finding out if* they will finish on time. As he states himself when asked what he does if somebody is lagging behind:

> Then I bring out the whip [jokingly]... No, that's what we *don't* do. We don't work that way [resolutely]. The important thing is that if someone is lagging behind, the assumption is that it's not because that person has been lazy, but it's simply because ... we *know* there are problems. [...] So it's important to realize that it's not because that person hasn't done his job, but the important thing, in fact, in *my* role, is to identify that the person might not be able to do this on time. Because if you *don't* follow up, if you don't break it down into smaller pieces, then: "is it in the pipeline?", "yes it's in the pipeline", and then you reach the end and then it's not really at the place in the pipeline where you thought it was. So I guess *that's* my most important role in project management *downwards* actually, to follow up the progress, and to scrutinize it, and to understand that we *are* here now. Or to understand that "we *think* that we are here but we are actually here, therefore we must add some new resources" ... and things like that.

Christian is thus aware of the difficulty of predicting when work will be finished, and he sees it as his task not to push the engineers to reach the deadlines, but rather to find out if there is something *else* that he can do (arrange for more resources, that is) in order to make the project run according to plan. As we have seen, he does not draw upon this logic at the meetings, but on the logic of MBO whereas the engineers draw upon the logic of engineering work. Holding the formal position of a manager, Christian seems informed by (or perhaps even trapped within) the MBO-logic which assumes that work can be controlled by managers in a rational process, but at the same time he appears to accept the logic of engineering work that stresses uncertainty and

complexity and therefore assumes that work can *not* be controlled by managers in a rational process. In the light of the mutual understanding of the logic of engineering work, however, it makes sense to view the infusion of uncertainty is a powerful tool that tends to decouple MBO from the practice of engineering work.

Decoupling by dislocation of the leadership

The difficulty and insufficiency of using MBO to control engineering work is also expressed in the engineers' tendency to base authority on technical expertise rather than formal position. Christian is the formal object leader of the Katla-object. It is he who asks the tracking-questions (i.e. asks the engineers how their work is going), whereby the engineers give their status, often in a very concise manner in the shape of a brief report. If there is something that needs to be discussed, however, there is a tendency among the engineers to turn to Alex instead of Christian, as in the excerpts below.

> Christian is running the tracking round, following up Nils' work. He asks how it is going. "Forward, but slowly", says Nils and adds that the simulation is rather time consuming". Christian makes some more notes and says: "Mmm … the other things that we said we would do here too … you haven't started with that yet … or?" Nils replies that he hopes it will be sufficient to finish it next week. Christian attempts to concretize what it is that will be finished: "Ok, so you'll finish the buffer with the linear mode next week…?". "Yeah", says Nils, and adds, "if nothing happens …", and then turns to Alex: "What do you think?", he asks him, "it looks promising at least, or?" "Yeah …", says Alex. Nils adds that "we do as much as we can so I don't know what to say", then asks Alex a technical question. They discuss what Nils has done. Nils tells Alex about the changes he has made. Alex points out what he believes is the most important thing to do. "It will probably work, but we'll have to check everything once more to make sure nothing has changed", he says. "Eeh … yes", Nils replies. "That takes time", says Alex and thereby finishes their dialogue. Christian makes a note, but doesn't say anything. Isac enters the room. "Let's turn to Isac then", says Christian.

A second example is presented below where Christian initiates the final part of the "tracking" where everybody is asked if they have anything to add regarding the current work. In addition to the fact that Isac turns

to Alex to discuss the issue below, Alex also prevents Christian's involvement in the discussion by dismissing his suggestion by a "no":

> "Let's take the usual round ... anything to add ... any great obstacles?", asks Christian. "Well it's this uncertainty regarding spread[61]", says Isac and turns to Alex. Alex replies and they discuss the phenomenon of "spread". The discussion between Alex and Isac is of an entirely technical character. It lasts for two minutes then Christian chimes in, replying to a question from Isac: "I think the spreads are estimated rather broadly", he says. "No", says Alex, "it's the [technical term] that are much worse than what was modulated", and the discussion between Isac and Alex continues. After a while Christian is yawning. The discussion has lasted for at least 5 minutes. Christian chimes in again, then Alex and Isac continue. After another while Christian says: "Ok, there's a lot of things going on at the moment. No other question marks?" "I think there's enough question marks", Isac replies. Christian chuckles lightly, says "Yeah …", and then continues the follow-up by turning to the next engineer.

In the third example, below, Alex sort of takes over the follow-up and manages to make Isac commit to a date. We enter the meeting during the tracking, and it is Isac's turn to report.

> Christian follows up Isac's work. Isac says he is "not done". Christian asks about his status and receives a very technical report. After a short discussion in which Alex is also involved Christian asks: "When do you think...?". Isac replies a bit evasively: "Well, I mean ... I can do it on the blocks we have today, but now there were some extra stuff added so...". Christian is about to say something when Alex chimes in: "I guess it's rather little, at least it's still the same interface". Isac asks Alex a question about the power. Alex explains in brief. Then Isac says: "Well, sure, I guess I'll have to add those things". Christian then asks again when this will happen. "Next week in that case", says Isac. Alex chimes in again, suggesting a way of taking care of the issue so that Isac will be able to send the document on Monday morning to RadioOne. Isac seems to think that sounds ok: "I try to make that tomorrow then", he says. "Good", says Alex.

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[61] "Spread", or "distribution", means in simple terms that a component spreads its effect to other components. There are 3GPP-requirements as well as firm-specific requirements that have to be fulfilled in terms of the amount of spread allowed. The spread is predicted with simulations and verified in the laboratory. It is sometimes difficult to predict the spread and thereby guarantee that the design will be within specified limit in all conditions (such as different temperatures).

The observations exemplify how the engineers listen to and let themselves by guided by Alex rather than Christian. They tend to turn not to their formally appointed object leader but to a specialist engineer when they need to discuss the time work will take or how to proceed if they have problems. MBO is thus not only decoupled from engineering work by the infusion of uncertainty, but also by the engineers counteracting the assumption of MBO that managers are the controllers.

It is notable that Alex, as opposed to Christian, actually intervenes in the engineers' work by making priorities among the issues they are dealing with. In the first example he tells Nils what is the most important thing to do. In the third example Christian attempts to draw out a date from Isac but does not succeed very well. But Alex intervenes, explaining, basing his argument on technical knowledge which makes Isac "soften up", accept that he has to do it and then commit to sending away his results on Monday morning. When the engineers turn to Alex they tend to be elaborate in their reports on work, whereas they, as we have seen, tend to be very brief in their reports to Christian. This tendency of turning to Alex instead of Christian, and of taking a more generous attitude when discussing with Alex can be said to *dislocate the leadership* from the one with the formal authority – the one who is thought to exercise "Management by objectives" – to the one with technical authority.

Alex does not only intervene in the work of the engineers, however, but also at times in the management attempts exerted by Christian. In the second example, Isac replies to Christian's question if there are any obstacles by directly turning to Alex. Isac and Alex then discuss for a while and when Christian chimes in, his suggestion is dismissed by a "no" from Alex. Thus, in addition to the fact that Isac turns to Alex instead of Christian, Alex also intervenes in Christian's attempt to influence the discussion. The leadership is further dislocated.

Little space for hierarchical leadership

The observations thus indicate that there is little space for hierarchical leadership; little space for the object leader based on his superior hierarchical position to exert any significant influence upon the engineers' work. Christian has quite a hard time making the engineers

commit to a date. This is supported by the interview statements of both Christian and the engineers. In the previous section he said that his most important role is to "follow up the progress" of the project. He also says that

> [...] it's important to make sure that the requirements are fulfilled, but also to listen, that is actually the first thing, the first thing you can do. There is somebody else who understands better what to do. There are those who are better at ASIC-design here than me, so to speak. (Christian)

According to the engineers, there is little he can do. Instead, they convey the impression that engineering work lives its own life as a decoupled uncertain process that cannot be controlled substantially by managers.

> Often, it's the designers themselves who control what they want to do. It's totally acceptable that nothing has happened in a whole week, because there may be things that don't work and so on. So I mean if there are people who don't *want* to do anything, then nothing happens. So it's more a matter of how committed people are and if they think the work is fun. (Alex)

> The atmosphere or drive has been the same with other object leaders, but the same designers. They work in the same way no matter who's putting up or keeps track of the time plans [...]. (Marcus)

> JR: Are there any situations where supervision takes place?

> No, he [Christian] doesn't affect me in that way. He never gives me any tasks so ... I do what I think is necessary. And I and everybody involved in the project know our own tasks so ... if I'm not able to finish my blocks then I inform him and he tries to find resources. Or if I finish early, then I can help others. That's the way it works. You don't need to be controlled. (Nils)

This view is not wholly unambiguous of course. At the same time as they do not see Christian as a controlling agent, the engineers do ascribe leadership-related tasks to him. Edgar, for example, says that it is Christian's task to "make sure that the team runs in the right direction, that everybody is on the right track". Such formulations tend to be sweeping however; it is unclear what it means to "make sure" that everybody is on the right track. But it indicates that – just as Christian – the engineers are not *only* informed by the logic of engineering work,

but also by the logic of MBO. There seems to be a clear bias among the engineers towards the influence from the logic of engineering work, however. The observations and interviews indicate that a lot of the "making sure"-activity is performed by the engineers themselves, and as we have seen, the engineers do not expect Christian to interfere in their work. This is a view that is shared by Christian. When asked what he does, being the supervisor of the group, he responds:

> Yeah, officially that's the way it is [that I am their supervisor]. Formally … then you don't need to work very actively by walking around and supervising more than what we do at this follow-up once a week [i.e. the object meeting]. They know what needs to be done, what they need to check and which quality level is necessary, so to speak.

Thus, Christian's hierarchically superior position seems not to guarantee him the ability to exert much influence over the work of the engineers. In fact, he does not seem to be expected to exert very much influence on work – neither by the engineers nor by himself – but rather to handle the administration of the object. Instead it is Alex, the technical authority in the group, who exerts influence, often called upon by the engineers to do so. As for example Isac points out:

> The most effective way [of leading] is to have enough authority among the ones you're supposed to lead by having deep enough technical knowledge and experience. Then you know that … when he [Alex] says something, then there is a reason for it, he knows what he's talking about.

As in the case of infusing uncertainty to the follow-up process, the engineers decouple MBO from their work practice when they dislocate the leadership from its hierarchic body to a body of knowledge. The MBO-rhetoric, as well as most rhetorics of organizational control, puts forth the assumption that managers are the ones controlling work by the construction, breaking down and following up of goals. For sure, Christian is engaged in the activity of following up at the object meetings and I do not argue that there is no MBO-practice performed; MBO does exist as a control attempt[62]. I just argue that the MBO-

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[62] Of course, there is never one exclusive method of control. Rather, various methods tend to coexist (cf. Storey, 1985; Sewell, 1998; Kärreman & Alvesson, 2004), which however does not exclude the fact that some methods dominate or are better for providing understanding.

rhetoric at best describes what managers are (and think they are) up to, but contains little explanatory power for enhancing our understanding of how engineering work is controlled.

Conclusion

There can be said to arise a *clash between logics* at the object meeting; a clash between the logic of MBO based on rational planning and control, and the logic of engineering work based on uncertainty, unpredictability and complexity. The logic of control thus diverges from the logic of work. The logic of control is argued to be decoupled from engineering work in two ways. First, decoupling takes place by the engineers' *infusing uncertainty* to the process. What the object leader does at the meeting is basically to check how the engineers are doing and asking them to commit to a date when they believe they will be finished. The engineers, on their hand, are reluctant to commit to a date and they often reply to the object leader's questions by drawing upon a different rhetoric that stresses the uncertainty and complexity of engineering work. By infusing uncertainty to the process they, I argue, decouple the operation of MBO from the operation of engineering work. Second, decoupling of MBO takes place by *dislocation of the leadership*. The observations of the object meetings exemplify how the formal hierarchy-based relationship between manager and engineer is replaced by another, knowledge-based order. During the follow-up practice, the engineers listen, turn to, discuss and comply with a specialist engineer with in-depth technical knowledge rather than with their formal object leader. By dislocating the leadership they, I argue, decouple from their work the operation of MBO, which builds upon a vertical division of labor with superiors following up subordinates' work/goals.

5.2 Vertical control attempt II – formalizing problem-solving

The frequent use of object meetings is the most apparent example of attempts to vertically control operative work. Another example where hierarchy plays, or is intended to play, a central role is in the way technical problems, or "errors", are handled. At GT, there is an error-

reporting system that is called "Guido", which is a database to which errors are to be reported and through which changes are thought to be managed. In the project specification for the D1-project it says: "All error-reports inside D1 shall be reported in the Guido. It is the responsibility of all project members to act on assigned error-reports."

In brief, Guido is intended to function as follows: If somebody finds an error or a problem s/he is expected to, via the database, write a "change request" (CR) to the "change control board" (CCB) which approves or disapproves of the request. The CCB is inhabited by both experts in different fields and people with a good overview of the development process (e.g. project leaders). The idea is that if a CR is approved, it is forwarded to the engineer responsible for the issue via Guido. The engineer works with the change and then reports it back to Guido, and if the change is approved again by the CCB, it can be formally documented in Guido that a change has been made.

Following the description made above, the management of changes seems to follow a formal sequence where the CCB takes on the role of an "expert board". In practice, however, the dynamics looks a bit different. Often, the way via the CCB is more a ritualistic turn than an actual check. Jake, one of the engineers in the radio-group (see Figure 3), exemplifies this when we discuss a situation where he discovered that an ASIC did not fulfill the requirements.

> Well the [circuit] did not fulfill the specified requirements and what you can do then is to change either the circuit or the specification, and this time they [the ASIC-people] asked if we could change the specification instead of the circuit because that's a smoother solution. So what I did was an investigation to see if we could loosen up the specification in terms of the systems aspect that I am good at. And I saw that we could. So I told them that they could change their specification, but I did that by saying that they have to make a change request on the specification.
>
> JR: To the CCB?
>
> Yes, to the CCB. And that's where Thor[63] comes into the picture. Because he's the one who makes the approval in the CCB. And after he has approved the request, that I have asked ASIC to write, then we can

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[63] Thor is the project leader of the hardware-project, as was outlined in Figure 2.

update the specification, and then I can update *my* specification too. [...] And then everything will look fine.

JR: So you ask ASIC to make a change request, and then it's approved.

... eh, it's not approved of until I say, "we can approve this".

JR: Ok, you're supposed to say that it can be approved.

Yes.

JR: But what about Thor?

He's not ... he's just a formal ... button.

Yeah. So he's just supposed to sign?

Yes. I say ... "write approved", to him.

JR: There seems to be quite a lot of this "sign here"-thing.

Yes [laugh]. Oh yes. Sometimes they don't even sign. There's a lot of ... that they don't even get in contact with the document. I think they get some sort of mail where they can check what they have approved [laugh].

What happened in the example above was thus that Jake discussed the issue with some people at the ASIC-department, who asked if it would be possible to change the specification and still fulfill the general requirements. Jake investigates the issue and finds that it will be possible. Instead of just changing his own and the ASIC-group's specification, however, Jake – along with the Guido-requirements – asks the ASIC-group to write a change request (CR) to the change control board (CCB) so that the board can approve of the change. The board gives its approval, an approval that is formally given by Thor, but in practice it is given by Jake who tells Thor to sign the document, to "write approved". According to Jake, as we see in the quote, this sort of parallel communication – one formal and one informal – is quite common.

Another example of how the formal use of Guido has to make place for a more informal and horizontal way of working comes from my shadowing of Jake. He worked on an issue where he "got a Guido" that indicated the need for updating some measurements. The formal way of working here would be that the CCB checks the change request and

then either approves or disapproves of it. Instead of waiting for a decision from the CCB to get approval, however, Jake catches Thor, who is a member of the CCB, when he walks by in the lab to get some sort of approval right away. The reason for this, says Jake, is that there is no time to wait for the next CCB-meeting.

In sum, Guido is another example of an attempt to vertically and rationally control the work process by creating a form that requires the engineers to report the status of their work to managers. The effect of the attempt is ambiguous in terms of vertical control, however, as it seems to be either loosely- (Weick, 1976) or un-coupled to the practical work. First, the supervisory element in the problem-solving process seems to of a ritualistic kind. It legitimizes vertical control as necessary for successful engineering work, and perhaps informs higher management about what is going on. There seem to be two parallel discussions going on when a problem is to be solved or an error is to be corrected: one where the engineers discuss what needs to be done, and one where the CCB-people (Thor in the observation presented) are informed. It appears to be the former that actually controls the proceedings of the problem-solving work. As Jake noted when asked about Thor's and the CCB's role in the process: "He's just a formal ... button." Second, it seems like the actual system – where change requests are expected to be sent to the CCB and the CCB is expected to make a decision – is a bit too slow to actually function. The formal decision making process tends to be circumnavigated by the engineers who take the faster, informal and seemingly more efficient horizontal way. This, as was the case with the follow-up at the object meetings, stresses the difficulty of vertically and rationally controlling an uncertain and complex process such as engineering work.

5.3 Conclusion

This chapter has stressed the aspects of uncertainty and knowledge and how they tend to decouple or be used to decouple vertical control attempts from the practice of engineering work. The decoupling of vertical control from engineering work, I argue, is connected with the existence of a discrepancy between the logic behind the vertical attempts to control work and the logic of engineering work itself. The

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vertical attempts assume that work is a rational process whereas the logic of engineering work instead stresses uncertainty and complexity and the fact that new problems tend to turn up all the time.

Two examples have been given to illustrate the decoupling. The first is an object meeting where MBO is practiced. MBO builds upon an assumption that work can be rationally followed up, i.e. that the manager can inform him- or herself about the status of work and control the engineers' work so that it is aligned with the time plan. This proves difficult, however, because the engineers tend to decouple the vertical control by *infusing uncertainty* into the follow-up process. Thereby they escape the demand that they account for their work and commit to a deadline. The infusion of uncertainty is portrayed as a powerful tool, not least because the logic of engineering work is understood by *both* the engineers and their object leader. The practice of MBO is also decoupled by the engineers' *dislocating the leadership* from the hierarchic body of the organization to a body of knowledge. This means that the formally appointed manager is placed in the periphery whereas the technically most knowledgeable engineer is turned to for advice and discussion.

The second example of a vertical control attempt is the use of the error-reporting system "Guido". Guido builds on the requirement to let changes go via a "change control board", but behind the systematic façade of Guido the correction of errors seems to be taken care of through horizontal communication between the engineers. The control attempt of Guido can thus also be said to be decoupled from the practice of engineering work. What Guido does, however, is to 1) give management the possibility to interfere, for they do have that *possibility* given that they know what's going on, and 2) *legitimize* management control as a necessary feature of engineering work.

I have thus argued that it is difficult to vertically control engineering work. The observations in this chapter indicate that the control of work tends to be based on horizontal rather than vertical relationships, something that will be expanded upon in the following chapters.

Chapter six

The use of knowledge

In terms of the four central aspects of engineering work argued for in chapter one, this chapter focuses on the aspect of *knowledge.* It will be illustrated how specific engineering knowledge is used to perform engineering work and how this use has consequences for the way in which work is controlled. In particular, I shall argue that it is more rewarding to understand operative engineering work as controlled by *self-control* (see also Whalley, 1986; Crawford, 1989) and, particularly, *horizontal control*, than as vertically controlled by MBO, by managers who formulate, break down and follow up goals. This argument is pursued by presenting a common day in the work of "Jake", an engineer in the radio group.

6.1 Intro

The main character of the workday is "Jake". He is about 30 years old and in early 2004 when the shadowing took place he had worked at GT for 5 years. He works in the radio object and his object leader is Carl (see Figures 2 and 3 in chapter four). As many of the engineers at GT, he wrote his examination paper to become an electrical engineer at GT, which resulted in employment[64]. Asked what it is that he does, he says: "I make sure that my part of the radio works, and that means that I give feedback to those who produce the things that I apply in the radio". The reader hopefully remembers the description offered in and around Figure 3 in chapter four. "My part of the radio" refers to the Wideband-TX (transmitter) block, and "those who produce" refers to

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[64] As noted in chapter four, this has been a common recruitment strategy at GT. The company offers good students the opportunity to write the exam paper on some technical problem that GT works on. After finishing their degree, it is common that the student is employed by the organization.

the ASIC-department (for example the people in the Katla-group observed in the previous chapter) that designs Jake's block.

A note on the method of presentation

As pointed out in chapter three, I followed Jake for a week and not for a day. But instead of presenting a whole work week – which would take up too much space and not offer the same possibilities of getting into details – an example of what a workday can look like will instead be presented, based upon the five consecutive days that I shadowed Jake. One single workday will function as the base of interpretation, but when it is necessary for the depth of understanding – mainly because the activity continues on the following day – I will make some excursions into other workdays. This approach is intended to give a general picture of a workday in the radio group.

I shall first present a whole day in brief. It is a typical workday. After that initial "briefing" I shall – by making some "close ups" – outline more in detail some episodes that are of special interest because of their capacity as illustrations of engineering work and the way it is controlled.

6.2 A day at GT

Jake arrives at GT just before nine o'clock. He seems tired; he looks like he has been hurrying. He has a meeting at nine, but before going there he grabs a cup of coffee from the coffee machine and chats with Carl who is also in need of coffee. Carl laughs at Jake's drowsy appearance. At 09.06 Jake enters the meeting room. The other participants of the meeting, Chris and Lars, are already there, discussing. Lars belongs to the ratio-group and Chris belongs to the ASIC-group, the group that develops most of the circuits that the people in Jake's group then put together into a radio. The meeting is about the future design[65] – Design2 (D2) – and they discuss different solutions. There is no discernable leader of the meeting, except for the fact that Chris has a lap-top, which is common among senior people or people who hold a meeting. They discuss for about one hour, and then they decide that Lars and Jake will – until tomorrow, when they will

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[65] As noted in the previous chapter, "design" refers to the construction of the whole product.

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meet up again for further discussion – come up with five suggested solutions each to a technical problem.

10 AM: After the D2-meeting, Jake goes for another cup of coffee and then walks directly to another meeting – a review. One of Jake's colleagues, Eddie, has done some tests that are reviewed.

10.45: Jake walks over to Fred, a colleague who works with the Power Amplifier of the radio. They discuss how to go about with a pre-study on a potential improvement of the Power Amplifier-solution. It is not quite clear to Jake when he is expected to start working with the pre-study and he tries to find out by discussing with Fred. The situation does not become much clearer, however. They have different opinions about who should do what.

At 10.58 Jake is back in his office. It is time for lunch. There is a group of people who always have lunch at 11.00. Jake does not necessarily go for lunch at this time, but today it fits his schedule. We go to the company restaurant located on the ground floor of the building and the natural lunch place for basically all GT-employees. Jake takes a seat at the usual, large table where everybody in their section sits. They talk about this and that – work, motorcycles, diving. After lunch they walk up one floor to the coffee area, which is situated right outside their office and lab-area. At the after-lunch coffee the discussion topics become more diverse: breast milk, can men be pregnant? a competitor, is there a Norwegian trend? (two people in the group have Norwegian girlfriends), introduction of 'naked Wednesday' etc…

At 12.05 Jake is back in his office. He goes through some old mails with information that he needs. At 12.40 Neil, who works with customers support, comes over to Jake's office to discuss a customer who has problems with something that only Jake has detailed knowledge about. Neil wants Jake to improve the prototype in a certain respect, which requires some new calibrations. They talk about how to make the improvements.

At 12.55 Neil leaves and Jake starts working on a "link budget"[66] because he "got a Guido"[67] on updating it. There are some figures that

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[66] A link budget, which is made by the engineers, is a simulation of how all the blocks work together. It contains block specific requirements and you are able to see theoretically how and if the components work in line with performance requirements. When you *make* the budget, you determine the requirements on each component.

[67] See chapter five for a description and discussion of the error reporting system "Guido".

Jake thinks are "unnecessarily pessimistic" and he inserts new, "more realistic" figures. Except for an interruption where a colleague comes to his office and they walk away for ten minutes, Jake works on the update of the link budget until 13.45. Then he switches to the program that handles Guido and reports the work he just performed.

14.19: Jake goes over to Andy to ask for some advice on lab-work that Jake is about to start. It is measurements in order to finish the APA[68] on Winona that Jake and Andy have worked on for a couple of months. They discuss for about ten minutes, then Jake works in the lab for three hours.

At 17.39, back in his office after a quick cup of coffee, Jake says that he is going to be creative. He starts a drawing program and starts outlining the five solutions to the problem that was discussed at the D2-meeting this morning. He is finished at eight o'clock. There is nobody left at the department when he leaves a little after eight. Jake is used to this silent atmosphere and he likes it. When we leave the building he says that he thinks it's great fun making things work in the lab as he did today. Then he rides home on his bike.

6.3 Some close ups

The workday presented includes a large number of activities. Not all the episodes presented will be treated in more detail; some are there to illustrate what a workday can look like. Others, however, are of special interest because of their proximity to and particularity of the engineering work observed in this study. These episodes – idea-work, lab-work and review-work – are presented in more detail as representations of typical types of engineering work with the purpose of providing a basis for understanding what Jake does and how his work is controlled.

The relationship between the work types can be described in terms of their position in the production process. It is possible to think of the production process as follows:

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[68] As you recall from chapter four, the APA (application approval) is a test procedure performed by the engineers where it is made sure that their products fulfill the requirements of the international standards of 3GPP.

- First there is "idea-work" that gives rise to theoretical constructs of how to develop something new or improve some piece of the product.
- Then there is "lab-work" to test and measure how the ideas work when actually applied in the real product.
- And last there is "review-work" where a group of people scrutinizes the quality of the lab-work.

Such categorization increases the sense of context, but is of course idealized. All work types take place all through the project: new ideas may turn up late, lab-work is carried out continuously until the product is finished and, as a consequence, so is review-work. Still, it is logically impossible to test an idea in the lab before it exists, and likewise to review lab-work before it has been carried out. In this sense there is a sequential element to the work process. Also, idea-work is more common in the beginning of a project, and review-work is more common at the end.

Working with ideas – exploratory work in D2

In order to avoid confusion, it should be pointed out that there are two episodes of work presented below which both belong to the D2-related work[69], but only one of them belongs to the workday presented. First Jake's work on finding out possible solutions on his computer at the end of the workday is presented, then comes the D2-meeting on the following morning where they discuss the different solutions that Jake and Lars have come up with.

Working out solutions

At 17.39 in the brief version of Jake's workday he goes back to his office after the lab-work and starts outlining possible solutions to the problems discussed at the D2-meeting in the morning, in order to have five possible solutions to present at the meeting the following day. We enter the observation when Jake is working on the solutions.

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[69] As a reminder, D2 (Design 2) is a project that recently been started up and is thus in its initial phase.

"Now I'm working in D2", Jake says while starting up a drawing program, adding, "I'm going to be creative now". He draws something that looks like a banjo. It only takes about ten minutes before the first solution is finished. "We're going to do this without involving him", he says. "Who?" I ask. "Chris Sharma"[70], says Jake and explains that they need five concepts that don't use Chris' components because those components are time consuming. It is thus not Chris himself but Chris' components that Jake has in mind.

"Damn, this is fun!" says Jake at about 18.00. "Write that down!" he then instructs me, laughing. We go and get some fruit, and then Jake continues working. At 18.37 he has three different solutions. "Damn, this is quick work", he says enthusiastically. Then he sits down to think, at least it looks like he is thinking, and he says "yeeah" after a couple of minutes and starts drawing again. At 18.54 he seems to have finished the fourth concept and he looks down at the floor, as if searching for inspiration. It does not seem to work that well this time and at 19.00 he is browsing through a book, seemingly searching for inspiration. At 19.05 he starts drawing again, it seems to work fine, but he looks a little tired. At 19.14 he sits staring into space, so to speak, but then he suddenly exclaims, "that's right!" and starts tapping on the computer. I come to think of professor Baltazar – the Yugoslavian cartoon figure who very serious-looking thinks and thinks while he is walking around in circles and then suddenly gets an idea that makes him jump and a light bulb pops up above his head. At 19.26 Jake does thumbs up, smiles and says, "that's five". I point out that he was a bit slow at the end. "You get exhausted, five brilliant ideas like that, to order!" he says jokingly. Then he adds more seriously and with a streak of self-criticism that it is actually wrong to say five because the last one wasn't very good. Before Jake goes home he starts up a measurement in the lab that will run overnight. He leaves at a little after eight.

D2-meeting

The next morning at 09.00 they meet up to discuss the suggested solutions. Jake, Andy and Lars are there from the radio group, Pavel is there from the ASIC-group and there is Jaime from the system group[71].

Lars starts by presenting his design solutions. The others watch his design. First there are only a few questions and Lars answers and explains, but soon the presentation develops into a discussion. The

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[70] As a reminder, Chris Sharma belongs to the ASIC-group that designs the ASICs that the radio group put together into a radio.

[71] People working in the system group concentrate on drawing up and dealing with the requirements on the product.

language is very technical. It goes like this: "When power detection is connected you will only get ER", or "If you think like this, if the DAC takes one dB, then …".

It is not possible to understand in detail what they are talking about, but it is possible to catch some of the dynamics. Below I have exchanged the most impenetrable vernacular for "[technical description]". They discuss one of the solutions presented by Lars:

Lars: The problem is [technical description].

Jaime: What is "gain expansion"?

Lars: It's [technical description].

Jake: That could become instable.

Lars replies.

Jake: My idea was that [technical description].

Andy: Yes, you have a regulator.

Jaime: Mustn't you have exactly the right effect?

Jake: No. It's [technical description] that makes the dimension.

Jaime: So it's [technical description].

Jake: Yes, it's [technical description].

Lars: There's got to be another way to run this. You can [technical description].

Jake: Ahh, it's got to be 0,05.

Pavel: What's the biggest error you're allowed to have there?

Jake: You can't deviate more than 2 dB … [technical description] … that's the requirements.

Etcetera …

They go on like this for about an hour. Then they take a coffee break and continue discussing while getting their coffee from the machine. Lars addresses me once regarding the topic of the their discussion in a way that makes me wonder if he has forgotten that I am not an

engineer. After the short break they return to the meeting room and continue. The discussion is quite intense.

Jake presents his suggestions and they discuss them for quite a while. It is about 10.30 a.m. when Andy goes up to the whiteboard asking rhetorically, "can I just draw a picture...?" He draws, and he explains how the power runs. He gets a bit uncertain at one point, saying "how is this going to...?", whereby Lars and Pavel come with some suggestions, which seem to get Andy started again. When he is finished they start discussing the design in the same manner as before. After some discussion it gets silent, and Andy puts down the marker and walks back to his chair. "That's a suggestion", says Lars in a positive voice. "I don't quite understand", says Jaime. Andy replies: "The idea is pretty clear to me but I find it a bit hard to explain". They start discussing again and soon Andy is back at the whiteboard. They discuss for about ten more minutes.

Time is starting to run out. It's 11.00 and the meeting was scheduled until 11.00. "I don't know, do you think this is totally way out?", Andy asks. "Absolutely not", says Lars. "I don't think it seems to be way out...", says Jake. Lars tries to tie the whole thing together, telling Andy: "your ideas are quite fun ... good ideas. Why don't you make a design out of this and present it next week. And Jake, you've got some additional concepts. Why don't you two talk about this and present something together."

Then Lars has some "further action points" that he goes through quickly. He gives one action[72] to Jake and he asks Jaime if he can take one action or if Lars should take it himself. "I don't have very much info", say Jaime. "Then I'll take it", says Lars. "It's getting *very* late", Jake points out [11.25]. "Yeah, let's go", says Lars, adding, "I think it was a quite good discussion". Jake agrees.

When we leave the meeting I ask Jake who the object leader is. "Yeah, I'd wonder that too", he says and smiles. There is nobody who is the object leader, according to Jake. We go for lunch.

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[72] As briefly noted in the previous chapter in terms of Christian's "action list", an "action" is a commonly used term for "task". You can give an action and you can get an action. There can also *be* and action *on* something. In this example, when they say that they don't think they should have any action on it, they mean that they don't think it is necessary to bring this up and have somebody take a look at it. The term will turn up and be further discussed in subsequent chapters.

The following day, after lunch, Andy tells Jake that he has a solution to the problems discussed at the meeting yesterday. They go to Andy's office and Andy explains. The discussion goes like yesterday. Both Andy and Jake draw on the whiteboard. Jake thinks it looks good, "we got to continue playing with this, it's really cool…", he says. Andy seems quite satisfied too. They finish after about an hour. Jake says, "Good Andy, maybe it's going to be like this". Then he leaves.

The work presented here can be characterized as "idea-work". There is a clear exploratory element and the degree of formalization is low. There is no obvious system of control that guides the work, and Jake's work with the suggestions as well as the following meeting almost resemble brainstorming exercises. Hierarchy appears to be absent at the meeting except for the "action-giving" performed by Lars at the end and if positions matter they are grounded on area of expertise rather than formal authority. Thus, the proceedings of work rely on horizontal rather than vertical relationships. Regarding the elapsed project time, the idea-work presented takes place in the beginning of the project's life.

Lab-work – autonomous action

Lab-work – making measurements and tests of different kinds – is a common activity among the engineers at GT. Among the people in Jake's group, measuring usually means testing how different components work when they are combined with other components and software. Below is a presentation of Jake's lab-work in more detail. As you remember from the concentrated version of the workday, Jake walked over to Andy at 14.19 to get some advice on the lab-work in order to finish the Winona-APA (see chapter four for further APA-details). That is where we enter this more detailed version.

Jake and Andy update each other and sort of make a scenario analysis, discussing the measurements that Jake needs to do. Although Andy has done something similar before, they realize that it is the first time they do exactly these kinds of tests. "Then I'm going to be a pioneer", Jake says cheerfully and walks over to the lab and starts connecting a washing-machine-looking device to a computer. The "washing machine" is called a "temp-box" and it can adjust its inside climate in various ways depending on the way it is programmed. Jake places the prototype inside the temp-box. What he wants to do is to measure the interaction between the different components in different

temperatures. Jake taps on the computer. After a short while he starts sorting out the cables. The measurement itself is automatic but it needs to be set up. "Ok, how the hell am I going to do this", says Jake, holding a number of cables and some other things in his hands. Then he leaves, and comes back with a new cable.

A colleague stops by and talks with Jake for a few minutes, jokingly pointing out that he is impressed by the way Jake is managing the computer. It is necessary to program the computer for the measurements to start; rather far from "plug and play", thus. Thor, the project leader (see Figure 3), comes by and he and Jake discuss how to handle a Guido-issue. It only takes a few minutes. When Thor has left Jake crawls down under the desk, messing with the cables.

It is 15.53 and Jake is reading a thick instruction manual of some kind. I ask if the book says how to go about with the measurements and Jake replies that it "sort of" does, but that it doesn't say what to do if you have a problem. Five minutes later he has finished the first part: to create an environment where the measurements can be made automatically. Now he is going to write a program so that the computer automatically fetches the information from the measurement instrument (the temp-box). Jake works on with the programming for quite a while.

At 17.22 Jake seems to be finished with the lab-work. The measurement instrument starts at his command and the numbers on the display are correct. He does some more programming and at 17.33 he says, "damn, this really went on well!" and puts the temp-box on minus 30 degrees Celsius. The temperature will slowly rise up to 50 degrees and the computer will continuously fetch information to measure the behavior of the prototype phone in different temperatures. Jake goes to the beverage machine for a cup of coffee, and a few minutes later he is back in his office.

On the following day, Jake goes over to Andy to show him the result from the measurement and Andy shows Jake the results from his previous measurements. They discuss, they analyze and they compare. There is a slight problem with loss of output power in high temperatures but they don't think they should "have any action on that" because it seems not to depend on the measured component. They seem satisfied with the results. This is understandable because it was the last measurement that had to be done before the completion of the Winona-APA. Now Jake only needs to finish a document that represents the measurements and have the work reviewed by some colleagues.

The laboratory is the place where all measurements and tests are made, and it is therefore the place where the basis for all documentation is produced. Lab-work is a fairly common activity – during the week I shadowed Jake he spent about 8 ½ hours working in the lab[73] – and I shall outline a few of its characteristics.

One characteristic is that lab-work builds on *horizontal relationships*. Lab-work is largely carried out on an independent basis, but when help is needed it is colleagues who are asked: Jake needs to consult Andy (a colleague) before, during and after the measurements because Andy has done similar measurements. It is thus not a managerially supervised activity. Jake knows in broad terms what to do and who to talk to, and this "who" is not a manager but another engineer: Andy. It is also Jake and Andy who conclude that it is not necessary to "have an action" on the "slight problem" with output power they found.

This aspect of "helping each other", as the engineers refer to it (which was also touched upon in chapter four), is put forth as a natural part of work by the engineers, as for example one engineer notes: "it's sort of a cultural thing that you don't say no when somebody wants help", or another: "... even if I have ten emails to write and five phone calls to call ... if someone asks something, I want to help out you know". Instead of being supervised by managers, the engineers thus cooperate to solve problems and make decisions of how to proceed with their work.

Another observation is that lab-work is rather *complex and knowledge-intensive*. Jake does not know quite how to do the tests at first but he gradually figures it out by reading manuals, which however do not tell him how to solve his problems. Jake thus needs to be familiar with the instruments, which are *not* like washing machines but rather complex devices that need to be programmed before they will perform the desired activities. He must also be able to improvise because this type of measurement seems not to have been done before and there are no exact instructions of how to tackle it. It is hard to illustrate what is required to work in the lab, but Carl, Jake's object leader, puts it quite

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[73] Monday – 4 hours; Tuesday – 2 hours; Wednesday – 30 minutes; Thursday – 2 hours; Friday – nothing.

well when asked what it is that Jake can do that, for example, the author of this book cannot:

> [Laughs] What it is he can do? Most of the time it's complicated enough for you to need some sort of strategy for how to do it. He may need to measure the behavior of different blocks in different temperatures. He needs to collect a bunch of data so [he can understand] that "based on this characterization, the fact that it behaved in a certain way, I want to choose the following setting". He must be able to evaluate previous test results so that he knows that when the amplification decreases, the temperature will change in a certain direction. He must have the link budget under control. He has made a theoretical calculation prior to the tests, what the results *need* to be, what the performance *needs* to be. Then he wants to fulfill the requirements by programming the circuit in the right way. And what's right; there he fetches data from some sort of characterization of a block. It can be output from a simulation too, he may have to read simulation data for how a certain block spreads[74]. It may also be a matter of analyzing statistics. He must have a good picture of the requirements on the entire system, and then be able to break them down onto this tiny little amplifier in order to know that it's good enough [when it is used] in the whole application. So it requires knowledge about the system … plus some feeling too … in fact. Because it's not entirely digital. Because it moves a little. That requires good, comprehensive knowledge.

Jake not only knows "how to" perform various tasks, however, but also "how good" the result is supposed to be, as it were, and the norm seems to be "good enough" rather than "as good as possible". As he states when describing the link budget that defines the requirements on the different components:

> [Making] a budget means that I link the requirements from several components and define how much shit [e.g. spread] each component is allowed to contribute with … as much shit as possible, then, in order to precisely fulfill the requirements, the top requirements, in the end. Because otherwise there's sub-optimization you know. if you're doing things that are unnecessarily good.

It is quite apparent that a fair amount of knowledge and expertise as well as communication with colleagues are required to work in the lab.

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[74] As you may recall from the previous chapter, "spread" refers to the extent to which the effect of a component spreads to (affects) other components.

Another thing that is quite apparent about the lab-work is that Jake enjoys the experience of it and is committed to solving problems in the lab, as he points out when leaving the building in the evening. In short, lab-work is complex, knowledge- intensive work whose forward movement is based on horizontal relationships.

Review-work – peer controlled output

Review-work is carried out during the major part of the project's life and it is formalized to the extent that there is a formal requirement that reviews are held. But what, then, is a review and how does it work? I will let the engineers and their immediate managers explain in their own words. Carl:

> It simply is that, when one man, or it can be cooperation between several men, that you have reached a certain level on this [work] and you want to make a document that you want to distribute to others, you want it as a reference. Then you bring a crowd together, everything from one person to several, who in some way have the competence or are affected by the work you have done, and then you ask them to scrutinize the work. And the purpose is partly to detect errors and partly to detect things that are missing; that you discuss the result at a certain point in time with some people who should be competent to produce sensible feedback.

Sebastian, one of the engineers in the radio group, gives a similar explanation.

> There is one thing that is more developed here than where I worked before, and that's the fact that we have reviews on everything. In the beginning I thought it was quite ... a bit unnecessary or it felt a bit annoying, but it is quite good. Because if I have written an important document, then I must have a review before I release it, before I publish it so to speak, where others can give their points of view. And it's not only criticism, somebody pointing out mistakes, but there are also new things added. "Maybe you should include this" and so on. So ... I think it's good that we are several people who scrutinize the documents that are released. Otherwise you could ... it's easy to make a mistake you know ... and if there is only one person who's been working on it, and if he has made a thinking error, there can be serious consequences for the ones who read the document. I think it's a good way of working. Before you let go of something you're several people who go through it and look at it ... although it takes quite much time.

And Jake's statement regarding the role of reviews is in line with Carl's and Sebastian's.

> A person can make mistakes and it [the review] is about having several eyes directed towards the problems in order to cover up for the possibility that you miss something.

In addition to the descriptions presented above, it could be said about the review that it makes up a central feature in Jake's and the other engineers' work. Many types of work are reviewed. There are reviews on basically all lab-work. And as Carl puts it, there are reviews on "everything from verification reports to requirements on a component, link budgets … anything is reviewed". In order to fill "anything" with content, it could be added that also APA-work, time plans and CAD-drawings[75] are reviewed. Reviewing is also a common activity in the work of the engineers: Jake estimates that he participates in one or two reviews a week and Carl says that he attends a review almost every day. Last, it is noteworthy that it is the engineers themselves who call the review meeting.

Participants

The participants of the review, as indicated, are people who are knowledgeable enough to scrutinize the work performed. In more specific terms, and in Jake's words: "there is often an object leader present, who mainly looks at the time aspects, or the plan in a larger perspective. And then there's the author of the document, and the receiver is always present on a review". Those – object leader, author, and receiver – can be seen as the participants of an ideal typical review. It is rather common, however, that the author and receiver is the same person. For example, when Jake makes a link budget there is nobody else who will receive it. Jake will instead continue working on it after the review and the idea with the review is mainly to have others see the link budget in order for them to detect errors and for them to be informed about Jake's work. In these cases, the reviewers are there only to "help" Jake in his work, which indicates that his work is a collective product.

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[75] A CAD-drawing can be described as a computer drawn map showing exactly where the components of the phone are to be placed on the printed circuit board (PCB)

The higher echelons of the organizational hierarchy are seldom represented at the meetings. There may be higher managers participating but, as Carl puts it when asked if there is any sort of hierarchy at the review:

> No. In fact, it's unusual with managers at the reviews. And if they are there then it's often … Let's take an example. There may be project leaders sometimes if it's something critical. They are seldom there, but sometimes they may be, for example if it for some reason has been highlighted that something very important will come out of the review. Then they may participate and … that person is usually not familiar with the details but basically just wants the time plan, just wants to know what it means in terms of delay.

The object leader is thus the only manager who regularly participates in the reviews (and s/he does not *have to* be there either). Despite the regular presence of the object leader, hierarchy is not seen as a significant element at the reviews. As Jake noted above, the object leader looks at the time aspects and the plan in a larger perspective and this task is not seen as being superior to, for example, the task of detecting errors and problems. We remember this dynamics from the previous chapter; the division of labor is often based on knowledge rather than formal hierarchy. Jake also tones down the significance of formal hierarchy by pointing out that "anyone is free to say anything at a review. It is a forum for discussion and wishes".

The review touched upon in the workday (starting at 10 AM) exemplifies this non-hierarchical feature of the review. It is presented in a slightly extended version below:

> There are quite many people present, thirteen to be precise. Four of them are from the ASIC-department and the rest from the radio group. It is Malcolm Smith from the ASIC-department who has made a "fix" that is thought to solve a problem with temperature dependent distortion and Eddie has tested how the fix works in a prototype phone. At the meeting, the object leader (Carl) is mainly busy documenting the outcomes of the review, sometimes stopping the presentation in order to get his notes right. The author, Eddie, is the most active participant. Some participants seem to be there mainly to keep themselves informed of what is going on; they leave rather early and don't ask any questions. Other participants, on the other hand, ask questions and make comments regarding the results that clarify the picture. Those active participants are some people from the radio group

(Jake, Sebastian, Andy) and Malcolm Smith, the latter being the "receiver" of the review as he has constructed the "fix" that Eddie has tested. Listening to Eddie's presentation and the comments from the audience, it is apparent that the result is not as good as expected. Malcolm will need to work more on the fix, and Eddie will have to make new tests.

Review-work, in sum, is described by the engineers as a common and central feature of their work, whose major function is to have a "crowd" brought together in order to "scrutinize" or "discuss" a piece of engineering work. The "crowd" invited consists of people who can be expected to give "valuable feedback", which are typically not managers but other engineers. Abstracting slightly from their description, I would say that reviewing is to be seen as a knowledge-intensive practice based on horizontal relationships where people with relevant knowledge are invited to scrutinize finished or (more often) partly finished engineering work.

After the review

Thus far I have talked about review-work in terms of the quality of the actual review. Of interest in terms of control, however, is also what happens *after* the review. How does the result of the review have impact on the engineers' work? Carl explains:

> After the review you take the feedback from the review and update the document [...] and then you release it in a revised version. *Before* the review we say that we have a "preliminary revision" of what we review. *After* the review we create a new updated revision that we call for example revision A or B or C or D ... and then we know that 'ok, this is the most recent status' [...]. But then, the review can also generate feedback that takes several weeks or months to solve. Then there's an action to do it [solve the problem], which may cause a change in the time plan, and then [the solution] may not be finished until three-four months later. And then there will be a new review. [...]

> JR: Who decides if there is need for a new review?

> We basically do that ourselves. We decide ... there's nobody who ... we basically decide upon all reviews ourselves, in fact.

> JR: We?

It's me, together with Jake and Andy in this case ["this case" refers to the work on the ASIC called "Winona" that has been carried out by Jake and Andy].

The review thus has considerable impact on the work: either the document that was reviewed is updated based on the feedback and is "published", or, if the feedback indicates the need for extensive alteration, a new review will have to be held. As during the actual review, there is little managerial involvement when it comes to dealing with the aftermath of the review; it is largely the engineers themselves who determine how to go on with the work after the review.

6.4 Engineering knowledge as a prerequisite for controlling

In the discussion below, I will distinguish between engineering work as *production* respective *presentation* of symbols, a distinction that stresses the central place of *knowledge*; knowledge about both the material and the symbolic realm of engineering work. Although there may be overlaps, lab-work and idea-work are related to production of symbols, whereas review-work is related to the presentation of symbols. It will be argued that the dominating methods of control are either self-control or horizontal control.

Production and presentation of symbols

A central element in Jake's work is the movement and creation of a link between the material and the symbolic realm (see also Barley, 1996). Jake's lab-work exemplifies this. In the lab, he measures the way the prototype (which belongs to the material world) reacts to different temperatures. The result of the test is a symbolic representation of the material world in terms of figures. In most cases the test results are not satisfactory and therefore Jake needs to make changes – or ask someone else such as the ASIC-group to make them – on the components in the prototype in order to make it function in a desired way. The representation of the material is thus produced and then used in order to manipulate the very same material. These two complementary processes of producing representations of and manipulating the

material world can be referred to as "transformation" and "caretaking" (ibid: 418 ff.).

When Jake is working in the lab he could thus be said to engage in the transformation into symbols of that which is going on in the prototype. And when he uses the symbolic representation as a basis for manipulating the prototype he engages in "taking care" of the material. By producing the representations the engineers create the foundation for their own work: the symbolic representation produced is used as a basis for further manipulation of the prototype. There is thus a circular movement in lab-work. Or in other terms, self-control is inherent in the process of lab-work. Material is turned into symbols, which are used to manipulate the material, which is turned into symbols again etc.

In order to carry out engineering work, one can therefore be said to need an understanding of the material world, the symbolic world and the links between them. Earlier studies of engineering work have fruitfully conceptualized such understanding as based on a high level of both *contextual* and *formal (theoretical) knowledge* (Crawford, 1989; Whalley & Barley, 1997). Contextual engineering knowledge is contextual because it has been acquired by practicing and experiencing in the context of engineering work, for example by making a certain type of measurements. Experience and that which is often referred to by the engineers as "feeling" would count as contextual knowledge because they are acquired through practice. Formal engineering knowledge, on the other hand, is formal because it refers to general assumptions or "laws" that may not have been experienced but upon which the science of engineering rests. In its most general sense, formal engineering knowledge can be defined as knowledge about how engineering as a discipline looks at the world.

Both contextual and formal knowledge help Jake interpret his work and act based on those interpretations. The distinction is thus made here based on the method of acquiring the knowledge, but there is no absolute line between contextual and formal knowledge and the distinction is made for analytical purposes[76]. There is a point in

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[76] It has been argued that theoretical knowledge will grow in importance and centrality in post-industrial society (Bell, 1974). Crawford (1989) who has

differentiating between work that requires "how to do it"-knowledge (contextual knowledge) and work that requires "how it works"-knowledge (formal knowledge), because it is a way of understanding the work as "complex". The need for *both* contextual and formal knowledge tends to complicate work.

The dual knowledge requirement is exemplified in the observation of Jake's work in the lab. The knowledge needed to handle sophisticated instruments and how to program a computer is largely contextual, whereas the knowledge required for understanding the relation between temperature and the behavior of the components he is testing is largely formal. Also, that a fair amount of formal knowledge is required is perhaps best indicated in the lab-work-observation where Jake asks himself, "Ok, how the hell am I going to do this?" before starting the work and by the fact that the exact kind of measurement he performs has never been done before. But as noted, there is no absolute distinction between contextual and formal knowledge, and they often seem to complement rather than exclude each other. As in Carl's statement regarding what Jake needs to know: "evaluate earlier results", "have the link budget under control", "make theoretical calculations", "program the circuit", "read simulation data", "analyze statistics", "have a good picture of the requirements on the entire system and be able to break them down onto the tiny little amplifier in order to know that it's good enough in the whole application" … and he needs to have "some feeling too". Thus, a clear distinction is difficult to make, but what is rather clear is that only one or the other type of knowledge is insufficient for performing engineering work.

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studied French engineers, however, argues that experience gained on the job is more important when it comes to engineering work. In my view, Crawford is somewhat too hasty in his argumentation. It is difficult to know the extent to which theoretical knowledge is used or when the knowledge used is theoretical or practical. They are typically used simultaneously. Often, theoretical knowledge is a prerequisite for acquiring the practical knowledge and especially for applying it in situations that are not identical with but only similar to the situation where the experience has been gained. Attempting to avoid such problematic distinction between theoretical and practical knowledge, I have chosen to use the terms formal and contextual knowledge and focus on the way the knowledge is *acquired* rather than focusing on when the one or the other type of knowledge is used.

Self-control

This knowledge-intensiveness of engineering work both enables and makes necessary a large degree of self-control. It is possible to work independently without the involvement of managers when one possesses a profound understanding of the work process, of what is needed and required. But independent work is also necessary because the knowledge-intensiveness of work makes direct managerial intervention ineffective and perhaps even impossible. I have not observed this impossibility, but indeed the fact that there *is* little or no intervention in the ongoing work. Lab-work is carried out independently and so is Jake's work in the D2-project when he constructs suggested solutions to their problem. Both are examples of the creative side of work and the necessity of being able to work independently with complex problem solving.

Self-control seems not only to guide the engineers in their technical decision making, however, but also to a certain extent regarding what is best for the organization. Jake stated regarding the link budget that "there's sub-optimization if you're doing things that are unnecessarily good", and Carl says that Jake needs to know that the requirements are "good enough". Jake thus knows that he, even if he perhaps could, is not supposed excel in terms of producing a radio that by far exceeds the requirements. Instead he shall, as he puts it, allow "as much shit as possible in order to precisely fulfill the requirements". Knowing and understanding the meaning of "unnecessarily good" is to be seen as a part of his contextual knowledge. He thus strives to optimize his own work and make the requirements of technology (maximization of technical quality) converge with the requirements of the firm (maximization of profit), which is to be seen as an example of self-control.

The possibility and necessity of self-control gives rise to a new dimension to the type of knowledge used by Jake and his colleagues that is more explicitly related to the possibility to control work. The dimension is based on a distinction between everyday knowledge and that which is here, drawing upon Freidson (2001), referred to as *discretionary knowledge*. Freidson separates between everyday knowledge whose use requires little more than what we have learned in our everyday lives, and knowledge whose use involves the performance of

tasks "in which discretion or fresh judgment must often be exercised if they are to be performed successfully" (ibid: 23). It is the latter type that is referred to here as discretionary knowledge and it is this type that is argued to be used by the engineers.

As its definition indicates, the use of this knowledge requires a high level of self-control. In other words, the engineer must be *trusted* to use her/his knowledge without being supervised by any external actor, such as a manager (Whalley, 1986). As we have observed in Jake's lab-work and idea-work, he is not required to follow a certain routine or form and there is nobody supervising him. Instead, how to go about in the lab and how to find out solutions to the problem is left to his discretion; he seems to be trusted, *and* required, to control himself in his use of engineering knowledge to explore, innovate, simulate and create.

Horizontal control

The relative absence of explicit external influence in terms of management control enables and requires Jake to exercise a large amount of self-control, but it does not mean that he works, or even *can* work, alone. Although much work is carried out on an individual basis, there is a strong collective element in engineering work. Jake may for example perform most of the lab-work on his own, but it is not a solitary procedure for he needs to consult with other engineers to get advice on how to perform the lab-work. This is exemplified by him talking to Andy both before and after doing the APA-tests in the lab. A perhaps more apparent example is Jake's and his colleagues' "idea-work" in D2, which is to a large extent based on interaction. When the engineers meet up the day after Jake has worked on his solutions, the problem solving activity takes a collective shape. They discuss possible future solutions and end up with a solution that seems to have emerged in Andy through the interaction with the others during the meeting.

The collective element in the production process stresses the importance of *shared knowledge* for engineering work to proceed, best illustrated by the use of a for an outsider virtually impenetrable

electrotechnical "vernacular"[77] that enables them to discuss the rather complex material world they are working on. Again, knowledge should be regarded as formal as well as contextual since they must know how to apply the solutions to their existing technology (contextual knowledge), but also how a radio works in order to understand how a theoretical solution will lead to better performance.

This shared knowledge enables horizontal control. Horizontal control takes place in the informal idea-work at the D2-meeting, but it also takes place in more formalized settings such as review-work. Review-work is performed at the review meeting where one or more engineers present their produced symbols (e.g. their test results) to other engineers, to their *peers*[78] as it were. As has been observed, the people present at the review are not there to supervise but they, recalling Carl's statement, are people who have the competence to say something about and/or are affected by the work done, people who may find errors or things that are missing. In the example presented the object leader, Carl, participates but his object leader role does not seem to give him any privileges in terms of control. Carl does not review the work more than any other person and his role seems mainly to be to document the work done in order to enable comparisons with previous reviews. It is other people than Carl who make comments and suggestions. The authority to review does not come from the formal hierarchic position held by a person, which is also stressed by the interview statements. Instead, authority to review comes from the relevance of a person's engineering knowledge. And those with relevant knowledge are typically not managers but other engineers. Control is thus not exerted vertically, but horizontally between peers.

It is not only the review itself that is performed on a horizontal basis, so is the interpretation of the review. One may perhaps expect

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[77] Cf. Goode (1957) who discusses professional work, which he says tends to be exercised by use of a "*common language* which is understood only partially by outsiders" [my italics].

[78] These presentations are done both horizontally and vertically, or in other terms, both to peers and to managers. In this chapter focus is mainly directed towards the presentation of symbols to peers, whereas the presentation of work to managers was discussed in the previous chapter and will be discussed further in the next one where the object meetings are focused upon.

management to enter the picture to a larger extent when it comes to deciding upon the consequences of a review, but that seems not to be the way it works. As Carl stated when asked who decides if there is need for a new review: "we basically decide upon all reviews ourselves, in fact". "We" here refers to Carl, Jake and Andy. Carl because he is the object leader and Jake and Andy because they are the ones who have performed the work that has been reviewed. Thus, the object leader tends to be involved in the interpretation of the review, but the extent to which the object leader can exert more influence than a "peer" depends on his/her access to "knowledge based control devices" (something that will be discussed in the next chapter). As was observed in the previous chapter, just *being* the object leader does not guarantee the power to exert influence. Carl, however, is a knowledgeable engineer, participates in more reviews than the engineers, and he has a finger in most of the ongoing processes. Still, when it comes to reviewing either the quality of the work or interpreting the consequences of a review, he is seldom more capable than anybody else with relevant knowledge. By and large, when it comes to controlling the quality of work in reviews, peership rather than hierarchical position is a prerequisite for exerting control.

In sum, the process of engineering work, of moving between the material and symbolic realm, is largely controlled on a horizontal basis. It is the engineers themselves who produce the representations, and it is also largely the engineers who control the quality of these representations.

6.5 Conclusion

This chapter has focused mainly on *knowledge* and to some extent on *ideas* as central aspects of engineering work. In the light of a presentation of a common workday at GT, it is argued that engineering work can be seen as guided by *self-control* and *horizontal control*, both of which require in-depth engineering knowledge.

An important element in engineering work is the ability to move between the material and the symbolic realm. Knowledge, contextual as well as formal, is put forth here as a prerequisite of carrying out this

activity. The knowledge is also argued to be of a *discretionary* kind because its use requires discretion and fresh judgment. Put differently, there is argued to be a relationship between what the engineers know and what they do that is complex enough to make managerial intervention difficult and probably ineffective. As a consequence, the engineers' work enables and requires self-control rather than management control.

It is also pointed out that the knowledge is shared among the engineers, something that enables horizontal control. Horizontal control is exercised when self-control falls short of guiding action. It is exercised in various contexts, but perhaps most apparently in review-work where the engineers on a peer-basis are argued to scrutinize each other's work and thereby control its quality, and when they do "idea-work" and try to figure out one best solution of a problem. In brief, operative engineering work is argued to leave little space for management control in the shape of a rational activity of goal processing. Instead, it is argued to enable and require self-control and horizontal control, which is exercised in a knowledge-intensive and peer-based context.

Relating the observations made in this chapter to the common assumption in the control literature that managers are the ones controlling work processes, and to the rhetoric of MBO expressed by the GT-managers, I contend that there is reason not to eliminate, but to redraw the image of managers as controllers of work and of control as a rational process of creating, breaking down and following up goals. Being a manager does not guarantee possibilities of controlling engineering work. However, neither does being a manager necessarily *exclude* the possibility of controlling engineering work, which I shall turn to next.

Chapter seven

Dealing with deadlines

I have argued thus far that access only to rationalistic control devices such as goals and follow-up lists do not enable a manager to exert much influence over engineering work. Engineering work is too uncertain and knowledge-intensive to be controlled by that type of rational means. Instead, I have argued that it can be understood as controlled through self-control and horizontal control. As a contrast to that argument, it can be claimed that when work is of an uncertain character and requires specific knowledge, the *deadline* is one of the few devices that can be used to control work (Mellström, 1995). One could contend that the deadlines are in the hands of managers; that managers are the ones who decide *when* work needs to be finished. To a certain extent, there is a point in such contention. But it is not quite that simple. In this chapter I shall delve deeper into the issue of deadlines: how are they managed and who is managing them?

As in chapter five, an object meeting is presented in this chapter. There are two reasons for presenting another episode of the same kind. One is that the object meeting can be seen as the social context where deadlines are most apparently dealt with. The other reason, as was noted in chapter three, is that it enables comparisons. References to chapter five will therefore be made. In addition to the object meeting, I shall present interview material that problematizes a central control device when time is dealt with: the time plans. The role of time plans and deadlines will be discussed in the light of the somewhat mysterious phenomenon that the engineers often perceive deadlines as absolutely unrealistic, but yet they manage to finish on time.

7.1 Time control at the object meeting

The object meeting presented here is similar to the one in chapter five in terms of its general structure. As in the case of the ASIC-group, the meeting takes place once a week and follows a certain pattern, which consists of two main elements:

- *General information*, which is where the object leader presents the information that he has received from his project manager, and
- *The status round*, which is where the engineers present the progress of their work, thus the same type of activity as "tracking" in the ASIC-group.

There are two organizational positions involved in the object meeting – the object leader position and the engineer position. There is no specialist in the radio group (such as Alex or Isac in the ASIC-group). The object leader is Carl and he is the one running the meeting. He has the agenda and he has more information from the project as a whole than the engineers. The engineers describe the meeting as a situation where they inform Carl about their work, where they discuss their work and their (technical) problems, where they "plan what to do" together with Carl, and where Carl gives feedback and suggests or points out how the engineers shall proceed and what they should prioritize. It is also a situation where the object leader "reports information that comes from above". In short, the object meeting can be seen as the follow-up can part of MBO put into practice.

A reminder on their work

In chapter four I outlined in simple terms the structure of the work in the radio object but I believe a short reminder will be helpful before the rather detailed presentation of the work meeting that will follow.

The main activity of the engineers in the radio group is to put radio components together and make sure that they work according to both internationally established standards (3GPP) and internal requirements. In simple terms, a radio in a mobile phone consists of seven components: a transmitter, a receiver and a power amplifier (PA), which all come in a GSM-version and a wideband-version (see Figure

3). These components are ASICs[79] and are partly designed by the ASIC-department. All ASICs have names: we observed the ASIC-group work on "Katla", and at the meeting in this chapter we will hear the engineers talk about for example "Winona" and "Wendy". Then there is an antenna switch (the seventh component) that leads the reception to the right band (GSM or Wideband). Every engineer works mainly with one of the components, but there are connections between them and the engineers need to communicate about this and they often help each other out, as we saw in the previous chapter where Jake and Andy discussed how to run the tests on Winona. Further, some components require more time and therefore more than one engineer work on them.

Most of the engineers at the meeting presented in this chapter are in the middle of or about to finish APA-tests, which have been preceded by lab-work as well as review-work. The work carried out is in the final phase of the project called D1, as opposed to the work in the ASIC-group which was carried out in the initial phase of D2.

Meeting, part one: General information – imperative consequences

Participants:
Jake – engineer
Fred – engineer
Eddie – engineer
William – engineer
Sebastian – engineer
Andy – engineer
Jonas – engineer
Ben Moon – visitor, works in Asia
Carl – object leader

As usual, the meeting takes place on a Tuesday at nine o'clock. Also as usual, the meeting takes place in one of the rather sterile rectangular rooms with a large white board on the one short side and bare white

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[79] This is a bit simplified because a transmitter, for example, may consist of more than an ASIC, and more than *one* ASIC.

walls on the other sides, except for the door on the other short side and small windows along the ceiling on one of the long sides. The first people drop in a few minutes before nine and some a few minutes after. Waiting for everybody to arrive, there is some small talk and Carl prepares today's agenda by writing it on the board:

- General
- APA
    o Isabel
    o Winona
    o Wendy
    o GSM PA
    o Antenna Switch
- Tina – Link budget

"General" means "General information", and we have learned from chapter four that "APA" is the application approval. The names (Isabel, Winona, Wendy, Tina) are ASICs on which the engineers are working. The "antenna switch" and the "GSM PA" (power amplifier) are not ASICs but they are parts of the radio, also attached to an engineer. Then there is the link budget, which, as noted in chapter five, is about creating a simulation/a theoretical version of how all the blocks will work together.

As to the general information, Carl always goes through it in the beginning of the meeting. He tells the engineers about what is going on in the organization and he answers questions – which are usually few – regarding the same. The general information tends to be imposed upon them; it seems to be *imperative* and the group has to deal with its consequences in one way or another. The general and imperative information at this meeting is a new track that Carl informs about: "As you heard from Jerry Moffat[80], the new prototype is a new track in the project plan. It's going to happen". He also points out that the time plan for the new track is "very tight". After Carl has finished the general information he asks if anyone has questions. Fred asks about the consequences of the new track, whereby Carl replies: "Lack of

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[80] Jerry Moffat is the Head project leader.

resources. But it's a matter of making priorities. I mean ... if the program has decided it..." The new track is thus decided upon by top-management, and it seems to be taken for granted that the decision is none of the engineers' business, as Carl explains in an interview:

> These main-milestones, when it comes to what we call releases, like here is one called R8, and R7 there [he points at the time-plan sheet on the desk]. *These* ones are established by the project ... by program management.

But changes in tracks and new milestones have to be dealt with. Carl points this out at the meeting by stating that "it's a matter of making priorities" if the program has decided to go for the new track. The consequences of the new tracks in terms of work are thus not included in the decisions from top-management, but it is up to Carl and the engineers to make priorities or adapt in other ways in order to handle the new situation.

Part two: The status round – accounting for work

The general information is typically followed by the status round (cf. "tracking" in the ASIC-group), which usually sticks to the following structure:

1) Carl mentions the name of the area of interest, often referred to as a "block" (such as Winona, Wendy, GSM-PA, Wideband-PA)
2) The engineer responsible for the area/block reports his status.
3) Carl asks questions, he might suggest actions, he might praise, or he might point at problems or delays.
4) Carl asks, or suggests, *when* work can be finished.
5) The engineer says what he needs to do and usually a deadline/date is set.

They go through this procedure on all blocks. The status round is thus a means of following up work on an individual basis, as it was in the ASIC-group. However, this group differs in the sense that the object leader does not only ask about, but also more apparently attempts to align their work to the time plan. The follow-up in the ASIC-group was seen as an evaluation process, an interpretation that fits this

meeting too, but with the addition of Carl's more apparent *alignment attempts*, as observed below where Carl follows up Eddies work.

> Carl asks Eddie about his status on the "study of the nx13 MHz spuriousis[81]". Eddie says that he checked the results after they did some modifications, but he doesn't seem quite satisfied with the result. Carl asks: "Have you looked through this thing with [technical term]?". Eddie replies that he hasn't, but he is going to measure it. "Have you started?", asks Carl. Eddie says that has started but he "can't really make it work". Sebastian chimes in with a suggestion. Carl then suggests that it could be "the classic that ..." [he explains what "the classic" means]. "Mm ... it could be ... ", says Eddie. Carl tells Eddie to check with Malcolm Smith, a colleague at the ASIC-department. Eddie starts talking about how he thinks that he might be able to solve the problem by "opening up a phone". Sebastian chimes in. Carl then says: "But ... I mean, are you working on this now?" Eddie replies, a bit sarcastically: "Mm ... well, no, I'm in a meeting now but ... otherwise ... mm". Carl says "okay" and asks ho much time Eddie is spending on this at the moment. "About half of my time", says Eddie.
>
> William asks Carl if he can bring up another thing regarding the nx13 MHz. "Yes, bring it up now", says Carl and they discuss it for a short while. Then Carl continues where he was with Eddie: "Ok, the measurements Eddie". Eddie is talking about something else, however. "Eddie, the measurements...", Carl repeats. "Mm", says Eddie. "I think this is a bit too slow", says Carl and adds that they have had this "action" for quite a while and suggests that they talk to Victor, their section manager, about this, to see if they can "borrow or request" some extra people from the ASIC-department to help them solve the problem. Then he adds: "We put what we call a C1 on this, so it's a stopper[82]." "Mm", says Eddie. "So we'll have to make sure we get help ...", says Carl. "What is the error about", asks Ben Moon, whereby Carl explains. He adds that this action has high priority.

Eddie is thus working with something called "the n x 13 MHz", and he is lagging behind a bit, according to Carl. This is why Carl is following

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[81] The "n x 13 MHz", pronounced "the n times thirteen megahertz", is not a component but a signal that always arises in a radio. If n = 1 the signal is unproblematic, but if n > 1 there is a leakage from the radio out into the air which can disturb other electronic devices. Spuriousis, as they call it, on the n x 13 MHz thus means that there is leakage, and it is Eddie's job to make sure that the spuriousis does not exceed the limit of what is permitted.

[82] This means what it sounds like: something that will stop the project if it is not taken care of.

up Eddie's work rather strictly, pushing him to get a picture of what needs to be done, thus attempting to align his work to the time plan. Then he suggests measures both in terms of possible causes of the problem and in terms of suggesting people that could help out. In contrast to Christian, Carl seems to have access to more resources for exerting influence over the engineers. He has an information advantage and also appears to be technically knowledgeable. In the ASIC-group, it was Alex rather than Christian who (successfully it seemed) did the alignment work.

After the follow-up of Eddie's work, Carl continues following up Jake's and then Andy's work:

> Carl asks Jake how his work on "Winona" is going and Jake replies that he is "waiting for approval from Thor" [83], then he can update his document and have a review. Carl then asks when Jake can have the review. "Thursday, if nothing goes wrong", replies Jake, and they decide to have it on Thursday. Then Carl switches to the APA on Wendy, simply by saying "Wendy, APA", which triggers a report form Andy who says that there are some problems: "There's a thing that doesn't fully match our requirement specification, the 1301, but I think I can fix it anyway, so that it works in reality, but I'll have to fiddle a bit with the budget, I think it's hard to make both ends meet". "Can we decide on a time for the review?", asks Carl. Andy suggests tomorrow afternoon, given that a person at the ASIC-department has finished his work. "Let's aim for that", says Carl.

Jake is thus working on the block called "Winona" and Andy on the block called "Wendy". In contrast to the follow-up of Eddie's work, there are no alignment attempts. The follow-up on their work is smoother because they are on time and they have clear answers to Carl's questions. Carl doesn't have to do much. In the case of Andy, he just says "Wendy", and then Andy reports and there are no comments. In both cases there is the usual pattern of asking for a date, however, which results in a commitment from the side of Jake and Andy; a commitment to having a review on Thursday and tomorrow. It can be noted that the infusion of uncertainty that was common in the ASIC-group is less pronounced in this group.

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[83] Thor is the project leader and Carl's superior. Jake needs Thor to perform his role as a "formal button", as Jake put it in chapter five.

After Carl has received a date from Jake and Andy, he continues to follow up Fred's work. Fred is working on the Wideband-PA together with Arvid from the ASIC-group.

> Carl asks how the cooperation with Arvid works. Fred thinks it is ok, but a lot of work. Carl asks for a "list of deviations" that should be available, but there is no such list yet. Carl thinks that Arvid should do the list. Then he, as in the cases of Andy and Jake, asks when Fred thinks that they can have a review. Fred says that it is a long list, that he needs to talk to some people first. "I don't think we should wait too long", says Carl and suggests that Fred move some items from the list, and that they have a review soon so that he, Fred, Arvid and Victor get a common picture of the issues. Fred says that he's been working with something else the last week "because there was a hurry", so he didn't start looking at the Wideband-PA until today. "Here's a hurry too. Here's a great hurry", replies Carl. "I see ... but...", Fred starts but Carl interrupts: "I would like to have this review on Thursday at the latest". Fred thinks it will be possible to have the review already tomorrow. Carl, of course, is satisfied with that, but adds: "I feel a bit bad about putting an action on you because it hasn't been your responsibility before but…" Then they discuss for a short while more.

As in the case of Eddie, there are alignment attempts in addition to the evaluative follow-up practice. Carl is more "pushy" in the follow-up of Fred's work because he thinks Fred is lagging behind and points out the urgency and importance of working faster with the deviation list. It is also indicated that there has been an "action put" on Fred to make the list (although it seems to be outside of his area of responsibility). "*Actions*" are common, as we have seen. You can "get" an action and you can "give" an action, or "put an action on" someone as Carl does with Fred above. In the military an action would be called an "order", in school an "exercise" and in many organizations a "task". Carl does not only give the actions but also seems to understand what it means to fulfill them, which enables him to follow up more effectively than Christian.

In the next passage of the meeting, it is Eddie's turn again to be followed up, and again there are more alignment attempts than with Jake and Andy.

Carl brings up the Baluns[84] and says, "Eddie, you are responsible for doing an APA on them". Somebody opens the door and asks for the phone number to the room. Carl continues to talk to Eddie after the door has closed, but now he switches to the n x 13 MHz-topic, saying "Ok. Eddie, your prio [priority] number one right now is the n x 13 MHz". "Mm...", mumbles Eddie. "I would like the work on that one to be more in line with the time plan", says Carl. Eddie replies that it depends what Carl means by work because if he means solving the problem, then it is too much. "No", says Carl, "but investigating the actions we know about. It's partly the slowrate and..." "I'm only going to measure it...", Eddie interrupts. "Yes, but then there's another action. Investigating the low pass filter and balancing the n x 13 MHz", says Carl. "Mm", Eddie mumbles again. Carl goes on: "And in between ... maybe we could do this APA on the Baluns..."

There are two things that should be pointed out in this passage. One is that Carl is defining what should be prioritized and what he wants Eddie to do in order to keep the deadline. Eddie tries to infuse some uncertainty, it seems, but Carl does not appear to find much uncertainty in the situation. Instead, he points out rather clearly what he wants Eddie to do, which is quite different to the dynamics in the ASIC group.

The other point is related to the general knowledge required to exert influence. The importance of mastering the electrotechnical vernacular is brought to light when Carl "gives actions". It is necessary to know what a "slowrate" is, how to "investigate a low pass filter" and how to "balance an n x 13 MHz" … and how to "do an APA on the Baluns". This vernacular of the electrotechnics hardly belongs to everyday language, and much of it does not even belong to GT-language because people working with other parts of the product (such as software) would not entirely understand it.

After the follow-up of Eddie's work, it is Sebastian's turn to report on his work on the Tina-linkbudget[85]. He, like Eddie, is a bit late.

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[84] A Balun, in simplified terms of course, is a component that reformats a signal. For example, the output from a circuit consists of two signals but the component that receives the output, here the PA, can only receive one signal. The Balun then reformats the two signals into one so that the PA can receive it.

[85] Reminder: A link budget is a simulation/a theoretical construct of how all the blocks work together.

"OK, link budget", says Carl and Sebastian reports. "How much time remains?" asks Carl. Sebastian answers a bit evasively that "TX"[86] remains to be done. "TX is not started?" Carl says, sounding alarmed. "No", says Sebastian. Carl then asks if "the blocking for Tina" is done. It is, says Sebastian, then adds: "but I realized that I did a logical error when calculating the distortion ... so I'll have to recalculate". Carl silently reads his notes, and then says clearly that "there is little time left". "Yes", says Sebastian. "There's much left to do" Carl says, "among all the things, can you do the blocking first?" Sebastian says that he can do that. They discuss how to go on with the work. Carl then says: "I think we should think like this: 'What parameters do we need to modulate this?' That's one thing. Another thing is blocking, we must correlate it with reality. We must do some kind of measurement there." Sebastian seems to agree and suggests that they discuss the issue with the people at the ASIC-department. Carl agrees and they discuss this briefly.

The follow-up order repeats itself, as well as the feeling of an almost impenetrable electrotechnical vernacular. Like Eddie, Sebastian is a bit late which is pointed out by Carl and he also suggests how Sebastian should prioritize.

In contrast to the ASIC-meeting, Carl seems to be significantly closer to their work than Christian. He suggests how they should think, not in detail but, it seems, in order to put them on the right thinking track, for example: "I think we should think like this: 'What parameters do we need to modulate this?'" He thus acts a bit like a mentor, or even master, who teaches his apprentices how to "read" the situation, and he leaves the rather mechanical and detached follow-up practice in favor of something that seems to be more organic and involved in the work.

7.2 The repertoire of control devices at the object meetings

Carl uses a repertoire of control devices in his attempts to align the engineers' work to the time plan. This repertoire differs somewhat from that of Christian. There is also, however, a repertoire of control devices

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[86] Remainder: TX is the technical term for the transmitter (see Figure 3).

discernable at the meeting that is not necessarily used by management, but belongs to the collective.

Carl's repertoire – experience, information and organizational symbols

The follow-up practice is performed in a similar way in the ASIC- and radio group. Christian and Carl follow up the engineers' work and take the role of the evaluator and the engineers respond by accounting for their actions the past week. This dynamics seems to be inherent in the object meetings and internalized by the participants, which is for example indicated by the engineers' statements regarding the meetings and by the fact that nobody questions the order of the "tracking" or "status round". The meetings can thus be seen as institutionalized time-evaluation processes, processes that are similar in the two groups in terms of the formal hierarchic order of the follow-up: it is the object leader who evaluates and the engineers who give account.

But there are differences in terms of the control devices used by Christian and Carl. As we saw in chapter five, Christian relied much upon his "tracking lists", formalized devices stating *when* various work process are to be finished. It was argued that Christian had little possibility to intervene in the details of the engineers' work; his control attempts were basically restricted to checking how the engineers were doing in terms of time and then asking them when they thought they would be finished. If they did not know when, which was common, there seemed to be little he could do.

In the radio group, the object leader intervenes more in the "intimacies" of engineering work. Carl intervenes in the order in which various activities are performed and to a certain extent even suggests how the engineers should proceed. He makes priorities, gives instructions, follows up, interrogates sometimes, knows what's best, and squeezes out a deadline from the engineers. And both Carl himself and the engineers seem to expect him to do just this. Carl says that it is his role to "pick out the most important things" and "build a road to the goal", and the engineers say for example that "Carl is supposed to tell what's prioritized".

So what is it that enables Carl to intervene in the intimacies of the engineers' work? An answer can be found in the *access* to control devices. Compared to Christian, Carl seems to have access to a broader repertoire of such. Let's take Eddie and the n x 13 MHz as an example. Carl asks for the status, Eddie replies that it is unsatisfactory. Carl then suggests different actions that might help Eddie proceed, presenting the palette of devices available to him. By stating that it could be a "classic" that has caused Eddie problems, Carl draws upon his engineering *experience*. An experienced engineer would reasonably not be stopped by a "classic". Carl also tells Eddie that he should "check with Malcolm Smith", thus suggesting that Eddie use the network of resources available at GT, a network of which Carl seems to have more *information* than Eddie. Carl also, when pointing out that he thinks this is serious business, uses organization-specific *symbols,* saying "we put what we call a C1 on this, so it's a stopper". The control devices available to Carl – (1) his greater engineering experience, (2) his informational advantage and, (3) organizational symbols – seem to allow him to rather energetically ask for the status in terms of time and point out that Eddie's work is insufficient, going: "Are you working on this now?", "How much time do you spend on this?" and "I think this is a bit too slow".

That which separates Carl from Christian is not the access to (formal)[87] hierarchy-based control devices, but his additional access to *knowledge-based* ones. Christian is likely to also have access to information about the network of recourses, he uses organizational symbols in the shape of tracking lists, and he probably has access to the terminology of "stoppers" and "C1's". Those are hierarchy-based control devices, and access to them comes with the object leader position. Engineering experience, on the other hand, is a knowledge-based control device, which Christian seems to lack access to. Carl on the other hand is experienced and, most importantly, his engineering experience and competence is acknowledged by the engineers, as stated by the engineers below.

> He's got a lot of experience from this kind of work, so he doesn't start up unnecessary work. [...] Then, he has everything in the object under

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[87] When say hierarchy-based control devices, I refer to the formal hierarchy that is based on organizational position.

control, even on a detailed level, both in Wideband and GSM. (Sebastian)

I think he's good at making priorities, management you know, control of work. He motivates well why he makes a certain judgment. You agree with it [...] because it agrees with your ... [you think that], "yes, that sounds reasonable". (William)

He is good at the practical work, has a lot of experience. So you can go and ask him and actually get an answer too. It's not like you ask him and he just says that "you have to be finished at that time" [...], but he knows the practical aspects and if he doesn't know, then he knows who will know. (Eddie)

When it comes to coordination, Carl must be the world champion. I think I've never met anyone with a sense of details as his. (Victor)[88]

This should be compared with the statements about Christian in chapter five, which indicated that he could do little to control work. Hence, it is not the formal practice of holding object meetings that enables a manager to exert control, but rather the knowledge s/he possesses: it is not Carl's position as an object leader that enables him to intervene in the intimacies of the engineers' work, but his access to knowledge-based control devices. The major type of intervention (which is pointed out in the second quote above) that these knowledge-based devices enable is to *make priorities,* to control the order in which tasks are made. This is perhaps most clear in the passage in the status round where he suggests an order of priority in Sebastian's work, telling Sebastian that "there's much left to do ... among all the things, can you do the blocking first?" Sebastian agrees to do the blocking first.

Carl's repertoire of control devices can be seen as a combination between hierarchy- and knowledge-based ones, a combination that seems to be effective. The effectiveness of the combination can be explained by its ability to *bridge the gap between the rationalistic MBO-logic and the logic of engineering work*. Because of his in-depth engineering knowledge, Carl is like a *buffer* that softens the clash between the logics that was observed in the ASIC-group. Carl not only

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[88] The reader may have noted that Victor is sometimes referred to as section manager. He became section manager in 2004. This interview was made in 2003, when he worked as an engineer.

asks for a date, he actually supports the engineers in their work, perhaps best expressed in the third quote above where an engineer says that "it's not like you ask him and he just says that 'you have to be finished at that time' [...], but he knows the practical aspects and if he doesn't know, then he knows who will know".

Carl is in an influential position in relation to the engineers. In a sense and to a certain extent, he is both Christian and Alex in one person. But his "powers" should not be exaggerated. As has been argued in chapters five and six, the engineers most of the time know what to do and they actually have little contact with managers. And there are important control devices whose powers are not necessarily used by managers but belong to a collective repertoire.

The collective repertoire I – knowledge of physical artifacts as mediating control device

In the example with the n x 13 MHz, Carl is following up Eddie's work rather meticulously and points out that things got to move on faster. Most often, however, there are no alignment attempts such as in the case of Eddie. Let us take another example from the meeting, that of Jake and his work on Winona. The structure of the follow-up is the same but there are no problems and no alignment attempts – it looks more like the follow-up Christian did in the previous chapter. Carl asks how it is going and Jake seems to have the situation under control. Jake accounts for both the present and the future of his work. He is not finished, but he waits for approval from the project leader (Thor) and after that he will just make some changes and then they can have the review, and they decide that the review will be on Thursday. Carl just follows up Jake's work and his control attempts are limited. Another example of this is Andy and his work on Wendy, where Carl just says "Wendy, APA", whereby Andy reports and Carl has no comments. In this case there is no discussion at all, but a date is set for the review of Andy's block – Wendy. This scenario is more common than the one with Eddie and the 1 x 13 MHz.

Thus, most of the time there is no need for alignment attempts and the status round takes the shape of either a simple "check of what's up" and the object leader "asking for a date", or of a horizontally based process

where the engineers collectively discuss pros and cons and how to proceed with work in the best way[89]. This is where the knowledge of *physical artifacts* becomes especially relevant for explaining what it takes to make comments about time.

As indicated by the follow-up of Jake and Andy's work – and as was observed in the previous chapter – the engineers most often know what needs to be done and do not need much guidance from object leaders or other managers. This observation was also made in the ASIC-group. But how, then, do they know what to do and what to expect? The clear connection between the physical product (a block) and a physical person (an engineer) helps.

As we have seen, Carl mentions the name of the block or area of responsibility – n x 13 MHz, Winona, Wendy etc. – whereby the engineers to report their status[90]. From the observation we can tell that Eddie is working on "the n x 13 MHz", Jake on a block called "Winona", Andy on "Wendy", Fred on the "Wideband PA" and Sebastian on the "link budget". They are thus all attached to a specific piece of the product for which they give account, and they know to a large extent what needs to be done on their piece. Knowledge of these physical artifacts is to a large extent *contextual*. It has been acquired by working on the physical artifacts, by "transforming" them into symbols and "taking care of" them or suggesting how they should be taken care of (cf. Barley, 1996). It is also acquired by interacting with adjacent physical artifacts and understanding the way they are connected and affect each other. This contextual knowledge is necessary for meaningful participation in the horizontal control process. The physical

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[89] That the exertion of horizontal control emerge at the object meetings was noted in chapter five and I will not use much space here to present additional observation material, but just note that it is common in the radio group too that the other engineers chime in during the follow-up process and thereby stress the horizontal dimension of control. For example, at one meeting when Jake tells about some problems of his, William chimes in and explains a possible background to the problem. Carl doubts William's explanation, but William persists. "This is something that we need to check", he says, and discusses with Jake. After some discussion Carl changes his mind and thinks William has a good point and suggests they follow William's advice.

[90] Referring to Figure 3 in chapter four, Winona and Wendy are ASICs which are parts of the transmitter and the receiver.

structure thus implies certain actions, possibilities and constraints, however only to those who understand the meaning of the different physical artifacts (blocks) and their relationship to each other.

The contextual knowledge shared among the radio-engineers can be used to make sense of the observation that they seldom complain or make objections when Carl makes priorities. For those involved in the "context" – i.e. in the process of developing a certain physical artifact or set of physical artifacts – there seems to be a mutual understanding of "how it works" that makes changes and priorities seem logical and self-evident. As William points out in an interview when I ask him how it can be that the priorities seldom or never cause any conflict: "You know, there are never any surprises regarding what needs to be done, actually, so that's why you agree with [Carl's priorities]".

In sum, the mutual understanding of the physical artifacts and their relation to each other may be seen as a prerequisite for Carl's intervention in their work. They can be said to function as a third part, as a mediator between the engineers and the object leader. If the object leader shares enough contextual knowledge with the engineers, s/he is seen as a peer, which makes his/her attempts to control time more legitimate. But at the same time as the mutual understanding of the physical artifacts enables the exertion of control, it limits it. Most of the time the physical artifacts and the actions they imply seem to offer enough control, and Carl seldom needs to draw upon any of his resources to align the engineers to the "right track".

The collective repertoire II – knowledge of linguistic artifacts as control device

The physical artifacts are represented by *linguistic* ones. The engineers' way of talking about the material world is a linguistic artifact. They use a very specific *vernacular* that is almost impenetrable for a non-(electrical) engineer and hard to follow even for people working in the same organization but with different parts of the product. Every technical object or phenomenon – such as components, signals, errors – has its (seldom associative) name. We have encountered for example the components Winona and Wendy and the signal n x 13 MHz. There are also terms for allocating responsibility, where the use of "*action*" stands

out most as a versatile linguistic artifact. When somebody has an action on him, he is obliged to execute it. Actions therefore become reifications of responsibility and a management control device, for it is typically managers who give actions. To the engineers, the vernacular is a resource for making sense of work, but it is also a control device that is largely produced by themselves. All language serves the double purpose of both defining possibilities and limiting them (Clegg, 1989).

Linguistic artifacts do not need to be named "action" to have action inherent in them. Czarniawska-Joerges (1993) discusses linguistic artifacts that are "used as control tools" (p. 19). She sees *labels* as examples of linguistic artifacts and (referring to Weick, 1985) points out the actions they imply. For example, "cost" implies that it needs to be cut. A cost is better the smaller it is. In the context of the engineering work presented here there are labels connected to the physical artifacts. The labels are linguistic artifacts that determine the quality of the physical ones.

In the observation, Carl asks: "Eddie, what's your status on the study of the n x 13 MHz spuriousis?". After some discussion on the n x 13 MHz spuriousis, Ben Moon asks what the error is about. Somewhat later when Carl asks for Fred's status, he asks for a list of deviations that should be available. Later still, when accounting for his work, Sebastian says: "I realized that I did a logical error when calculating the distortion". One of the qualities of the n x 13 MHz is thus that it can be flawed by "spuriousis". There are spurious signals, there are errors, deviations and distortions. All these are labels that indicate action because of their capacity of implying minimization: lesser spuriousis, fewer errors, less deviation and distortion is imperative in the construction of the radio.

The labels do not imply action or make sense to everybody, however. They do not imply action to me because I do not know how to minimize distortion. But, as in the case of the physical artifacts, the engineers possess knowledge that enables them to act. Spuriouses, errors, deviations and distortions are supposed to be minimized. Every GT-engineer knows it and those who work on a certain artifact also, most of the time, know *how* to do this. Quoting William again, "you know, there are never any surprises regarding what needs to be done,

actually, so that's why you agree with [Carl's priorities]". The knowledge of the engineers is shared to a large extent, which often makes directions superfluous. But when directions are given, the use of the vernacular is an important control device.

Conclusion

In this section on the repertoire of control devices, it has been argued that Carl has access to a broader repertoire than Christian. Most importantly, he seems to have access to not only hierarchy-based but also *knowledge-based control devices* through his experience and competence as engineer. In contrast to Christian in the ASIC-group, he manages to bridge the gap between the rationalistic logic of MBO and the more uncertain nature of engineering work. He can be seen as a *buffer* between the two logics, which puts him in a rather powerful position and enables him to exert *time control*, i.e. to influence the time it will take until the engineers finish their tasks.

Despite this rather broad repertoire available to Carl, it is the collective repertoire that makes up the most powerful control device. *Physical* and *linguistic artifacts* can be seen as collective control devices because of their capacity of implying action for the people who understand their function and meaning. The people who know about these artifacts are primarily the engineers, and in varying degree their immediate managers. Knowledge about the artifacts is what makes a person into a peer, and it seems to be a prerequisite of making comments upon the time it will take to perform engineering work. Thus, knowledge about the artifacts seems necessary for controlling work in a division of labor based mainly on horizontal relationships.

We have seen that Carl is able to make influential comments about time in terms of how the engineers shall go about to finish on time. He "makes priorities", they say. But how do these priorities relate to the original intention of the project? Is Carl just an instrument of program management that tries to make the engineers work faster? Next, I shall delve deeper into deadlines as vertical control devices by discussing the role of one of the most central tools of time control: the time plans.

7.3 "It's better to deliver *something* than nothing" – on the ambiguous nature of time plans

It has been noted by presenting the "general information"-part that program management's (see Figure 2) decisions regarding time plans tend to be imperative, i.e. they tend to be imposed on the engineers and there seems to be little they can do to affect what is imposed on them. We have also seen how the time plans play a central role in the control attempts directed towards engineering work, especially in the follow-up activities at the object meetings. The time plans define goals for the engineers, and time plans and goals are put forth by project leaders as the main method of controlling work. As Dave, a project leader, put forth in chapter four:

> Yeah, this company is controlled by times to a large extent. That's the way it is in the IT-business, that if you miss the launch date with a week, then it's impossible to regain that volume you know.

But the objectives created by program management, formulated in time plans, do not function as instruction manuals for the engineers, telling them how to go about in order to produce a functioning product. Instead, the objectives are vague and requirements expressed by the plans are often viewed as unrealistic by the engineers. As one engineer points out regarding the deadlines:

> I think it's fun most of the time, but sometimes you get a bit pissed off because the project, I think it's too optimistic. I don't know ... it seems like the project leaders just won't listen when someone comes up with a realistic time plan. [...] If the object leader, the one who works closest to us who are going to do the work, comes up with a time plan saying "this is the time it's going to take", then it seems like it's not accepted, that it's not good enough, "you'll have to come up with something better". And then it's, "well, then we'll make it shorter, then we'll make an unrealistic time plan".

As has been noted, objectives and requirements are thought to be formulated by program management and then broken down on project and object level. Carl, as a consequence of this, is an object leader onto whom these goals are thought to be broken down. In other words, he needs to take the directives and decisions of program management into account. Below he gives his view on this process.

Because what they say here [points on an organization chart at John Gill, the top-program manager], it can break through no matter how much you ... you can protest as long as you like of course, but it is also a matter of *understanding* that 'ok, that's the way it is, and then we have to do it'. Of course you can refuse to do it if you want to, but that's not the way it works because we're a team you know.

Carl thus takes a rather pragmatic stance towards the requirements and objectives from project management. He may not like the requirements, but he "understands" that program management's words are imperative. Questioning their decisions and requirements is not feasible to Carl for the simple reason that "that's not the way it works".

This does not mean that he regards the decisions as unproblematic, however. It happens that the requirements of the time plans well exceed what Carl considers possible within the given time frame.

Of course, we have an opinion about this [the time plans], and some things that they want us to do require a *totally* different time plan you know. And because there is a demand, or an obvious requirement, from the customers, then you have to fulfill it, which forces you to compromise.

There is thus, according to Carl, a discrepancy between the requirements and what "really" can be done. Still, they *have to* finish on time because the customers, says Carl, require them to do so. The "customer orientation" that was outlined in chapter four hence manifests itself through Carl who portrays the customer as something that sets up requirements that they "have to fulfill".

The view of program management's requirements as simultaneously imperative and unrealistic appears also at the object meetings. Below is an excerpt from a meeting where Carl informs about the requirements from the project that are perceived as ... well, "problematic". We enter the meeting, which is held on a Tuesday, when they are talking about a deadline on Friday the same week. Carl says:

Ok, we are talking a lot about RF5 [a version of a prototype], and everything should be finished this week. Actually, it's a *very* tough job to do all that we *should* do this week, but I have tried to ... I made a plan for RF5. I will just briefly go through this and I think the status you have presented now ... [the engineers have just presented their

work status, i.e. how far they have proceeded in their respective areas of responsibility] yeah … it doesn't fit too well into this really tight schedule [laughing a bit]. If we focus on PCB-related changes, then I think we can do it … I'm sure we can do it. So actually, according to the present plan, we must have some kind of … a small design review already tomorrow [some laughter] … that's tough [smiling, and then laughter from everybody] … it's *really* tough … [some people are whispering] … but this gives you feedback, because your status is the only thing that can more or less stop, or change, this. It must fit into some deliveries in the end.

What Carl is saying here is that it is basically impossible to fulfill the requirements. "It's a *very* tough job to do all that we *should* do", he says, but he has made a plan, thus pointing out that they will fix it somehow. Their laughter indicates that they find the requirements unrealistic, perhaps even ridiculous. For an outside observer, they may seem to be in an impossible situation: they cannot do everything that they should do until the deadline on Friday, but they are still going to keep the deadline on Friday.

Carl's statements and the observation leads us towards the "mystery": how is it that the engineers manage to finish on time, to fulfill the requirements and demands of the customers, and deliver a functioning product despite the "unrealistic" time plans?

Carl indicates above that it is impossible to do everything that the general time plans require. The discrepancy between the requirements of the time plans and the perceived possibilities is thus what lies behind the constant need for "making priorities" that we have observed at the object meetings, a need that Carl often comes back to in interviews, saying things like:

> … it's better to deliver *something* than nothing.

> If it's a real deadline, then we modify it's content in order to keep it. That's … that's often the only way.

> It's more important to deliver than to … perhaps reach all the way, in every delivery.

Making priorities thus seems to be a matter of a quite autonomous interpretation of the situation. Priorities are made both on an ad hoc

basis at the object meetings or in everyday interaction with the engineers, and more formally by creating time plans based on general decisions from top-management. Decisions and requirements, as they come down to the engineers from program management, come in a rather inapplicable shape and need to be *modified* before they take the form of a feasible plan that can be used for work. As Carl states:

> Since nobody gives any directives from above, we try to define those kinds of things [intermediate goals] on our own.
>
> JR: Ok, so you have to try to decide that 'this is our intermediate goal'.
>
> Yes, it's very often like that. Because it's like this: it's easy to say "now we're going to make a [product]". But when everything is changing all the time, when is it ready? And for example, when it's ready for production and so on, then we have to qualify the hardware, approve it etcetera, then we have to figure those things out ourselves, without decisions from John [the top-program manager]. He only sets the top goals you know.

And:

> We control this very much on our own actually.

According to Carl, it is initially unclear to them what actually needs to be done. He and the members of his object (but mainly he) have to put up their own goals and find out on their own what is necessary to do. Their focus is on keeping the deadline that is set by top-management. This is often problematic in the eyes of the engineers, because of the discrepancy that has been touched upon above: the discrepancy between the requirements of time plans and that which is possible according to the engineers.

The practice and perceived necessity of modifying deadlines is also further elaborated upon by Lars, an experienced engineer with a background as object leader. In an interview, I mentioned my observation from the work meetings that they tend to laugh sarcastically about some of the requirements from top-management, but that they still in the end seem to manage to keep this "unrealistic" deadline. Below, he gives his view of what this is all about.

> When people laugh a bit at it like that, it can be either ... sometimes you make sure that you finish it on time, as good as you can. I mean ...

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a deadline, it's something that is to be done, and it is to be done before that deadline. And they are often very sacred; you can't move those deadlines. And if you can't move the point in time, then you can change what it is that is to be done. So you give it your best shot and redefine the content in order to keep the deadline. And this is often a very informal process, you do what you manage to do or ... people can sort of make decisions under the table regarding what they find appropriate to do, or you so to speak interpret it as constructively as possible and do what you think should be done, although it's not really what you *said* you would do.

JR: So you change the content a little sometimes ...

Yeeeah ... not that little either ... quite much. Just in order to keep that deadline.

Jake communicates a similar picture when asked how they manage to finish on Friday despite their sarcastic laughter at the work meeting Tuesday the same week.

[laughs]. Yeah ... Carl, he's good at ... limiting things, making them realistic. And he can pick out something that is optimal in order to get the delivery done or whatever it can be. It can be a verification report or something, and then it's a matter of writing more or less text, or that you skip a measurement here and there. […] He says 'yeah, but do like this, just include those parts', or 'skip that measurement, we just measure the temperature there, then we don't have to do it three times'.

A deadline, it seems, is not something that just needs to be kept. It is also something that needs to be *managed*. It needs to be modified and altered and its ambiguity needs to be resolved so that it becomes usable in the community of the radio-engineers. Those who can modify the deadline and resolve its ambiguity can be said to hold a rather powerful position (cf. Weick, 1985). It is true that deadlines on the one hand affect the work of the engineers, or as Dave has pointed out, "this company is controlled by times to a large extent", and as Lars also notes: "they [deadlines] control the business in every way". But the controlling effects of the deadlines are uncertain and the direction of control is unclear. Deadlines control the business, says Lars, but he also says that the engineers control the deadlines. The more precise content of a deadline takes shape *in* and not *before* the development work, and it takes shape as a result of a collective process of modification involving

the engineers and their object leader. The deadline only says *when*, whereas its meaning in terms of work requires a resolution of the ambiguity that comes with the deadline, a resolution that lies in the hands of Carl and the engineers of the radio group.

One could perhaps expect this type of modification practice to be a problem, because when it becomes clear that the content of the deadline has been altered, project managers or other people who put up the deadline would get rather annoyed and dissatisfied. But:

> Nobody checks it up. The project leader doesn't have it under control. It's very hard for them to check up things like that. They don't have the time and they don't have the knowledge and ... no interest either sometimes, that's my feeling. They in their turn are very dependent upon saying that they have met the deadline, so they can report that they did what they promised to do. They don't have any great interest in checking up quality and performance because it would mainly hurt themselves actually. (Lars)

And similarly put by another engineer:

> We know that it [the time plan] doesn't work, but the project leader in his turn must show his manager you know. It seems like we're fooling ourselves all the time, and I think that's bloody weak.

One may perhaps also view this behavior as a problem in terms of organizational effectiveness, that this way of working results in low quality and performance because the engineers do not stick to the plans. But although it is beyond the scope of this thesis to discuss how quality and performance could be improved and whether their way of working is optimal in terms of quality, it should be kept in mind that GT is considered to produce one of the most qualitative telecommunications technology in the world. "Letting" the engineers modify the content of the unrealistic deadlines may indeed be a way of ensuring a balance between quality and effectiveness. It may be a way of solving the vertical control problem of making the engineers subordinate technical goals to the firm's goal of profit maximization (cf. Whalley, 1986b). Because if it is as Carl and Lars' statements indicate, that the content of the kept deadline *cannot* be controlled by project leaders because there is no time and no knowledge to do it, then there is little left from a managerial perspective than to trust the engineers to

find ways of keeping up a quality that is "good enough", despite the "unrealistic" deadlines. This knowledge discrepancy, in combination with the deadline-oriented production process that gives project leaders little incentive to check up the *content* of deadlines, helps us understand why the engineers are treated as "trusted workers" (Whalley, 1986) that are largely expected to control their own work on a peer basis.

7.4 Conclusion

This chapter has focused on the aspect of *deadline focus*, but also, and again, on *knowledge*. The episode of engineering work presented is based on another work meeting, this time in the radio group. One point with the chapter is to nuance the picture of the absence of management control a bit and point out that it *is* possible for a manager to exert control, but that *only* being a manager does not leave any guarantees.

Carl, who is the object leader of the radio group, is argued to be able to exert control because he has *access to knowledge-based control devices* in addition to the hierarchy-based ones that come with the management position. These knowledge-based control devices are specified as knowledge about the *physical* and *linguistic artifacts* used in engineering work. Thus, engineering knowledge rather than hierarchical position seems to be the key to control exertion. It is not the fact that Carl is a manager that enables him to exert control, but the fact that he is seen as a knowledgeable engineer, as a peer, and perhaps even as a "master" or a *primus inter pares*. His access to the intimacies of engineering work appears to enable him to make influential comments about time.

Comparing with the object meeting presented in chapter five, there can be said to be a new meaning added. In chapter five, the meaning of Christian's follow-up activity is mainly of a ritualistic kind; he follows up work because he is supposed to but it does not mean that he is controlling the engineers to any significant extent. Carl, on the other hand, is doing the same thing as Christian but he is also exerting control by aligning the work of the engineers to the time plan. Thus, there is reason to argue that Christian does one thing: he performs the ritual that is expected of him because of his position as object leader –

whereas Carl does two things: he performs the ritual that is expected of him because of his position as object leader *and* controls the future work of the engineers. The meaning of the meeting as a disciplinary practice is added.

But the controlling effects of the physical as well as linguistic artifacts also urges us to be careful about ascribing too great powers to Carl as a person. What he knows is not more than what is known by the engineers, and in terms of contextual knowledge he is not as knowledgeable as they are. The physical and linguistic artifacts can be said to have action inherent in them, action that is understood by the engineers, which tends to make most decisions and priorities seem self-evident and normal.

Controlling time is not only a matter of influencing the engineers' behavior so that they reach the deadline on time. It also seems to be a matter of controlling the content of deadlines. From the perspective that I take here – that of the operating core – it is the engineers who take on a lot of responsibility for finishing things. Once they and their object leader have received the overall time plans, the ball is with them. The engineers perceive it as their responsibility to produce a functioning product on time, not seldom because they, as Carl notes, "must" fulfill the demands of their customers. But they often receive tasks that they perceive as more fantastic than realistic, which produces a situation that they and their immediate managers (typically object leaders such as Carl) must manage and make sense of. They have techniques for this, for managing to finish on time, including modification of the deadline content and "constructive" interpretations of the work to be done.

From a management perspective this behavior may be seen as some form of "cheating". I would put forth a different interpretation however. The behavior may be seen as an example of a *professional attitude*. It seems to be an important part of the engineering identity to be a technical problem solver; the engineers take for granted that they are there to solve technical problems. The solution of a technical problem seems not to be thought of only in terms of technical quality, however, but also in terms of time. This is indicated by the fact that when the problem cannot be solved by following the MBO-logic (that

would take too long), the engineers take the matter in their own hands and modify the content of the plan. This is testimony of a *dual responsibility*, for technical goals (engineers are supposed to solve technical problems) on the one hand and for organizational goals (managers have said it must be finished at a certain time) on the other. It is worth noting that this dynamics between time and quality suggests a modification of the common view of engineers as unwilling to sacrifice technical finesse and quality in favor of more profitable products[91]. Although the engineers at GT often view deadlines as unrealistic and state that time constraints interfere with the quality of the product, they do seem to understand and to a certain extent adopt the business perspective. Their modification of deadlines can therefore be seen an expression of a professional attitude that is necessary for the success of the project.

In the light of the observations presented, the MBO-rhetoric – the idea of breaking down goals as a rational process of, out of a larger whole, producing small pieces that perfectly fit together – seems a bit alien as a way of describing how the work process is controlled in the quest for producing functional products. Rather than rationally breaking down big goals onto small goals, it seems to be a process of breaking down fantastic ideas into realistic work.

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[91] For example, Mellström (1995) sees an "antagonism between 'the engineering perspective' and 'the business perspective'" (p. 57), the engineering perspective being more focused on quality and the business perspective on delivery on time.

Chapter eight

Controlling ideas

It was noted in the previous chapter that the direction of the control that is associated with the time plans is uncertain because on the one hand time plans control the engineers' work, but on the other the engineers control the time plans by modifying their content. Nevertheless, there is no reason to deny that the time plans, even if they can be modified, are a management control device because they *do* make up the general and initial *idea* of what shall be produced. One may thus contend that the control of the product is in the hands of managers; that they control work by deciding *what* will be produced. To a certain extent, there is a point in such contention. But it is not quite that simple, and in this chapter we will delve deeper into the issue of ideas of what shall and can be produced. In the same vein as the aspect of time as a management control device was problematized in the previous chapter, the aspect of ideas will be problematized in this: how are ideas managed and who is managing them?

Time plans do not emerge out of nothing but are the result of ideas of how to improve the product. Developing and dealing with ideas is a central aspect of engineering work, and studying the way ideas emerge is important for understanding how engineering work is controlled. The reason is that it gives insight into the dynamics not only behind *how* work is performed, but also behind the process that decides *what* work will be performed. The idea-work (at the D2-meeting) presented in chapter six can be seen as an example of how an idea is developed *after* it has been decided that it will be implemented (however *before* the idea has been incorporated in the formal time plan). We observed how the engineers worked both individually and collectively to find the best solution for implementing a certain function in the product.

This final empirical chapter exemplifies the initial stages of "idea-work", the work that takes place before it has been decided whether to implement an idea or not. In other terms, the chapter is an example of how ideas evolve and how they are managed before they become objectives and hence parts of a time plan. The aim of the chapter is to argue that the management of ideas is a central aspect of engineering work, and to show how an idea to exchange a part of the product evolves and is controlled largely horizontally by use of knowledge-based control devices.

8.1 The PA-track

The empirical material of this chapter consists of an episode where some people in the radio-group initiate and discuss the idea to exchange the power amplifier-solution of the radio. This idea is referred to here as "the PA-track". I shall outline how the idea arises, how it develops and how eventually a decision is made upon whether or not to exchange the part.

There are a number of significant actors figuring in this chapter and in order for the reader to follow the development of the PA-track more easily, I shall make a brief presentation of them here. The actors are all members of or superiors to the radio-group so you have met most of them before and you can find them in the structures presented in Figure 1, 2 and 3 in chapter four.

Harry was the section manager of the radio-group until recently, when he was promoted department manager of the department where the radio-group works. One of his responsibilities as department manager is to bring customer needs into the product development process.

Lars is an experienced engineer. His formal position is a bit unclear. He has been an object leader, but is now involved in setting the requirements for the radio, based on for example 3GPP guidelines. In his capacity as experienced engineer Lars can be said to fill some sort of an expert role in the group.

Fred is an engineer who is responsible for the PA-block in the radio, but also works with Wideband-TX (see Figure 3). Working with the PA means having contact with suppliers – referred to as Moonbeam and P-AMP in this chapter – since GT does not develop its own PA.

Carl, as you know from the previous chapter, is object leader in the radio section.

Thor is Carl's project manager. He is responsible for the hardware project and reports to program management (see Figure 2). It is thus Thor's responsibility to make sure the hardware project is finished on time and that the products fulfill the requirements set by the project plan.

These are the central actors. When other actors show up, I will use footnotes to provide brief information about their positions in the organization. Now let us turn to the PA-track and its development.

The idea arises – the background to the PA-track

This section presents a background to the initiative; how the idea of a need to exchange the PA-solution came up and how it materialized into a *technical problem*. The very origin of an idea is impossible to trace down, but there are perceptions about how it became a part of the work of the radio-group at GT and those perceptions are presented here.

Creating a need for change

Not long after New Years Eve 2004, Harry considered the future competitiveness of GT's product. This sort of consideration is a part of his job, or as he puts it, "it's our duty to look over the competitiveness of our design and keep our eyes open about what others have to offer, and what's good and bad in our construction". Harry regarded their solution for power amplification as somewhat outdated and in need of improvement. He thought it was a quite good solution in terms of power consumption, but bit complicated and, above all, it was unique for GT. The uniqueness gave their customers no choice but to use GT's PA-solution in their phones. Harry said that there was a demand from the customers that GT enable the use of various PA-suppliers, pointing out the importance of not "confining the customer to the solution that

we have chosen". A standard-PA would be better, argued Harry, so that the customers can choose if they want low power consumption, which GT's solution offers, or perhaps rather a solution that requires less space, but in return uses more power.

A few days later Harry talked to Peter Johnson, the head of R&D, and put forward the suggestion that they should do a "pre-study" in order to find out more about the pros and cons of their PA-solution. Peter Johnson thought it was a good idea and Harry wrote a "pre-study directive", on which Peter "put his name", as Harry says. There was some turbulence around the directive, but after a couple of weeks there was a decision made that gave Harry the authority to act. Harry:

> It was kind of messy, but at some point we had to put our feet down and do something. Anyway, the end of it was that we had to ask Peter to decide how the hell we would go on. [...] So we insisted upon a decision, which we got, and it was to go for this study, and then go for the solution that it turned out to be.

Harry thus got the approval from the head of R&D to go ahead and find out the pros and cons of a new PA-solution. He then delegated the work to Lars, an experienced engineer in Harry's section.

> Being a section manager [at that time], I'm the one assigning tasks to Lars I guess [...] so it's my responsibility to check what solutions we have and come up with suggestions about what we can change. [...] So I simply asked Lars to have a look at it ... and he did.

Creating a technical problem

Lars started to work on the PA-problem. He considered the possibilities of improving the PA-solution and made a suggestion which he then presented to Harry and later to program management, as he describes below in an interview during the early phase of the PA-track:

> ... well, I'm guilty of starting up a new activity [laughs]. [...] The suggestion I came up with was to take away a piece of the radio in order to save money and space. But it would use more power. Talk time would be perhaps ten or fifteen percent shorter, and it's kind of a delicate thing to shorten talk time, there's almost a bounty on that, so you can't do that [sarcasm]. But it was quite a lot of money and quite a lot of space so ... Harry wasn't very happy about it either, so 'we got to talk with program management about this' [said Harry] and so on. So I

> brought up the issue and I asked the question in front of this group [program management]. [...] It came out that maybe the important thing was not whether to take away this little piece of the construction, but the important thing was that the PA would be exchangeable; that our customers could easily exchange it.

The dynamics of product development are illustrated here. It is characterized by a trade-off between power consumption, space and price, but also by the "needs" of the customers. Thus, there is the classical trade-off which in the eyes of the engineers is a well known technical problem, then there is the additional factor of customer needs which also tend to produce new technical problems. This, in broad terms, is what the engineers have to deal with.

The technical problem facing the engineers can be summarized as follows: It is possible to save money and space by using Lars' suggestion. Lars suggests taking away "a piece of the radio". The piece is called a "DCDC-converter". What the DCDC-converter does is to lessen the power consumption of the mobile phone, but it takes up space. This is why taking it away would save space and money (because then GT does not need to purchase the component), but shorten the talk time. The problem here is to find out what is more valuable: space and money, or talk time. Then there is the other idea of making the PA-solution exchangeable. There is no doubt that it would be good for the customers with an exchangeable PA, but the problem facing the engineers is the cost of making it exchangeable. How can it be done? Is it possible at all? And if it is possible, what would it take in terms of workload and how is this workload to be valued in relation to the possible benefits of an exchangeable PA?

Developing the idea – negotiating the PA-track

From the point of a relatively clear problem formulation, the investigation now enters a second phase where the PA-track is brought up at object meetings and its formal management is taken over by Carl, the object leader. In this section we will follow the idea further via the meetings where it was discussed and see how it develops: from the technical problem emerging out of Lars' suggestion, via a collective negotiation process, to a decision whether to implement the PA-track or not.

Object meetings, February 17th and 24th, 2004 – Placing the PA-track on the agenda

The first time the PA-idea is brought up "officially" is at one of Carl's object meetings. The PA-track is not a central topic at this meeting, but it is brought up at the end. It is Fred who says that he has got "something that it's perhaps time we informed about", whereby he informs about the PA. He informs about different suppliers, and says that he will make an estimation of the increased workload that changes in the PA would create. Carl also chimes in and says that program management and "some other people in the house" want them to find a solution that supports a PA both with and without DCDC. "And that means that we've got to make a suggestion, I mean what it means in terms of work and all", he adds. Then he stresses that the existence of this track will have big consequences for them: "You know, *if* this is going to be serious, this parallel track on the PA, then it's going to be a giant job for us". They discuss this for a while and then finish the meeting.

At the next object meeting, on the 24th, Carl repeats the message that the PA-track will be a giant job, saying "it's going to be our biggest thing this year, if it will happen". He also says that the plan is to have a review of the first draft on Friday where they discuss what activities they will need to engage in if they are to develop the idea. When they have a suggestion, says Carl, they will give it to program management and they will make a decision. If it will be yes, he adds, "it will cover basically everything that Jake does [...] … and Fred will work 100 % on this too. I mean, the whole project will be focused on it."

The reason why a decision to go for the new PA-track would cover 100 % of Jake's and Fred's work time is that Jake is the one who constructed the algorithm that the old solution builds upon and he will therefore be involved in the construction of a new one. Fred, as we know, is the one who handles the contact with the suppliers, an interaction that will intensify if they decide to construct a new PA-solution.

They will thus hold a "review meeting" on Friday, where they will discuss the work related consequences of a new PA-solution. The meeting, however, is postponed to Monday the 1st of March.

The review meeting, Monday, March 1st – A view of the PA-track from different positions

The document under review is the "schedule", which is a draft of a time plan. Present at the meeting are Jake, Fred and Andy who could be said to possess the detailed knowledge about the possibilities of exchanging the PA. Lars is also there with his experience and expertise in terms of systems requirements, and also in his capacity as one of the initiators of the idea. Carl, the object leader, is heading the meeting and Victor, the section manager, is there to get an insight into the work process.

The meeting revolves around two issues: 1) the activities necessary for developing a new solution and when to start with these activities, and 2) which PA-supplier to choose for the new solution. As a basis for their discussion they have a preliminary plan, which is the result of Fred's, Jake's and Andy's work. Everybody has had as an "action" to write down main activities necessary and estimate the time a new PA-track will consume.

They discuss the different activities necessary in terms of pros and cons, time consumption etc., and get to a point where they need to decide when it is possible to start working on the new solution. Their opinions differ. Fred who handles the contact with the suppliers of PAs wants them to start right away in order to have a specification finished for the suppliers by the end of next week, which is week 11. But in order to make a specification for the suppliers they need to make an "inner loop budget"[92], which only Jake can do, and Jake says he cannot do it until week 14, adding that it's a "big job" and that "it's gonna be a difficult task".

Fred thinks week 14 is too late, because the suppliers have one "production round" in week 11 and the next one will not be until the end of the summer. For a while the problem seems unsolvable, Carl at one point exclaims: "Now I'm a bit puzzled … what possibilities *do* we have to change the PA ... really?" The solution they eventually end up with is that Fred has to talk to the suppliers about their problem and tell them that they will get a specification by week 14.

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[92] Making an "inner loop budget" is about breaking down requirements regarding the output power of the radio onto block level.

The next topic of the meeting is about which PA-supplier to choose. They are currently working with two suppliers: P-AMP and Moonbeam. Their opinions differ again. Fred thinks it would be wise to continue working with both for a while longer in order to see what they can offer and to have one as a backup if the other does not work well enough. Carl thinks that they don't have resources for running both PAs. The others seem to agree with Carl. They discuss for a while then Andy argues that they will not know what they want before they have to decide what they want, "then you've got to take a chance", he says. "Exactly!", Carl exclaims, and now establishes that "that's the way it's going to be", that they may have to make a decision without a specified offer from both suppliers. Getting the offers would take too long.

They thus decide to go for just one PA-supplier. Then the question is which one to choose. Lars suggests they have a "decision meeting" in order to get more information about the pros and cons with the two suppliers. They decide that Fred will hold the meeting on Friday this week after all. Carl adds, "I think this is high priority stuff", then they discuss a little more. At the end Carl thanks everybody and they leave.

Decision meeting, March 8th – Too many positions?

The "decision meeting" is not held on Friday the same week, but on the following Monday, the 8th. Carl only participates for 10 minutes, then he has to leave for the dentist. The meeting is characterized by indecisiveness, by the difficulty to come to an agreement on which supplier to choose. Fred favors Moonbeam and the others favor P-AMP, and most of the time is spent interrogating Fred about details on the suppliers. The meeting ends without any decision upon a preferred supplier, and they conclude that they have to discuss with Carl "because he's the one responsible for this". I leave the meeting with Fred. "There are so many people who want to decide things", he says.

The following day there is some brief discussion about the PA-track at the work meeting (where Carl is object leader). Carl who did not participate at yesterday's meeting asks Fred if there is anything to say about the new PA. Fred says that they need some more information because there are still many questions regarding the both suppliers. For that reason they will continue to work with both for a while. Carl does

not seem entirely content with the situation and says that he hopes Thor will call a meeting where they can discuss the PA-track further. Thor does call a meeting, and they meet on Friday the same week.

Meeting with Thor, March 12th – Considering trade-offs

They thus meet again four days later to discuss the work on the new PA. This time there are some new people among the participants:

Harry
Thor
Fred
Carl
Kyle Donovan (working with customer relations)
Victor (section manager)

They would want Jake to be there but he was busy. And perhaps a bit surprisingly, Lars does not attend the meeting.

The meeting starts by Thor framing the situation by pointing out the purpose of the meeting, saying that "the main reason for this is that we saw that our customers are confined to the PA that we have, plus that we want to lower our costs and decrease the size of the PA". He adds that this is not an official project yet, but only an investigation of how to solve the problem. He also summarizes the situation thus far, saying that they have "tossed this up to the top" but program management did not know what they wanted more than that they "wanted to have the cake and eat it": thus both the old power-saving solution and the new space- and cost-saving solution. He points out that he sees large costs in terms of resources, and that it is going to be "a gigantic job" to start up the PA-track. "So what I want now is that we summarize what kind of solution we believe in", he says, "and then give it to program management". Thor wants to know what they "really think" about introducing this before March 2005: "You must have something that *we* believe in, that we can succeed in […] because if *we* are fuzzy and don't quite know what we want, then management will *never* be able to make any decision either, but they will just be fuzzying around."

After Thor's rather long statement about the purpose of the meeting they start discussing the possibilities of implementing the PA-track. The participants' general attitudes to the idea of the PA-track soon appear: Fred is clearly in favor of going for the PA-track. Carl has troubles understanding Fred's planning in terms of time, but seems otherwise to be taking the possibilities of changing the PA before the next big release seriously. Thor is highly skeptical and wants to play it safe because he is not sure they have resources for taking care of unexpected things that "pop up". Harry is positive but wants the scenario to be discussed further.

They discuss but do not come to any conclusion. Then Harry asks: "What does your gut feeling tell you?", in an attempt to move the discussion forward. "*Will* we get a solution here, now? Let's say we take Moonbeam. Will our customers be able to change PA easily?", he continues. After some discussion Carl says that his gut feeling tells him that the suggested solutions will be problematic for the customers to handle. Fred thinks that the costumers will certainly still need assistance from GT, but also that "sooner or later the customers are going to protest against the old PA ... and we'll have to change to this [new] solution". He thinks now is the right time to change. Harry points out that if they make the change, the customers will at least have a theoretical possibility to switch the PA: "It might include a lot of work, but will at least be *possible*". Thor's gut feeling seems to indicate "danger". He issues warnings, pointing out that this idea means work for the software department too, although he does not know how much. "We have to look at the whole picture, so that we won't risk the R9-release [bid deadline in March 2005]", argues Thor. He also stresses the uncertainty of the project, that "everything must be analyzed and systemized", that it will include much work, stressing that they have to be able to do it on time, adding: "These kind of things are deadly dangerous you know".

The discussion continues for quite a while. Then Thor asks: "Do we still believe that it's possible and that this has been sufficiently investigated?" Harry replies: "It hasn't ... I've got a feeling that we need a comment from Jake".

When the meeting starts coming to an end, the discussion turns more and more into a dialogue between Harry and Thor, where their innovation- vs. "follow the time plan"-logics are contrasted against each other and their positions crystallize. They do not reach any agreement, but they do agree that they need to have another meeting, and that they need to make a list of the pros and cons of developing a new PA-solution. They will meet up again in a week, and Harry suggests that they will have such a document until next week. He asks who is in charge of this, "is it you Carl?", he says and Carl replies: "yeah, I can do that". Harry points out that he wants Carl to look at costs and how many people will be needed and how long time it will take. Thor also chimes in with a reminder: "If we're going to show this upwards, then we should try to make it as simple as possible. Not a lot of … you know: [just] advantages and disadvantages; the first thing we talked about, costs and consequences". "Maybe we'll need a first internal meeting, just us", says Carl. "Yes, yes", replies Thor. "Then we'll have to cut out 90 percent" [before they show it "upwards"], adds Carl, and Thor nods. People start leaving the room. Thor suggests that they meet the same time next week. They leave. [end of meeting]

We shall see below how the PA-track ends. The next meeting does not take place the following week as planned, mainly because Thor does not have time. Therefore they postpone it for a couple of days. It turns out that Thor has difficulties finding time for those days too, so Carl and Thor decide – after a very short discussion at one of the project meetings that Thor holds with the object leaders – that they will have the meeting without Thor.

PA-decision meeting, March 24th – Drawing conclusions

Two days after the project meeting, on the 24th, only three people meet to decide whether they think the PA-track is a good idea or not. It is Carl, who has made the list of pros and cons, Harry who is the department manager, and Victor who is the section manager. They meet up in a small room.

Harry starts off by saying that the most interesting thing is "workload, how much work will this mean?", and "what are the key advantages, technical advantages that we see? Can the *customer* really use these advantages", and last, "what is the alternative use of the people that will

do this?" Carl agrees. Harry then asks Carl: "What's your feeling, or what is Jake's feeling?" Carl replies that a standard, exchangeable PA will be impossible according to Jake. Harry points out that it would be naïve to believe that it would possible to use just any PA with the system of power regulation they have now. Carl agrees, and says: "Exactly. That's Jake's short summary. Advantages in terms of flexibility: None." They seem to move toward a negative decision, but then Harry's fascination with the possibilities of an exchangeable solution rises again. "Ah it ... damn!, it *is* attractive to let the customer make that decision", he says.

The discussion continues. Then Harry says that he has to leave and sort of delegates the decision to Victor and Carl: "I would like you to look through this and think, both of you ... two people, 26 weeks ... can we do this? I have to go now." Harry is standing in the doorway, ready to leave. Carl seems to feel a need for more comments from Harry and asks him if there is anything that he, "just spontaneously", thinks is missing in the list. Harry does not think there is anything in particular missing, but adds that he is uncertain. Still, he says, "if I had to make a decision now based on this, then I would probably say that we won't do it." Carl says that he "feels the same way". Before Harry leaves he says that they have to talk to Thor too, then adding, "he has no problems with the decision that we recommend, has he?" "No", says Victor.

Harry leaves and Victor has to go out for a short while. It is only I and Carl left. "This doesn't feel good", Carl tells me. I ask him who is making the decision in this issue. "Who's making the decision?", he replies, "... eh ... it's sort of a decision now, and the decisions are made ... well they are highlighted by us but they are made by Thor. That's the way I would put it." Then Victor comes back and although the decision seems to have been made he and Carl stay for about half an hour, discussing the list of pros and cons in more detail.

When I interview Harry a few days after the meeting, I get the "decision report". It is two pages, containing a short background to the problem, a short comparison in terms of technical performance between the existing and the new PA-solution, and the decision that they (the ones present at the meeting) do not recommend the use of a new solution in the present product. On the front page of the decision

report it is stated who was present at the decision meeting and who should be informed about the decision. The ones who should be informed are Thor, Fred and Lars. According to Harry the decision never even reached top-management, which becomes clear when we discuss what happened after the meeting.

> Afterwards we checked that the project was okay with this. And it's rather like … the opposite would have required a decision [from project management], but choosing this path as we did, to drop it, actually only required business as usual for the project. So we just checked with Thor, and told him what we had decided.
>
> [JR:] Yeah … and that was to drop it.
>
> Mm. Not to do it. That's the way it was done.

8.2 Controlling the idea – a largely horizontal process

There is no absolute birthplace of the PA-track, but it can be seen as a result of interaction between Harry and Lars. Both seem to view themselves as initiators of the idea: Lars states that he is "guilty of starting up a new activity" and Harry tells us about him considering the future of the product and finding PA-solution a bit outdated. From different positions they seem to have constructed a problem, which is thought of as a "gap" between the perceived current situation and some object of comparison (cf. Sahlin-Andersson, 1996)[93]. Harry can be said to have constructed a "business-problem" based on a comparison between the customers' future needs and the radio in its existing form: he sees that the customers want an exchangeable PA. Lars can be said to have constructed a "technical problem" based of a comparison between the "truths" of telecommunications development (the smaller, cheaper

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[93] Sahlin-Andersson (1996) does not focus on ideas such as this one, but discusses how organizational forms and practices move around, how they are imitated and translated. What is relevant here is that she puts forth the importance of paying attention to how problems are constructed in local settings in order to understand the movement of the practices, and suggests that problems are constructed "through comparing the local situation with that of other organizations", and that "the gap between the local situation and the one to which it is compared is then defined as a problem" (p. 70).

and less power consuming, the better) and the radio in its existing form: he sees the possibility of constructing a smaller and cheaper PA-solution.

Program management as loosely coupled to idea-management

Both Harry and Lars consider it to be their work to identify such potential problems and possibilities of improvement. As Harry noted, "It is our duty to look over the competitiveness of our design". It is also considered common that ideas emerge "from below":

> That we're working on things like this from below, that's definitely common, because there's no leadership from above regarding issues like this. So all initiatives must come from below, yes. Management takes no initiatives, no. You can easily count on that. (Lars)

Carl, the object leader, also says that ideas emerge among themselves rather than at the level of program management, and that program management do not quite comprehend the scope of the ideas.

> Yeah, I don't think there's going to be any clear decision, but if we make an investigation and show what *has to* be done, then it's going to be good input for them so that they can make a decision more easily. So it's our own ... we simply see that it's necessary. [...] But the problem is that it's 100 % sure that they will say "yes, of course we're going to have that". But there is nobody there who knows how much work that means to us. (Carl)

The involvement of program management in the process is indirect and often seen as peripheral. They are expected (and likely) to have a more comprehensive view of the situation, but they seem not to be very active in the process, which is indicated by Harry pointing out that they needed to "insist upon a decision". In another passage, Harry portrays the value of program management's input as rather limited.

> Program management gave us some input, I guess. [...] They gave the input that the situation today was no good; that we have to change it. [...] And they also said that the power consumption is almost too bad already as it is today [...]. So that's the input we got from there. (Harry)

Harry further says that program management does give input to their work, but that it mainly consists of pointing out what the customers need, as he states when I ask him if program management has any reason to doubt the information that the engineers produce.

> No it ... they only see "what's the customer's benefit?" "What do the customers ask for?" They see what the customers ask for, and then we discuss it with them and then we have to take a look at the technical solutions [...].

Program management is mentioned as a quite insignificant actor who had little to do with the initiation or management of this idea. As pointed out by Harry, they needed the head of R&D to "put his name" on the directive that Harry had written. Harry also says that they had to struggle to get answers from program management, indicating that program management shows little interest in decision making that gives the engineers authority to go ahead, and Lars sarcastically remarks that there is "almost a bounty on" shortening talk time, indicating that he finds program management's view of technical problems rather simplistic. Lars is also more explicit about this. When I ask what he thinks that program management has said regarding the PA-track he replies: "What I feel?! ... I feel that they are genuinely uninterested in hardware. I'm actually quite disappointed in them being so incredibly uninterested."

The distance between program management and the work with ideas is also illustrated in the meetings where the idea is discussed. At the review meeting on the 1st of March, Carl, Fred, Andy and Jake discuss the activities necessary for developing a new solution, when to start with these activities, and which PA-supplier to choose for the new solution. The observation exemplifies how much of the *planning of work* takes place at the bottom of the hierarchy. It is the "operating core" discussing not only "how shall we do?", but also "*what* shall we do?" and "what *can* we do?"

At the meeting on the 12th of March program management is again portrayed as an indecisive and marginal actor from which they get little support or guidance and to which one "tosses" things and hopes for them to come down in a comprehensible way. This time, it seems, the idea that was tossed up came down in a rather useless shape since they

"want to have the cake and eat it". Thor reveals the perception that program management can do little if they are not confronted with *established facts*: "because if *we* are fuzzy and don't quite know what we want, then the management will *never* be able to make any decision either, but they will be fuzzying around." This indicates that program management will acknowledge their solution if they will only say that they think it is the right thing to do, and thus that the responsibility for a successful development of the PA-solution rests on the shoulders of the engineers and their immediate managers.

Another indicator of the loose coupling between program management and engineering work is the engineers' consensus that they have to "make it as simple as possible" and "cut out 90 percent" before they present it to program management. The perception is thus put forth that program management do not understand the dynamics of work, the information given to them needs to be strongly simplified, and they do not take initiatives but initiatives must come, as they say, "from below".

A last note regarding the peripheral role of program management regards the last decision meeting on the 24th. It appears that even when it comes to the final decision, initiative and control to a large extent come "from below". Harry even delegates the decision to Carl and Victor. Perhaps most striking is the fact that top-management was never even informed about the decision because it was "only business as usual" for them anyway, as pointed out by Harry in the interview some time after the last PA-meeting. It seems like the PA-track emerged in a collective process initiated, managed and terminated by Harry, Lars, Carl, Thor, Fred, Andy, Victor and Jake.

In conclusion, in the episode of the PA-track the engineers and their immediate managers can be seen as both "carriers" and "users" of the ideas (cf. Erlingsdottír & Jonnergård, 2006). It is they who make sure the ideas emerge and it is they who manage them into something useful, but it is also they who will later use the ideas in the actual construction of a product. A parallel can be made to the circular movement in lab-work, where it is the engineer who is both producer of symbols (when manipulating materials) and user of symbols (when using the results of the manipulations for further manipulation of the

material, and when controlling the manipulations in the review). Program management, on the other hand, is portrayed as only "loosely coupled" (Weick, 1976) to the development and management of the idea.

Knowledge positions as sources of control

If the relationship between program management and the work with the idea can be described as "loosely coupled", the relationship among those who actually work with the idea can be described as "leveled". The traditional hierarchy-based asymmetry between managers and employees tends to be replaced by a knowledge-based one in the management of the idea. Put differently, if we look at the formal organization structure, the participants of the PA-track are not formally peers because they are positioned on hierarchically different levels. But in the management of the idea they can be said to *become* peers. Positions are therefore understood here as *knowledge positions*, indicating that holding a position means knowing something particular instead of being of a higher rank. And it is the access to this knowledge, rather than to hierarchy-based rules, that makes it possible to influence the idea.

As we know from previous chapters, Carl is the object leader in the radio-group. He is not using his position as object leader much to exercise control however; neither he nor anybody else draw explicitly upon his leader role or address him as a leader. For example, at the review-meeting on the 1st, everybody involved possess valuable knowledge about the PA-track, but depending upon position they know different things: Fred knows about the suppliers, the way they work and their requirements, and Andy and Jake know about their blocks and the time they have available to work on the PA-track. Another example is the fact that it is Fred and not Carl who brings up the PA-track on the agenda at the work meeting on February the 17th. It is he who informs about it and about his work with the information needed. This is a necessary action for the PA-track to move on instead of staying on an ideal level. By bringing up the PA-track at the meeting, Fred can be said to create the possibility for the idea to disseminate. Carl then supports this dissemination by picking it up himself saying that they "got to make a suggestion" to project management. He also –

at the object meeting on February 24th – makes it clear that now the PA track is a part of the engineers' work and that it is *they* who have to make a plan, iterate it and then formulate a suggestion to Thor and program management. Nevertheless, Carl's position as object leader does not seem to make his knowledge count more than anybody else's.

The discussion on the 12th of March is characterized by uncertainty. Various versions of possibilities and threats appear. Perhaps a bit surprising – considering the context of high technology and the relatively exact science of engineering – Harry asks them: "What does your gut feeling tell you?", thus consulting their feelings in order to deal with the uncertainty. Fred works with the suppliers and (gut-) feels the fact that the suppliers will be able to give them more exact information if they just wait a little longer to choose supplier, and in general his gut feeling seems to be: "we have to change". Carl is object leader and feels that working on two PA-solutions will interfere with other object work, his gut feeling thus saying: "technical problems". Thor is project leader and feels that the PA-solution will interfere dangerously with his time plan, irrespective of the number of solutions, and his gut feeling seems to call out: "danger!". Harry is department manager and his task is to make sure that changes are qualitative, i.e. that there are improvements that contribute to increasing the quality of their product in the eyes of the customer, his gut feeling thus telling him: "customer value first".

That which is called gut feeling, however, could be replaced by their different knowledge positions in the organization. The positions to a large extent seem to control the actions of their inhabitants. As noted before, holding a position means knowing things, and the difference between positions can be understood by the difference in (mainly contextual) knowledge. This knowledge position, in turn, is then *acted out* in the discussion.

The knowledge seems connected to the interactions of the holder of the position. Fred interacts with suppliers, Carl with project managers that demand him to keep his deadline, Thor interacts with program management and other project managers (e.g. software project managers) and Harry interacts with other line managers working with quality issues and with customers. All these interactions create contextual knowledge, and the people involved in the work on the PA-

track act to a large extent in line with these knowledges. All through the meetings, Fred has focused on the relationship with the suppliers, Carl on time and its effects on their work with the technical solutions, Thor on the environment external to their project and the risk it brings with it, and Harry on the quality of the whole idea in terms of customer value.

There is no apparent hierarchy among the knowledges, however. Instead, all seem to be about equally influential and nobody claims to really know what is best. It may even be the case that the more general knowledge of Thor and Harry is less influential than that of the engineers. Harry and Thor's discussion – focusing on whether to "play it safe" and follow the time plan (Thor) or take more chances and aim for new innovations (Harry) – seems insufficient for making a decision here. The need for in depth engineering knowledge to decide how to go about is most clearly indicated when Harry after a lengthy discussion on pros and cons concludes: "I've got a feeling we need a comment from Jake". And when Harry at the "Decision meeting" on the 24th asks Carl regarding the possibilities for the customers to actually exchange the PA: "What's your feeling, or what's Jake's feeling?" By referring to Jake, both Harry and Carl indicate that their own positions are not sufficient for a satisfactory understanding of the idea, thus playing down hierarchy and management knowledge as a basis for influence, and instead playing up engineering knowledge.

Moderate elements of vertical control

Knowledge is emphasized here as a source for forming a position and for exerting control. This is not to say that hierarchy-based control is totally absent. For example, at the last part of the meeting on the 12th of March the character of control changes when Harry outlines what he wants Carl to do and he more or less points out Carl as responsible for the investigation, thus structuring Carl's work. Harry "initiates structure", as it is often labeled in traditional leadership terms (e.g. House, 1971; Stogdill, 1974).

This initiation of structure, or task orientation, appears as rather peripheral as a means of controlling the development of the idea as a whole though. During the main part of the meeting, Harry, Thor, Carl and Fred are all engaged in the knowledge-based exertion of control.

Harry is basically just telling Carl to do what is expected of him: to take responsibility for finding out more facts about the PA-track. Thus, there are elements of vertical control attempts, but they are moderate rather than significant.

In sum, the idea seems to emerge in a horizontal process; its management is largely based on a horizontal division of labor, where a number of people from different but equally influential knowledge-positions discuss how to proceed.

8.3 Conclusion

Time plans have been put forth as central to the engineers' work. In the previous chapter I argued that the content of the time plans was modified by the engineers, thus making the distinction between the controller and the controlled ambiguous: are the time plans controlling the engineers or are the engineers controlling the time plans? Irrespective of the direction of this relationship, it was noted that time plans at least determine a framework within which the engineers work, a framework that seemed to be created by program management.

This chapter does not argue that program management are inactive in the creation of the time plans, of course, but that the information – the *ideas* – used to produce the time plans is largely a product of the engineers' work. Thus, ideas about what is technologically feasible are established by the engineers, and program management then considers these ideas as established facts (e.g. by "putting their name on it", as Harry says). Managers do bring in customer needs as a guiding principle (Anderson-Gough et al., 2000) and they provide coordination with other groups involved in the process of production (such as coordination between software and hardware), but their role seems to be rather peripheral on the whole. Program management is argued to be at best loosely coupled to the management of ideas.

The relationship between that which in Mintzbergian (e.g. Mintzberg, 1989) terms is called "the strategic apex" and "the operating core" is blurred. It may be expected that the problem of "how" to develop technology be solved by the operating core of the organization. But in

the PA-track they consider not only *how* to solve problems, but also *what* problems to solve and the advantages, disadvantages and consequences of choosing different alternatives. The engineers can be seen as both "carriers" and "users" of the ideas (cf. Erlingsdottír & Jonnergård, 2006) and thereby engage in activities that are traditionally thought to be the privilege of the strategic apex.

To a certain extent, the "middle line" is involved in the discussion. But the formal hierarchical differences between those who manage the idea tend to be leveled out. Formally, the actors in the PA-track are not peers, but they *become* peers in the process of managing the idea. In contrast to the management of lab-work, the management of the idea requires knowledge about customers, suppliers and the overall project. Still, the people involved are to be seen as a "community of the PA", since they do share contextual knowledge about the idea, which enables them to meaningfully contribute to its development.

The idea is thus not seen as something that is pushed through by management, but rather as something with an uncertain origin that is picked up by various actors from varying knowledge-positions; knowledge-positions that are *necessary* for picking up and managing the idea, and knowledge-positions that indicate to their inhabitants that they *should* pick up and manage the idea. There is argued to be an extensive horizontal division of labor where conception as well as execution, mental as well as manual work, are carried out by the same people, and where one's knowledge-position rather than formally hierarchical position determines the possibilities to exert control.

The development and management of the idea of an exchangeable PA – the negotiation of pros and cons and the possibilities and problems and finally a decision against it – seems to be performed by the engineers and their immediate managers. It is thus feasible to conclude that the engineers and their immediate managers are not helpless subjects to the objectives. Rather, they to a large extent control the ideas that will eventually become objectives. As Harry puts it: "You know, there's nobody telling us what to do, so if we want to change something, we sort of have to fight for what we think is good, and come up with suggestions of what we should do and then see if it's possible to

implement from other perspectives than our own". Or in other terms: they both do and are engineering work.

Chapter nine

Peer reviewing as a method of horizontal control

I have argued throughout this book that vertical control plays a peripheral rather than central role in the control of operational engineering work. The argument is to be contemplated in the light of the dominant theories of organizational control which almost exclusively focus on vertical relationships in their attempts to understand what makes organizational action come about: direct supervision (e.g. Fayol, 1916; Taylor, 1911/1998), MBO or project management (e.g. Drucker, 1954; Kerzner, 1992; Maylor, 2003), standardization of skills (Mintzberg, 1979), the development of technical systems (e.g. Edwards, 1979), bureaucratic rules (e.g. Edwards, 1979; Ouchi, 1979) norms and values (e.g. Etzioni, 1961/1975; Ouchi, 1979) or identities (e.g. Ashforth & Mael, 1989; Albert, Ashforth & Dutton, 2000), are all thought of as methods by which superiors influence the actions of subordinates. Some scholars are skeptical of the extent to which managers can intentionally control work, but still keep focus on what managers do in their attempts to understand the phenomenon of organizational control (e.g. Kunda, 1992; Alvesson & Willmott, 2002).

A general and methodological argument in this thesis is that, albeit insightful and important, a too narrow focus on the vertical dimension has a hampering effect on the interpretative possibilities within the field of organizational control, because organizational control does not by definition equal vertical control. In an attempt to open up for alternative interpretations I have employed an ethnographically inspired method where – in search of control and taking the argument seriously that organization studies would gain from focusing more on what

people actually do (Barley & Kunda, 2001) – the empirical gaze has been directed towards operative work rather than managerial work.

Through this method I have found that there is a discrepancy between the rhetoric used by managers – conceptualized as "the rhetoric of MBO" – when accounting for the way in which work is controlled, and the way control appears when searched for in various episodes of engineering work. The rhetoric of MBO suggests that work is controlled vertically by managers who formulate goals, break down general goals onto lower and more specific levels, and follow up the very same goals to make sure they are reached. MBO is indeed practiced, but I have argued that it is only loosely coupled to the practice of engineering work. The engineers tend to decouple MBO from their work by "infusing uncertainty" and "dislocating leadership" (chapter five).

Instead of accepting the rhetoric of MBO, I have argued that the capacity to exert control does not so much reside in the access to formal hierarchy-based control devices as in the access to engineering knowledge. As discussed in chapter six, engineering knowledge contains a high level of both contextual and formal knowledge (Crawford, 1989; Whalley & Barley, 1997) whose use requires "discretion or fresh judgment" (Freidson, 2001). This makes it difficult for anyone but the engineers themselves to use the knowledge as a control devise. Managers may be able to control the operative work, but it requires access to engineering knowledge rather than a formally higher position, as discussed in chapter seven. To a large extent, the engineers can be seen as "trusted workers" (Whalley, 1986) who must be trusted to do a good job for the organization.

Formally, it is program management that make decisions regarding deadlines and which objectives to pursue. But as shown in chapter seven, the control over the meaning of the deadlines lies to a large extent in the hands of the engineers. They modify the content of the time plans, converting what they perceive as fantastic deadlines into realistic work. Similarly, the control over the objectives to a large extent appears to be in the hands of the engineers. Detailed engineering knowledge plays a central role when finding out which objectives are feasible and which are not. This is shown in chapter eight, where I

argue that the engineers are highly involved in the management of new ideas, influencing not only the ways in which objectives are to be fulfilled, but also which objectives that will be pursued.

All this boils down to the argument that horizontal relationships play a central role in "the processes and methods by which an organization's members determine what things get done and how they are done", i.e. in organizational control (Johnson & Gill, 1993: x). This brings me to the topic of this chapter: the development of an understanding of organizational control of engineering work as a horizontal phenomenon.

I shall do three things in this final chapter. I shall develop and discuss that which is to be seen as the main contribution of this thesis in terms of conceptual development: the notion of *peer reviewing* as a way of understanding horizontal control. I shall also discuss the wider relevance of peer reviewing by relating it to other methods that have been argued to control complex work. And last, I shall discuss the implications of this study for future research.

9.1 The concept of peer reviewing

Peer reviewing, I argue, is a concept that can be productively used to capture the central method of controlling operative engineering work. I shall therefore expand on it here. First, I shall discuss the conditions that make the peer review possible, in general and at GT in particular. Second, I shall outline different types of peer reviewing at GT. And third, I shall discuss the nature of peer reviewing by focusing on the meaning of "peer", the notion of authority and the notion of unobtrusiveness in peer reviewing.

Conditions and characteristics of peer reviewing

We may think of peer reviewing as an activity where reviewers are external to their own organization and as far as possible impartial[94].

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[94] I would assume that this type is what academics think of first when they hear the term. This may differ from the more general view. For example, the first entry under "peer review" in the Oxford English Dictionary does not include these

This is one way in which physicians review each other's work through a referral system, asking colleagues at a different hospital to comment on the diagnosis of a patient[95]. It is also one way in which the peer review system is used in academia to control the quality of research, where external and impartial researchers control the quality of the production of other researchers through "blind" reviews (e.g. Smith, 1990; Quinlan, 2002; Starbuck, 2003). In a similar manner, accountants use a peer review system as quality control (e.g. Fogarty, 1996; Erlingsdottír & Jonnergård, 2006). It may also be thought of as a planned and standardized evaluation procedure of self-regulation where professionals, typically doctors and nurses, from one organization (e.g. a hospital) are expected to control the quality of another organization in terms of various aspects such as education, teamwork or staffing (e.g. Van Weert, 2000; Lombarts & Klazinga, 2001).

The peer reviewing that I refer to deviates in a number of respects from this type. At GT, peer reviewing is internal and the reviewers can therefore neither be seen as external nor impartial. You basically need to work with the same or a connecting piece of the product to be able to review. The peer review at GT is thus not only internal to the organization; it is internal to a certain work activity. As a consequence, the impartiality (if there is such thing) of the reviewers is a bit flawed: being members of the same organization they have a common stake in the success of the company, and being involved in the same work activity they have a common stake in the success of this very activity. The extent to which this matters for their review practice is uncertain, however. The engineers have little interest in just letting the work pass without critical scrutiny since dysfunctional technology is unlikely to make *anyone* happy; if it does not fulfill general internal requirements

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aspects. It reads: "The review of commercial, professional, or academic efficiency, competence, etc., by others in the same occupation; an instance of this".

[95] Of course, the (external) referral system is *one* way of controlling the work of physicians through peer reviewing, not *the* way. I would suspect the phenomenon of internal peer reviewing to be applicable to the work of physicians too.

or the requirements of 3GPP[96] it will not be considered successful work. But still, there is a certain difference in terms of politics between an external and an internal peer review.

In addition to being internal, peer reviewing at GT stresses the importance of local, specialized and contextual knowledge. It can be said to require a *community of practice*, which is seen by Lave & Wenger (1991) as an "intrinsic condition for the existence of knowledge" (p. 98)[97]. The community of practice is not to be confused with the occupational community of engineering, a community that is initially constructed through the formal schooling where the members have acquired common experiences as well as their formal knowledge (see Van Maanen & Barley, 1984; Freidson, 2001). Nearly all GT-employees are members of the occupational community of engineering. The community of practice considered here is more specific. It refers to engineers who on a detailed level share both formal and contextual knowledge. These engineers are the full members of the community of practice and it is these engineers who are considered to be *peers*. Peer reviewing therefore cannot take place in just any group of people but requires people with access to the same type of knowledge. This access, as we have seen, tends to be local and specialized.

This frames what I mean by peer reviewing. It is understood here as *an activity that takes place at an operative level within a community of practice, where one or more members of the community discuss, scrutinize and evaluate the work of another member or other members.* As for the nature of the control exercised in peer reviewing, it does not take the character of a "check", as it does for example in the follow-up practice.

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[96] As described in chapter four, the 3GPP is an international partnership between a number of officially recognized standardization organizations that control the standards of telecommunication.

[97] Lave & Wenger use "community of practice" as a part of an analysis of learning, where learning is seen as a process of *becoming*, typically illustrated by the apprentice who moves from peripheral participation to full membership of a community of practice. This analysis contains a clear dimension of hierarchy and power (see also Contu & Willmott, 2003), since learning is associated with a move through the hierarchy of a community of practice. In my analysis, however, the learning aspect is toned down and I focus on the aspect that views a community of practice as an arena in which knowledge is used.

Rather, it resembles the activity of *editing*, of suggesting an alteration – typically an addition or subtraction – of the object towards which the control is directed.

Types of peer reviewing at GT

In the light of the above it is possible to identify different types of peer reviewing that take place at GT, for it is not only the practice formally labeled as "review" that contains the dynamics of peer reviewing. In the table below, four different types are identified:

Type of peer review	Empirical example	Relative degree of formalization	Purpose
The explicit peer review	The review meeting	High: - Includes invitation - Target of control = a finished piece of engineering work - A verdict is given	Quality control and evaluation
The "managed" peer review	Guido	High/Low: - Intended procedure: high. - Procedure in use: low. - Target: as above	Quality control and evaluation
The peer conference	- The D2-meeting - Parts of the object meetings - The meetings of the PA-track	Medium: - Includes invitation - Target of control= an idea or an ongoing piece of work	- Making work move forward - Developing or evaluating ideas. - Reducing uncertainty
The peer consultation	Jake and Andy negotiating Andy's solution	Low: - Ad hoc basis - Target of control = an idea or an ongoing piece of work	- Making work move forward - Developing or evaluating ideas - Reducing uncertainty

Table 2 Types of peer reviewing at GT

The *explicit peer review* is exemplified by the "actual" review meetings. The explicit review is more formal than the other types because people are invited in advance, there is a formal meeting held, there is a specific piece of work that is up for review, there is a verdict given and the purpose of the review is to control and evaluate the quality of work.

This differs from the second type, *the managed peer review*, which is formal in the sense that there is a control system – Guido – that requires the engineers to search for and report errors in the work of their colleagues, and to let the decisions regarding how to proceed go via the Change Control Board (CCB). There is no formal meeting held

where the reviewing takes place, however. And there may be an intention to formalize, but the degree of formalization is ambiguous in the managed peer review since, as we have seen in chapter five, the actual process of taking care of errors and solving problems seems to take place on a horizontal and informal basis.

The third type, *the peer conference*, is less formal because the target of control is not a "finished" piece of engineering work, but an idea of some piece of work that is going on. Furthermore, the purpose of the peer conference is not to control quality in any direct sense, but rather to make work move forward, to develop and evaluate ideas or to reduce uncertainty by having peers look at and comment on one's ideas and work. The best example of a peer conference is the D2-meeting where they discussed the different solutions to a technical problem. But many meetings take the shape of peer conferences: ideas were developed at the meetings where the PA-track was discussed, and at parts of the object meetings – where the follow-up activity turns into discussions among the engineers of how to solve various technical problems – the engineers get ideas and inducements from peers of how to carry out their future work.

The formal element of the peer conference consists of the fact that the peer reviewing takes place within the framework of an announced meeting, which is what makes the peer conference different from the *peer consultation*. The peer consultation – although it takes place within the framework of a meeting in the sense that two or more peers meet up to perform the review – is not preceded by an announcement. It takes place on an ad hoc basis, the best example being when Andy and Jake discussed Andy's solution to the technical problem dealt with at the D2-meeting.

As we can see, the types of peer reviewing differ quite much in terms of formalization – from the formally held quality control in the explicit peer review where a verdict is given to the informal discussion between colleagues of how to go about in the peer consultation – but what they all have in common is that *they are examples of situations of uncertainty where the decision regarding what to do and how to do it is made by or among peers instead of by managers*. The strength of control in terms of coercion diminishes as we move down the table of peer review

situations. The element of evaluation becomes less salient and a formal verdict is only given in the explicit peer review. It is therefore possible to say that the explicit peer review is the strongest type, whereas the peer consultation is the weakest type.

The fact that managers play a peripheral role is probably more conspicuous in the stronger forms of peer reviewing. For example, according to the literature on MBO and/or the project management literature, it is the manager's task to follow up or "measure" work[98], tasks that are performed more in the explicit peer review than in the peer conference or the peer consultation. Is it then *in*conspicuous that colleagues rather than managers are turned to for consultation? If the consultation is about practical things that you may not want to bother your manager with, the answer is perhaps yes. But even the weakest type of peer reviewing – peer consultation – should not be mistaken for general chatting with colleagues about work. It requires more than that. In common with the stronger forms of peer reviewing, peer consultation requires 1) that turning to colleagues for advice is a *systematically and typically used method for solving problems*, and 2) that the issue discussed between the peers is *central to the production process and of a knowledge intensive kind*. This means that the problems are not discussed between peers because the engineers do not want to bother their manager with such details, but because the manager would probably be of less help than the peer.

The meaning of peership

Being a peer means in general terms to be of the same rank. But it is possible to be more specific than that. In order to expand on the notion of peer, I shall discuss it in the light of a type of work that is often conceived of as highly *peer intensive*: professional work.

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[98] This is not specific to the MBO literature, of course. These tasks are attributed to managers in most forms of management control; as noted by for example Alvesson & Kärreman (2004b), "[m]anagement control typically includes an apparatus for specifying, monitoring and evaluating individual and collective action" (p. 424).

Peer control of professionals mainly refers to an institutional and indirect level of control[99]. As noted in chapter two, professionalism is often referred to as "the institutional circumstances in which the members of occupations rather than consumers or managers control work" (Freidson, 2001: 12). This level is also emphasized by Torstendahl (1990) who writes that "the theory of professionalism has to do [...] with how knowledge (and/or skill) is used by its owners as a *social capital* and *not* only for purposes connected with the immediate problem-solving to which the system itself may refer" (p. 2, my emphasis). The perhaps best example of these institutional circumstances are the professional, supra-organizational associations of which lawyers and physicians are members, but other examples are licensing and other training arrangements that support professionalism (Abbot, 1991). The professional associations prescribe what is good and bad behavior (they have a "code of conduct"), and if a member is excluded from the association s/he loses the right to practice the profession.

It is beyond the scope of this study to discuss in depth the extent to which "institutional circumstances" matter[100]. I restrict myself to note that such circumstances make up a work context in their capacity as socialization devices and producers of a common formal knowledge. But they refer to peership and hence peer reviewing on a different *level* than the one I have studied. "Institutional circumstances" refer to peership on an indirect, general and occupational level (see

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[99] I put forth institutional peer control here in order to differentiate between the type I am talking about and the type often connected with professionals. The fact that professional peer control is often *thought of* as institutional, however, does not prevent professionals from being guided by intra-organizational controls rather than institutional controls. As Etzioni noted already in 1961: "a large amount of control over professional performances has been transferred from the professional community to the professional organization" (Etzioni, 1961/1975: 361).

[100] The institutional pressure is often considered to be weaker in the case of engineers than in the case of the traditional professions because engineers do not have such strong associations. As a result and as has been noted in chapter two, engineers are seldom considered to be "real" professionals, but instead "semi-professionals" (Etzioni, 1969) or less successful professionals (Whalley, 1986).

Erlingsdottír & Jonnergård, 2006). I refer to peership on a direct, local and operative level.

In addition to the difference in terms of level, there is a difference that pertains to the *scope* of peership. I have argued that managers in the engineering context are not seen as peers and thus not as capable of reviewing engineering work. This is different to the depiction of law firms, accounting firms or hospitals, where professionals are considered to grow more knowledgeable *and* gain more managerial responsibilities as their professional experience increases (see e.g. Greenwood et al, 1990). For example, the physician becomes a chief physician or the lawyer becomes a partner of the law firm. Whether the chief physician is actually more knowledgeable than his/her junior colleagues after some years of *both* administration and medical practice should be left unsaid. The point is that they continue with their professional practice and are therefore considered to remain members of the community of practice: they *remain peers*.

Engineers tend to switch from doing engineering work to doing management work (Orr, 1996), and according to some, (e.g. Abbot, 1991), engineers are also more likely to switch occupational identification (from "engineer" to "manager") than are physicians or lawyers. At GT, you are unlikely to practice operative engineering work once you have become a manager. People may ask you for advice during your first years as a manager, but you will not do any hands-on work as will a physician or a lawyer. Rather, you will deal with administration. As a result, engineers who become managers often lose their membership in the community of practice (but keep their membership in the occupational community), which means that they lose their role as controllers of engineering work through peer reviewing.

In sum, the meaning of peership that I want to convey differs somewhat to the way it is commonly portrayed in the literature of the professions. The main condition that enables peer reviewing to take place is the existence of a community of practice, which exists on an operative rather than institutional level. This has consequences for the scope of peership. Peers are referred to as members of the community of practice rather than members of the occupational community of

engineers. Such restrictions do not prevent peer reviewing from applying to the operative work of professionals such as physicians[101]; indeed, it may fertilize the literature of the professions through its more operative focus. It may very well be possible to identify local communities of practice among physicians, communities that control their work through peer reviewing and that grant access only to a few full members.

This determination of peership brings with it the suggestion that the control of operative engineering work is very *peer intensive*. Engineering work is therefore argued to be uncertain, knowledge intensive, deadline focused, idea intensive, and, as an addition to the four aspects listed in the introduction, peer intensive.

The unobtrusiveness of peer reviewing

A characteristic of peer reviewing is that it is perceived as *unobtrusive*. At GT, the review is described as a "good way of working" (Sebastian) that is about "having several eyes directed towards the problems in order to cover up for the possibility that you miss something" (Jake). In a similar vein, the peer review is not seen as disruptive or disquieting, which is often the case with vertical control, but rather as *constructive* and *productive*: "new things are added" in the review, as Sebastian says. In a sense, peer reviewing does not seem to be perceived as control at all, but as "support" or even "help", which was discussed in chapter six where the engineers talk about the importance of helping, and of helping as a "cultural thing".

Horizontal control does not necessarily have to be unobtrusive. Take for example the academic peer review where a "reject" is likely to be perceived as highly obtrusive (Starbuck, 2003)[102]. But taking the

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[101] Or, for that matter, to the operative work of members of so-called professional service firms (Løwendahl, 1997) such as accountants, or members of so-called knowledge intensive firms (Alvesson, 2004) such as management consultants.

[102] One reason why the academic review may be perceived as especially obtrusive is according to Starbuck (2003) that it is not really constructed as a *peer* review. He states that the editors of academic journals do not treat authors and reviewers as peers. Instead, they tend to "act as if reviewers are more competent than authors" (p. 345). This is different to the peer review at GT, where there is

context presented here into consideration, the unobtrusiveness can become understandable.

First, the local and internal nature of peer reviewing gives rise to what can be referred to as a *collective accountability*. By continuously reviewing each other's work, the engineers become collectively responsible for success as well as failure. Through peer reviewing, a certain amount of responsibility is dislocated from the individual engineer to the community of practice – the collective and not only the individual can be blamed for a not discovering an error or a deviation. Thus, there is a common interest constructed within the community of practice to optimize the work performance, which makes peer scrutiny be perceived as support and help rather than control.

Second, the direct target of peer reviewing is work and not the individual person. This is different to the horizontal control put forth by studies where employees are expected to evaluate each other based on their qualities as employees, such as their adherence to team- or company norms and rules (e.g. Barker, 1993; McKinley & Taylor, 1996). Colleagues who are expected to evaluate each other based on their qualities as employees may indeed find this awkward and obtrusive and invent ways of resisting requirements to perform such tasks (McKinley & Taylor, 1996). But peer reviewing is directed towards work. It is perceived as a "way of working" and not a way of control, and it does not clash with what the engineers have learned to do at work: solve technical problems.

Unobtrusiveness can make control very effective (Sewell, 1998). One reason for this is that the employees are unlikely to engage in critical reflection directed towards a control system that is perceived as "a good way of working", as a productive practice. As Barker (1999) who studied normative control in teams notes: "To cultivate means for critiquing these powerful and unobtrusive processes, the team must deliberately set aside time to review how they are controlling themselves" (p. 180). Such reflection is not a part of peer reviewing. Instead, its smooth integration in the production process, its alignment

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no apparent third part ("the editor") mediating between the reviewer and the reviewed.

with the engineering identity of a technical problem solver – perhaps best illustrated by Jake's enthusiastic work with problem solving, both alone and together with Andy – and the fact that it is decoupled from managerial practice gives it the appearance of "non-control". But it has controlling effects in that it makes work move forward by guiding the work and thus behavior of the member that is under review.

Peer reviewing and the vertical dimension

The notion of "peership" may indicate the total absence of vertical relationships, the absence of authority. But peership is unlikely to be absolute; it admits a certain power asymmetry. In addition, peer reviewing does not operate in isolation of other forms of control, but its relationship to other forms of control can be seen as *interactive* (cf. Sewell, 1998; Alvesson & Kärreman, 2004).

Perhaps a bit paradoxically, peer reviewing is a practice where authority is produced. As we have seen, there are persons who are *primus inter pares*, first among equals; persons who, although participating in peer review practices, appear to be more than peers and have more of a say than other engineers. We have seen two examples of this: Alex, the knowledgeable engineer in chapter five, and Carl, the object leader in chapter seven.

Alex' position illustrates that it is engineering knowledge rather than formal hierarchical position that counts. The case of Carl is a bit different because he *is* the object leader of the group. One way of interpreting Carl's *primus* position is that he holds it for the same reason as Alex, because of superior engineering knowledge. But Carl does not appear to be superior in terms of engineering knowledge; equal at times perhaps, but not superior. Another interpretation is therefore that Carl's formal position *amplifies* his influence. The engineers are indeed impressed by his "sense of details", ability to "make priorities" and understanding of the "practical aspects" of work, as outlined in chapter seven. His technical expertise does not need to be superior to that of the engineers, but it needs to be about equal. Equal knowledge *combined* with his position as object leader, however, makes him more than equal, because the engineers do not expect someone who has elevated the hierarchy to understand the details of their work.

When Carl proves knowledgeable, he therefore reaches the status of a *primus*.

It is clear that engineering knowledge is the main determinant for becoming *primus*, but a primus position may also be gained by combining knowledge with an elevated hierarchical position. Either way, peer reviewing is to be seen as a practice where authority is negotiated and produced. As a result, peer reviewing is not completely disconnected from vertical control, but rather interacts with it by being a site where local authority is produced in the shape of the *primus inter pares*.

The existence of *primus*-people enables peer reviewing to interact with vertical controls also on an organizational level. Specifically, the *primus*-people function as "buffers", which may conceal the obtrusiveness of MBO and other practices of vertical control. As we have seen, MBO has a limited effect in its rationalistic version portrayed by managers. But the very practice of holding regular meetings where goals are informed about and discussed may "encode" the engineers with organizational goals (Covaleski et al, 1998). The engineers may not experience this encoding, however, when it is facilitated by a *primus inter pares* such as Alex or Carl. The image of "the engineer" as someone who gets instructions from managers may be perceived as obtrusive, but less likely so when the instructions or goals are reformulated as technical problems by someone with authority *within* the community of practice. Along this line of reasoning, an effect of peer reviewing is thus not only prevention of critical reflection directed towards the practice itself, as was noted earlier, but also creation of a smokescreen that obstructs the view upwards and diverts the attention from what is coming down "from above". In this sense, peer reviewing interacts with vertical control by transforming its obtrusive features (instructions) into a form that appeals to the engineers (technical problems).

Another feature that enables interaction between peer reviewing and vertical controls is the existence of technical control systems (Edwards, 1979). Guido, the error reporting system presented in chapter five, is an example of this. It contains the requirement that actions taken by the engineers be approved by a "change control board", populated by

people of higher rank. We have seen that the engineers circumnavigate the board, but the influence of the board should not be neglected. Although the board seems to interfere little in the work of the engineers, there is always the *possibility* that they would. As long as everything works smoothly, as long as the engineers engage in productive peer reviewing, there is no reason for the board to intervene. Thus, if the engineers want to save themselves from managerial intervention they gain from taking care of problems through peer reviewing instead of through the board. In this way, by creating an incentive for engaging in horizontal control, Guido can be said to interact with peer reviewing.

A third element enabling interaction between vertical and horizontal controls is the very existence of peer reviewing itself. We have seen in chapter eight how the emergence of ideas to a large extent is controlled by the engineers. The actual selection between ideas, or projects, is left to top-management, however. Although the top-managers are confronted with more or less established facts from the engineers, they have alternatives to choose between, and their choices have consequences for the engineers. But at the same time, the choices could never have been made without the existence of peer reviewing. The top-management selection and the peer reviewing exist in a relationship of mutual dependence. The selection between established facts creates a context in which peer reviewing operates as a control mechanism in the implementation of the projects, but peer reviewing also creates a context for the selection process. In this way, by constructing each other's contexts, vertical and horizontal control interact through the existence of peer reviewing.

Not a glass cage, but a community with a firewall

The argumentation above states that peer reviewing to a certain extent invites vertical controls to interact. But as has been indicated throughout the thesis, it is only with great effort that vertical control makes its way into the operative work of the engineers. Today's employees have – by scholars influenced by the work of Foucault (1977) – been suggested to work under the gaze of a panopticon, disciplined by a source of control that they cannot see but that they feel is constantly present. Similarly, they have been suggested to work in a

"glass cage", an enclosure that emphasizes transparency, display, external and official reviews, and "exposure to the eye of the customer, the fellow employee, the manager" (Gabriel, 2005: 18). These images produce a fruitful illustration and critique of today's normative and unobtrusive control methods, such as the emphasis on teamwork, commitment, empowerment and participation. But they are too macro/institutionally oriented to serve my purposes. They do not capture the dynamics on the operative level that I wish to convey.

The exposure of the engineers is more limited than what is implied by the image of the panopticon or that of glass. Of course, to some extent, we are all under the gaze of something, such as a protestant ethic or the dynamics of capitalist production. But when it comes to less grandiose sources of control such as MBO or other managerially initiated methods of controlling what to do and how to do it in the organization, the work of the engineers seems to be relatively well protected. Peer reviewing indeed indicates that the engineers are on display in relation to their peers in the community, but towards the outside there is not the transparency and exposure conveyed by a shield of glass. As I have attempted to illustrate, the engineers are protected by an impenetrable vernacular, and by the necessity of contextual knowledge for making comments about work. Instead of working in a glass cage, they can be said to work in a community that is protected by a *firewall*.

As most readers have probably experienced, a firewall protects but is no guarantee against intrusion. Its code can be cracked. This relationship captures the interaction between horizontal and vertical control. Vertical control that wishes to influence the behavior of the community needs to "crack the code" of the firewall. It needs to have access to the contextual knowledge of the community, it needs to speak its vernacular. The most apparent way through the firewall, as we have seen, goes via a *primus inter pares*. The *primus inter pares*-phenomenon is an element in the peer review process that allows vertical control to interact. The *primus*-people function as buffers and translate potentially obtrusive managerial instructions into unobtrusive technical problems. Another way through the wall is via technical control systems such as Guido, which encourages the engineers to engage in productive peer reviewing in order to avoid direct exposure to vertical controls. And

once through the firewall, the vertical control is not perceived as vertical anymore, but as a "way of working" that provides "support" and "help". It becomes one with the community.

As most readers have probably experienced too, a firewall does not only protect against intrusion, it also obscures the view to the outside. Some things are stopped by the firewall although we want to (or perhaps ought to) know about them. So we may work in our safe-haven without knowing what is going on outside and without getting any indications that we should reflect upon how we relate to the outside. Perhaps we would even gain from taking the firewall away. The firewall thus not only illustrates protection, but also the unobtrusiveness of peer reviewing. The firewall of technical knowledge makes the things that take place within the community seem normal and as they should be. It facilitates the perception that the engineers just do what an engineer has got to do: solve technical problems.

Hence, although peer reviewing is a horizontal practice that requires discretion and contains its own "firewall", protecting against vertical control attempts that are likely to be perceived as obtrusive by the engineers, it also to a certain extent invites to interaction with vertical controls. In this sense, peer reviewing may indeed be "a good way of working". But it is more than that. It is a rather ambiguous process that on the one hand enables the engineers to exercise control over their own work, but on the other produces a local context that may prevent the employees from engaging in critical reflection upon more subtle ways in which vertical control is directed towards their community.

9.2 Peer reviewing and complex work

In the introductory chapter I asked how work is controlled when it is uncertain how long it will take to perform the tasks, when a high degree of both formal and contextual knowledge is required to perform the tasks, and when, as a result, the organization largely must trust the employees at the lowest hierarchical level to come up with ideas in order for the product to improve. I have argued throughout this book that engineering is an example of such "complex work" and suggested

that the question can be answered by arguing that work is controlled in a process that can be conceptualized as peer reviewing.

I shall start this section by discussing the notion of peer reviewing as a way of conceptualizing the control of engineering, relating it to earlier studies of engineering work. Engineering work is only one example of complex work, however. Therefore, I shall continue and discuss peer reviewing as a concept that adds and contributes to the methods that are said to be directed towards the broader category of complex work.

A way of conceptualizing the control of engineering work

In chapter two I outlined how organizational control has been portrayed in previous ethnographies of engineering work. The need for normative controls in the shape of socialization and recruitment strategies has been stressed as a way of preparing the engineers for an organizational life as technical problem solvers (Whalley, 1989; Crawford, 1989). Socialization has also been said to continue in the organization through management attempts of aligning the engineers' mind-set with the organizational values (Kunda, 1992), and there have been attempts to tie the engineers to the organization by offering them a career as managers (Perlow & Bailyn, 1997). When it comes to the operative work of the engineers, the control has been argued to be based on a horizontal rather than vertical division of labor. Further, engineers have been said to be "trusted workers" who work in "insulated involvement" (Whalley, 1986) or in "communities of practice" (Barley, 1996; Orr, 1996). In these communities they are said to be granted a high level of freedom in terms of deciding how to perform the technical work (e.g. Crawford, 1989; Zabusky, 1997).

This study acknowledges the argument that control is based on a horizontal division of labor, but takes the issue further and attempts to create an understanding of how this horizontal control can be described and understood. The concept of peer reviewing is central to this attempt and as a way of relating it to other conceptualizations of how engineering work is controlled, it is productive to make a separation in terms of "level", in terms of the "direction" of control, and in terms of what the control argument sets out to explain, as shown in Table 3.

Method of control	Level	Direction	Main idea
Socialization	Institutional	Vertical. University teachers design technical education.	Explains how the engineers, mainly through schooling, are prepared for organizational life as technical problem solvers.
Horizontal division of labor	Organizational	Vertical. Managers design organization structure.	Explains how engineering work is structured within the firm. Instead of superiors telling the engineers what to do and how to do it, the engineers specialize in different fields (which can be seen as "communities of practice") within which they are granted a large degree of autonomy. Much communication and knowledge transfer takes place horizontally instead of vertically.
Peer reviewing	Operative	Horizontal. Engineers control engineers.	Explains control on an operative level. The engineers, within communities of practice, exert control by discussing, scrutinizing and evaluating each other's work.

Table 3 Relationship between different methods of controlling engineering work.

As noted, this study should be seen as an extension of earlier accounts of the way engineering work is controlled. Still, some critique is motivated. Keeping in mind that many of the earlier studies call for an ethnographic approach to the study of engineering, closely examining the everyday practice of work (Whalley, 1986; Barley, 1996), and that they stress the importance of horizontal relationships, there is reason to criticize the accounts of control for being either surprisingly macro oriented or surprisingly focused on vertical controls. Socialization is often referred to as the time at university, something that all engineers go through and therefore belongs to the general and/or macro-related rather than everyday conditions of engineering work. Kunda's (1992) account of culture regulation is an exception to this, and so is Whalley's (1986) concept of "insulated involvement" which describes how it can be that the engineers are so relatively satisfied with their situation. These exceptions, however, are examples of vertical controls, of how

managers design control systems. They are worthwhile as such, but offer little understanding of how horizontal control operates.

An exception to both the macro orientation and the vertical focus is Orr's (1996) study of copier repair technicians. Orr observed how the technicians made and told stories based on their work experiences, and he suggests that these stories function as organizers of work and disseminators of knowledge. In other terms, he suggests that the stories have controlling effects; that they function as indicators for the technicians of what to do and (particularly) how to do it.

Orr's account indeed suggests *how* control operates in everyday work, and peer reviewing should be seen as an alternative to his understanding of story telling. Story telling á la Orr was not encountered in my fieldwork and it fails to offer satisfactory explanatory value as a conceptualization of horizontal control at GT. One reason for this, I believe, which was touched upon in the introductory chapter, is that the work of Orr's technicians and that of the engineers at GT differs in many ways. Particularly, it differs in the sense that the technicians only use technology, whereas the engineers use and develop the same. As a result of the development focus, the same thing is seldom done twice. Stories about how to perform work and how to solve problems would therefore become obsolete before they develop into "real" stories in the sense of: "Have you heard about the time when I had to fix the copier with a paper clip …", and the like. This is not to say that stories cannot matter in engineering work. It is just to say that if they matter, it will not be as "operating instructions" for technical problem solving, but rather as "hero stories" indicating what being and behaving as an engineer means.

Thus: as an alternative to story telling and probably as a more relevant method when it comes to engineering rather than technical work; as a development of the studies that argue for a focus on the horizontal dimension; and as an addition to the relatively small amount of ethnographic studies of engineering work, this study offers conceptual development through the introduction and development of the concept of peer reviewing as a means of understanding *how* control operates in the horizontal division of labor of everyday engineering work.

A way of conceptualizing the control of complex work

As has been noted, engineering work is seen here as an example of the broader category of complex work, the latter being used in this thesis as a concept that fuses the categories of "knowledge work" and "professional work". Under the circumstances of complex work, "normative control" (e.g. Etzioni, 1961/1975; Kunda, 1992) – with sub-categories such as "clan control" (Ouchi, 1979) and "identity regulation" (Alvesson & Willmott, 2002) – and "professional control" (Wilensky, 1964; Simpson, 1985; Freidson, 2001) are established ways of conceptualizing control. So are the concepts of "MBO", "mutual adjustment" and "teamwork". Peer reviewing shall be seen as a contribution to this line of conceptual development that attempts to create an understanding of how complex work is controlled.

Peer reviewing and normative controls

I have discussed peer reviewing as an unobtrusive form of control. This connects it with the more general notion of normative controls. Unobtrusiveness, I would say, is the gist of normative control because the latter is control that is not perceived as control. Another central feature of normative control is that it targets people's minds, beliefs and norms. This is in contrast to peer reviewing, which targets the work of the employees. Targeting work should not prevent a method of control from having normative effects however. It would be a limitation to the study of normative control if it only focused on people's minds. Studying people's mind is always problematic, and we – in the study of organizational control – are only interested in people's minds because they affect what people do. So if we accept that normative control can be directed towards other entities than the individual subject (Fleming & Spicer, 2005), peer reviewing can be thought of as a type of control with normative "overtones", that however targets work and not minds.

Peer reviewing can thus be said to contain a combinatorial feature: a direct work focus combined with normative overtones. The work focus more or less guarantees material effects – an engineer is unlikely to ignore the scrutiny or advice of the colleagues, particularly in the stronger forms of peer reviewing. This separates it from "pure" forms of vertical normative control attempts such as culture change attempts or identity regulation where material effects require 1) that the regulatory

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attempts result in a change in the employees' taken for granted assumptions or sense of self, and 2) that this change leads to a change in work behavior.

The normative overtones emerge in the capacity of peer reviewing as a practice where an engineering identity of being a technical problem solver is reproduced, for the main purpose of the peer review practice is to solve technical problems. As noted, peer reviewing takes place within a community of practice and behind a "firewall". Here, peer reviewing is perceived as technical problem solving rather than control, and therefore as being in line with the engineers' perception of what an engineer *does*. Peer reviewing is unlikely to interfere with the engineering identity for it is thought of as good and productive and a natural part of technical problem solving. There is thus a "two-in-one effect". Peer reviewing controls work, but it also reproduces what is perceived as normal, what engineering work is perceived to be all about. The combination between directly targeting work and indirectly reproducing an engineering identity that includes viewing peer reviewing as non-control may make peer reviewing a particularly powerful method of control.

In terms of similarities between peer reviewing and normative controls, there is a particular affinity to Barker's (1993; 1999) notion of "concertive control". Concertive control shares with peer reviewing the feature that it is exerted horizontally. Concertive control does not originate in managerial action but "arises from the team members' own negotiated and persuasive discourses about how to do good work for their organization", and, as noted in chapter two, the team members "act in *concert* with each other to create a mechanism for controlling their own behavior" (Barker, 1999: 35). Concertive control is a type of normative control since it targets the norms and values of the employee, and Barker's study shows how this normative control grew stronger after the introduction of teams at ISE Communications, a firm that was formerly controlled by more bureaucratic methods. His observation is relevant to this study because it offers an explanation of how work is controlled when vertical methods are absent or fail and the control emerges among the employees themselves. The concept of peer reviewing can be seen as a similar but different explanation to the same phenomenon.

Peer reviewing is similar to concertive control in terms of focus: it attempts to explain control methods that emerge horizontally among the employees. It is also similar for the reasons discussed above: it controls norms. At GT norms regulate what an engineer is supposed to do (solve technical problems); at ISE norms regulate what is good teamwork. Peer reviewing is different, however, in that its primary target of control is the work and not the minds, thoughts and beliefs of the employees. Thus, it does not control norms directly. It is also different in the sense that it requires peership in terms of shared formal and contextual knowledge. Concertive control does not place such requirements and is therefore wider in its scope. Nevertheless, peer reviewing contains concertive elements and may very well be seen as an example of indirect concertive control: it targets work directly, but has indirect normative and concertive effects.

Hence, based on the most commonly used definition, that normative control targets the minds and beliefs of the employees, peer reviewing is not to be thought of as a normative method of control. It targets work in the first place, and norms and beliefs only in the second. But peer reviewing shares the feature of unobtrusiveness with normative controls, and it may very well have normative effects, not least because the engineering identity can be said to be reproduced in the peer review process. Its focus on work in combination with its normative overtones may indeed make it a stronger form of control than "pure" forms of normative control such as vertical attempts of regulating culture or identity.

Peer reviewing and professional controls

I touched upon professional controls when trying to flesh out how the meaning of being a peer at GT differs from its meaning as commonly portrayed the literature of professional work. Peer reviewing as understood here is direct, local and operative; in professional work peer control is portrayed as indirect, general and institutional/occupational. But there are also similarities. What particularly brings peer reviewing and the professional model of control together is their common connection to complex work and the argument that work is largely controlled by the employees themselves.

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The common features appear more clearly if a distinction between indirect and direct forms of professional control is made. As noted in chapter two, indirect control refers to "administrative structures that constitute a framework of limiting constraints and rewards around the possibilities for behavior", and direct control refers to "the mutual influences of human beings in everyday settings" (Freidson, 1975: 7). Along this line of reasoning and as a complement to the often discussed indirect forms of professional control – such as the existence of professional associations, professional norms, restrictive licensing, formal training and educational requirements – peer reviewing can be seen as *a direct method of professional control*. It takes place through direct social interaction between peers and not through administrative structures such as bureaucratic rules or other management control systems.

The practice of peer reviewing may also suggest an explanation of how professionalism is maintained. As noted, professionalism can be referred to as "the institutional circumstances in which the members of occupations rather than consumers or managers control work" (Freidson, 2001: 12). Professional work is thus thought of as "protected" from management control and customer influences by the institutional circumstances (such as professional associations and norms, formal education etc.) surrounding the profession. A functioning practice of peer reviewing is likely to construct a similar protection, but on a *local* and *operative* rather than institutional level. Because of the "firewall" protecting the community of practice, the professionals are likely to remain in control of their knowledge, out of reach of knowledge-management attempts of making their tacit knowledge explicit (Sewell, 2005), or various attempts of commodification (Braverman, 1974; Cooley, 1980) that may threaten their professionalism. This is in line with an understanding of professionalism as not only dependent on institutional circumstances, but also on the ability and privilege of practicing expert knowledge (Abbott, 1991).

I have shown in this book how the engineers "protect" themselves by for example "infusing uncertainty" and "dislocating leadership". Similar processes may take place among professionals. The notion of peer reviewing may thus be relevant for the study of both how professionals

control each other on a local level, and for understanding how this control enables them to maintain their status as professionals.

Peer reviewing and other concepts of controlling complex work

Peer reviewing can add substance to other, more general, concepts that aim to describe how complex work is controlled. A number of such concepts were brought up in chapter two: teamwork and mutual adjustment as horizontal controls, and standardization of skills and MBO as vertical controls. I will discuss them here under the same heading because the same general argument applies to them all: that they assume some but do not really explain any form of horizontal control and therefore their explanatory value can gain from being combined with peer reviewing.

The perhaps most popular and frequently used concept of horizontal control is *teamwork*. As I noted in chapter two, the gist of teamwork is to have team members perform controlling activities that were once the task of managers (Barker, 1999; Thompson & McHugh, 2002). As a result, more control is thought to be exerted among the team members and less by managers or leaders (Galbraith & Lawler, 1993). Teamwork is thus a phenomenon that *presupposes* that team members use some method to control each other.

The idea of teamwork is applicable to my observations at GT because I argue that the engineers (the "team members") perform much of the control activities themselves. Peer reviewing is to be seen as a way of conceptualizing *how* this is done, something that is most often left out in the teamwork literature (see chapter two). In companionship with normative methods developed by team researchers – such as concertive control (Barker, 1993; 1999) or peer surveillance (Sewell, 1998) – peer reviewing is a concept that can contribute to a substantiation and further understanding of the control methods behind teamwork. It suggests an explanation of how "self-managing teams" are controlled, given that they consist of peers.

"Mutual adjustment" can be seen as an attempt of explaining how horizontal control operates. But the explanation lingers. What is pointed out is the *importance* of mutual adjustment between employees to take place for organizational goals to be achieved (Mintzberg, 1979;

1989). As discussed in chapter two, this has been done at the expense of developing an understanding of *how* it operates. Mutual adjustment is also very general: it is a method of control that takes place, to a larger or lesser extent, in all organizations (see Mintzberg, 1979). Peer reviewing does not take place in all organizations; especially not the stronger, more formalized explicit peer review, but not the weaker peer consultation either. As has been noted, peer reviewing is a systematically used method of solving problems that are of a knowledge intensive kind, that are central to the production process, and where managers' competence tends to be of little use.

The same line of reasoning as above can be applied to MBO and standardization of skills, which are to be seen as vertical methods of control (see chapter two). They too, in common with teamwork, presuppose some form of horizontal control. MBO – which has been used extensively in this thesis as a representative of the idea that work can be rationally controlled by managers – assumes some form of control that makes employees work towards the objectives (Drucker, 1954; Odiorne, 1965). "Standardization of skills" assumes that skills, once standardized, are used in a concertive effort to achieve organizational goals (Mintzberg, 1979; 1989). None of them, however, discusses what this control would look like, how it can be conceptualized and how it can be said to operate. This study suggests that it can be said to operate in a process of peer reviewing.

A comparative matrix

Based on the discussion above, it is possible to summarize the relationship between peer reviewing and other methods of controlling complex work in a table (Table 4).

Method of control	Target	Degree of expertise required	Degree of obtrusive-ness	Degree of directness
Vertical controls				
- MBO	Output	Medium	High	Medium[1]
- Standardization of skills	Behavior	High	Low	Low
- Normative control (General, e.g. identity- or culture regulation)	Minds, believes	Low	Low	Low
Horizontal controls				
- Teamwork/Mutual adjustment[2]	?	?	?	High
- Concertive control (Normative)	Minds, believes	Low	Low	Medium[3]
- Professional controls	Behavior	High	Low	Low
- Peer reviewing	Work	High	Very low	High

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[1] Formulation and breaking down of goals is basically the production of a system and thereby indirect. Follow up, on the other hand, is direct.
[2] Teamwork and mutual adjustment do not suggest how work is controlled. Their universal character makes it hard to make sense of any target, whether expertise is required, or whether it is perceived as obtrusive. As has been noted, there is reason to criticize the way these concepts have been used for pointing out what is necessary in complex work, rather than how control operates.
[3] Construction of norms produces a system of rules, which is indirect. It is common, of course, that the rules are followed up in direct social interaction.

Table 4 Peer reviewing and other methods of controlling complex work.

Naturally, the matrix is not exhaustive, the categories are not unambiguous, there are overlaps and there are combinations. The matrix shall be seen as an analytical tool and not a map of the empirical reality. It is a rough guide to the relationship between peer reviewing and other methods of controlling complex work. The use of the categories should follow a "more-or-less logic" and not an "either-or logic". For example, I argue that it is *more* worthwhile to think of the direct target of peer reviewing as work and less worthwhile to think of it as minds and beliefs (the argument for peer reviewing as targeting work, hence, does not, as we have seen, exclude the idea that minds and beliefs are affected indirectly).

Let us briefly go through the dimensions. "*Target*" refers to the target of control. The prime target of peer reviewing is work. In the review

situations, the engineers discuss, scrutinize and evaluate each other's work, which gives rise to new work and thus behavior. This is different to concertive control, which is similar to peer reviewing but targets not the actual work of employees but their minds, beliefs and norms.

"*Degree of expertise required*" refers to the extent to which the expertise that is associated with the work (in engineering work possession of formal and contextual knowledge) is needed in order to exert control. Peer reviewing requires a high degree of expertise, which again distinguishes it from concertive control that can be exerted irrespective of the complexity of the work performed. MBO is said in the table to require a medium degree of expertise. The managerial activity of formulating and breaking down goals is likely to take some insight into the details and conditions of work.

"*Degree of obtrusiveness*" refers to the extent to which the control is perceived as obtrusive by its receivers. As noted, this is a feature inherent in all normative control. (All successful normative control, that is, because as has been discussed, normative control *attempts* may very well be perceived as obtrusive.) The matrix indicates that unobtrusiveness characterizes most of the methods of controlling complex work, which is little surprising in the light of the argument that those who carry out the work are often experts who do not accept direct orders. It is worth noting that the unobtrusiveness is an ideal feature, and the way control is perceived is an empirical matter. Peer reviewing is argued to be particularly unobtrusive. MBO as obtrusive is based on my observation of how the engineers find the construction of the deadlines (objectives) unrealistic and how they resist follow-up attempts. One may argue that MBO can be exercised unobtrusively, as in the case of Alex or Carl's follow up. But in these instances, the practice shares more features with peer reviewing than with MBO. I have referred to this phenomenon as "interaction" between the vertical MBO and the horizontal peer reviewing.

"*Degree of directness*" refers to the extent to which control is exerted on an interpersonal level, without any kind of system or instrument between the controller and the controlled. This dimension distinguishes peer reviewing from professional control in its most common shape as exerted on an institutional level. Peer reviewing, as has been noted, may

very well be understood as a direct form of professional control, as a way of understanding how professionals control each other on an everyday level.

In sum, peer reviewing is a horizontal method of control that requires a high degree of expertise for its exertion, is perceived as unobtrusive, targets work and is exercised directly from one person to another.

9.3 Summary of the contribution

The main contribution of this thesis is the argument for and development of peer reviewing as a horizontal method of controlling engineering work. This adds to the previous studies of engineering work, which have pointed out the importance of horizontal relationships, but not engaged much in conceptual development aiming at understanding how horizontal control operates.

Peer reviewing has been given a number of characteristics:

1) It is understood as an activity that takes place at an operative level within a community of practice, where one or more members of the community discuss, scrutinize and evaluate the work of another member or other members. It is a systematically and typically used method for solving problems that are central to the production process and of a knowledge intensive kind.

2) In contrast to vertical controls, peer reviewing tends to be perceived as an unobtrusive and productive practice, but is has controlling effects: it targets and affects the work and thus behavior of the individual that is under review and it makes work move forward. In addition, it has normative overtones; it is a practice in which the meaning of being an engineer is negotiated.

3) It does not operate in splendid isolation, but "interacts" with vertical controls such as MBO. It thus generates more effects than what is implied by its apparent status as horizontal quality control.

The development of peer reviewing gives rise to additional contributions:

- By relating peer reviewing to other methods suggested to control complex work – a category of which engineering is an example – the concept can contribute to the understanding of how other types of work are controlled. The main contribution of peer reviewing here is that it focuses on and conceptualizes the horizontal dimension of control, a dimension that, I argue, is particularly relevant in complex work.

- A methodological contribution: The study is an example of how control can be "searched for" in everyday operative work rather than in managerial work.

- An empirical contribution: By presenting a number of episodes of engineering work, constructed through ethnographically inspired research, this study adds to the relatively few studies of this kind. It gives a general insight into the way in which a number of engineers at a major high-tech firm work, and it contributes to our understanding of the nature of engineering work by suggesting that it is characterized by: uncertainty, knowledge intensiveness, deadline focus, idea intensiveness and, last, peer intensiveness.

9.4 Implications for future studies

This study triggers questions regarding the role of horizontal control in the workplace. There are two inquiries that I wish to posit: 1) how shall we make sense of the interaction between vertical and horizontal controls, and 2) how shall we understand the existence of horizontal control?

Horizontal control has mainly been considered from a managerial perspective, either as something that should be avoided or as something that should be appropriated[103]. Managers have been thought of as the

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[103] This perspective has a long tradition. Scientific Management viewed horizontal relationships at the workplace as a disturbance that prevented the workers from focusing on working as hard as possible in order to maximize their wage and the profit of the organization under the often prescribed piece-rate system (Taylor,

ones who are to define and optimize the procedure through which work is carried out, as the ones who are to make sure that the social needs of the employees are fulfilled, or as the ones who are to make sure that the employees control themselves. But as this study indicates, the role of the manager is becoming increasingly vague. Although managers are still portrayed as constructors of effectiveness as well as well-being – for example in the popular literature emphasizing teamwork and empowerment – there is a body of literature accumulating that is skeptical of the possibilities of intentionally managing or leading workers.

"The manager" as the origin of organizational control is particularly problematic when it comes to managing complex work. As has been noted, Weick (1985), for example, has argued that what managers of complex work can do is basically to ask their employees to "see what you can do and do your best" (p. 115). This is in line with the results of studies of engineering work where engineers are portrayed as workers that must simply be trusted to do their best (Whalley, 1986), where the predominance of a lateral flow of communication is pointed out (Crawford, 1989), and where coordination is said to take place not through the formal chain of command but through "the collaboration of members of different groups working conjointly: a form of coordination in which practitioners retain authority over their own work" (Barley, 1996: 435). My study points in the same direction by arguing that control can be better understood as taking place in a peer review process than as guided by the intentional actions of managers.

The argument that much control takes place horizontally in engineering work triggers the suggestion that it might be fruitful to study peer reviewing in other contexts. As I have indicated, there is reason to expect the dynamics of peer reviewing to be relevant for understanding the control of other types of complex work. I especially pointed out how it may be used for understanding horizontal control among professionals on a local level, and how this may enable them to maintain their professional status. Not only professionals, however, but

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1911/1998). The Human Relations movement, on the other hand, viewed horizontal relationships as a resource because a good relationship with the co-workers was thought to constitute a reason for the worker to do her/his best at the workplace (Roethlisberger & Dickson, 1939; Schein, 1965).

also other practitioners of complex work such as IT-consultants, marketing specialists and accountants may engage in peer reviewing in their operative work. And if they do, how do they do it? Such a question is partly interesting to investigate in order to "check" the usefulness of peer reviewing as a sensemaking device. But it is mainly interesting because it may produce a modification of our way of thinking about organizational control.

Peer reviewing does not operate in splendid isolation but interacts with vertical controls. It may therefore be worthwhile to explore control that exists in the gray area between the vertical and the horizontal. A control mechanism that is initially horizontal can develop vertical characteristics over time, and a control mechanism that is initially vertical can develop horizontal characteristics over time. Peer reviewing with the *primus inter pares*-phenomenon exemplifies the former. It indicates that peer reviewing is mainly horizontal, but tends to develop an element of verticality as time goes by and some people become *prima*. Guido exemplifies the latter: it was initiated by managers as a vertical control device, but developed horizontal characteristics as the engineers started to interact directly with each other instead of via the Change Control Board. It may therefore be rewarding to think of additional dimensions than verticality or horizontality when exploring this gray area of control. Time is one such dimension: *when* is control vertical/horizontal? Space is another: *where* is control vertical/ horizontal?

Another question triggered by this study is how to understand the existence of horizontal control. If management controls are not the major source of influence, why do employees control each other, why do they work in the interest of the firm without anybody "controlling" them to do so: why peer reviewing? Socialization has been discussed. In the same vein, the existence of a "collegial ethic" (Simpson, 1985) may be an explanation, or the existence of professional norms (e.g. Wilensky, 1964) stemming from the employees' common education and later membership in professional associations. Or as Barley (1996) observed in his studies of technicians: the fact that they "work more or less autonomously in a reliable, responsible manner […] despite the disdain and ambiguities they sometimes encountered is strong

testimony to an ethos of practice that technicians called 'professional' attitude" (p. 434-5).

Socialization, collegial ethics, professional norms or attitudes are potential explanations for the existence of horizontal control. But they all use the image of a collective identity or consciousness to explain why horizontal control takes place. In other terms, the explanation is thought of as something (e.g. norms) that has been planted *inside* the employees, which makes them conditioned to behave in a certain way and take certain things for granted. In the vein of this study, it would be interesting to search for explanations in their everyday work. One particularly rewarding path to follow, I believe, would be to investigate further the role of "technology" as a producer of action at work. Technology is often said to be "the engine that drives global competition" (Galbraith & Lawler, 1993), thus referred to on a global level as the driver behind activity and development in general. It can, however, also be thought of more locally as the driver behind organizational activity.

Such a path is likely to be particularly worthwhile to follow when it comes to engineering work. "Technology" can be said to consist of the physical artifacts that the engineers work on and the linguistic artifacts, illustrated by their "electrotechnical vernacular" that they use to make sense of those physical artifacts. There is an interaction between the engineers and the technology in which one could search for alternative answers as to the question of why peer reviewing takes place. A possible point of departure for such an enterprise is to be found in this study's discussion on the role of knowledge about physical and linguistic artifacts. From that point, a more in-depth discussion of technology as an "action implying entity", "mediator", or "consensus maker" could be developed.

Another path to follow in the quest of understanding the existence of horizontal control is to further investigate the meaning of "peer intensiveness" in relation to organizational controls. This study indicates that operative engineering work has a firewall through which obtrusive vertical control can be transformed into a form that is no longer perceived as control, but simply as work. Perhaps this phenomenon is significant of peer intensive work, controlled through

peer reviewing. Perhaps peer reviewing, with its power to obscure the influence of vertical controls, is a particularly strong identity regulation device, "constructing an understanding of oneself that is attentive to the needs of others" (Anderson-Gough et al., 2000) through its emphasis on cooperation and helping. It would be interesting to study the question of how vertical control does or does not enter into peer communities in other contexts where the employees are engineering work.

Appendix – Quantification of empirical material

Phase one – from February 2002 to February 2004

The empirical material from phase one of this study consists of the following:

- Seven observations of work meetings of the radio-group. Each meeting lasts about two hours. The objective of the meeting is to coordinate work, inform each other about each other's work and make priorities.

- Five observations of section meetings. Each meeting lasts about one hour. The objective of the meeting is for the section manager to inform and discuss with the group members about what is going on in the organization on a more general level.

- Five observations of "department meetings", where the department manager (which is the section manager's manager) informs and discusses with the section managers what is going on in the organization on a more general level.

- One observation of a "competence development day" with the radio-group. The objective of the day was to have the group discuss the kind of competence they need, the extent to which they already have this very competence and how they can obtain or improve their competence.

- One observation of a "culture workshop" where the "culture program" is discussed. It lasted about three hours. The objective of the meeting was to inform about the "new culture", discuss it, and figure out how the group could contribute to it.

- One observation of a goal formulation meeting. The meeting lasted for about three hours. The objective of the meeting was to discuss and formulate the group's goals for the coming year.

- One observation of an "All-employee meeting". It lasted for about two hours. The objective of this meeting was, from the part of the CEO, to inform about what is going on in the organization on a general level.

- Three observations of "D1-meetings". The meetings were held by the top program manager and all members of the D1-project were invited. Each meeting lasted for about one hour. The objective of these meetings was to inform on a general level about how the D1-project (which at this time was the main technology development project) was proceeding.
- Everybody in the radio-group (15 people) was interviewed once, and ten individuals were interviewed a second time.

All meetings were recorded except the All-employee and D1-meetings, where too sensitive information was said to be communicated. As a complement to these meeting oriented observations, I have been sitting in the workplace of the radio-group; working, typing out observations or interviews and participating at coffee breaks, lunch breaks etc. I did this kind of "hanging-out"-observations about one day a week between August 2002 and March 2003, which has given me additional information and the possibility to talk in a more informal way with the employees.

For reasons of comparison, the members of two other groups in the company were also interviewed, including their line-manager and her/his manager. These groups consist of 10 and 6 people respectively. One section meeting has also been observed. In order to get a grasp of top-management's view, which is seldom referred to at the group meetings, the head of technology and the head of operations and quality have been interviewed twice, the CFO once, the head of product development once and a human relations manager responsible for competence development twice. Most interviews lasted for about 1 ½ hours and all have been recorded. Documents regarding top-management initiatives have also been studied, in particular in relation to the initiative of changing the company culture.

In purely quantitative terms, this means that 17 observations of meetings and 49 interviews were conducted during phase one.

Phase two – From February 2004 to June 2004

The proceedings of phase two have been outlined in some detail in the methods chapter. In numbers it looks like this:

Material for studying the work meetings

- Six consecutive observations of object meetings in the radio group
- Five consecutive observations of object meetings in the ASIC-group
- Three consecutive observations of work meetings in an "additional group" (this group has not been used explicitly in the text)
- Interviews with the participants of the meetings (engineers and object leaders = 22 interviews)
- Five consecutive observations of project meetings where the object leaders of the radio group and the "additional group" have meet with their project leader
- Three consecutive observations of project meetings where the object leader of the ASIC-group (Christian) meets with his project leader.
- Interview with the project leaders (two interviews)

Material for following the initiative to exchange the PA

- Five observations of "PA-meetings", i.e. meetings designated exclusively to discuss the PA-initiative.
- Interview with Harry, one of the initiators of the PA-track. (Other relevant people were asked about the PA-track when interviewed regarding the work meetings)

Material for following the work of an engineer

- One week's "shadowing" of Jake. See chapter six for details.

Other

- From February – June I spent much time at GT. In February I was there seven times, mostly for doing interviews but I usually stayed there having lunch with the engineers. In March I was there almost every day, and often for the whole day. April was more like February and whereas May was a bit more intense. I was at GT the last time on the 7th of June 2004.
- Observation of a large, three-hour "review"-meeting with about 12 people present.
- One follow up interview each with Jake and Carl in late summer 2005

In purely quantitative terms, this means that 28 observations of meetings, one week's shadowing and 27 interviews where conducted during phase two. All in all it adds up to 45 observations of meetings of varying length (1 hour to more than a day), one week's shadowing, extensive periods of "hanging out", and 76 interviews. As noted in chapter three, it is mainly the material from phase two that is explicitly used in this thesis.

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