Engineering Identity in a Japanese Factory

Martin Kilduff • Jeffrey L. Funk • Ajay Mehra
Smeal College of Business Administration, The Pennsylvania State University, University Park, Pennsylvania 16802

This is a most unusual paper. It is based on 11 months of ethnographic studies in a Japanese high-technology company. It investigates the structuring process of identity creation in organizations. The authors painstakingly detail how the technologies of production, routinization and spatial order combine into daily mutual dependencies, joint sensemaking and the formation of an intense social order to the exclusion of other social obligations. The findings have important implications for team based organizations and for the maintenance of a collective identity beyond the control of the individual.

Arie Y. Lewin

Abstract

Based on 11 months of participation in a Japanese high-technology factory, our account follows the working lives of 11 engineers involved in the development, building, and servicing of wire bonding machines necessary for the production of semiconductors. We examined how the technologies that structured time and space shaped the identities of the engineers. Despite crises of project development, the engineers sustained a group identity by participating in routines such as daily meetings, by the physical arrangement of the work site, and by team members' identification with the high-technology products they produced. In this system preoccupied with the construction of zero-defect machines, the engineers were vigilant in preventing the structures of work life from unraveling. We looked in detail at one project that linked wire bonder machines with other machines and found that problems with machines were related by the engineers to problems of group interaction. The engineers promoted an isomorphism between the structure of the group and the structure of technological design: the group was mirrored in the high technology it produced.

(*Organizational Identity*; *Japanese Organizations*; *High-technology Organizations*; *Sensemaking*; *Alienation*; *Enactment*)

How do employees of large industrial organizations develop and maintain a sense of identity in the workplace? How do they overcome the alienation from their work that Marx (1961) saw as endemic to industrial society? The problem of alienation has not vanished from the industrial landscape: the specter of workers denied opportunities for ownership, initiative, and creativity still haunts advanced consumer societies (Blauner 1964), although companies are increasingly seeking ways to overcome such alienation. For example, *The Wall Street Journal* reported recently that conveyor belt production was being criticized in Japan for reducing people to robots, and was being replaced in Japanese factories with craft work in order to encourage individual responsibility (Williams 1994). Alienation continues to plague even the most privileged members of the workforce, however: those who belong to well-defined and prestigious occupational communities. For example, engineers at a major multinational high-tech company tend to develop company selves compatible with the corporate culture, but find that these selves require "active and artful construction, a performance, a tightrope walk" with the constant possibility of burnout (Kunda 1992, p. 216). In the very different context of a small Tokyo candy factory, the careers of skilled artisans "are shot through with contradictions and creative tensions" as they develop "decentered, multiple selves" to cope with contradictory demands of the family-run business (Kondo 1990, p. 224). For both the U.S. engineers and the Japanese candy makers, passionate identification with the organization coexists with parody, dismissive irony, and resistance.

The process by which the organizational self is developed and maintained is therefore a topic of lively contemporary interest for both practitioners and researchers. From ethnographies such as Kunda's and Kondo's we learn that the organizational self is inherently conflicted, embroiled in contradictory commitments to individual and corporate interests. In the present paper, we examine the technologies of identity construction and reconstruction in a Japanese high-tech factory. We use the term

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"technologies" to refer to "not only the physical equipment and technical processes used but also the ways in which an enterprise, whether public or private, is structured and effectively operates" (Marceau 1992, p. 2). Specifically, we examine the structuring of time and space, and how organizational actors engage in identity construction through their everyday work. We focus on processes that are typical aspects of daily life rather than emphasizing unique features of the specific site we chose to study. The aim, then, is to study the mundane processes of "everyday organizational life" (Hatch 1993, p. 660) in "an ordinary place" (Bestor 1989, p. 6) that resembles many other such places across Japan.

We picked a Japanese company to study partly because of the relative absence in the organizational literature of prior work on identity-creation in non-Western settings. We thought that taken-for-granted patterns of behavior would be more easily identified in a culture foreign to us as researchers. Our selection of a Japanese high-technology factory as a research site also owed much to the current Western interest in Japanese zero-defect manufacturing processes, as well as to the relative lack of research attention to factory organization (cf. Fruin 1997), and to calls for more theoretically grounded research on Japanese organizations (Lincoln 1990).

Conceptual Overview

We assume that individuals' organizational identities are created and sustained through the individuals' experiences in the organization. Our focus is deliberately social: like Geertz (1983) we believe "the community is the shop in which thoughts are constructed and deconstructed" (p. 153). The community, in anthropological terms, is the natural community, the work group, to which the engineers we focus on belonged. Again, to paraphrase Geertz (1983, p. 58) we searched for and analyzed the symbolic forms in terms of which, in this factory, people represented themselves.

In particular, we began by examining the structures of time and space that give meaning to experience (Giddens 1984). Temporal order is imposed by the ritualization of activity, that is, by the repetition of events on a regular schedule. Thus, organizations schedule workers to arrive and leave at the same time. Daily, weekly, and monthly meetings punctuate the flow of activities. Procedures, both formal and informal, are devised to standardize blocks of time. Employees are often intensively socialized into the rituals that particular organizations use to structure the passing of time.

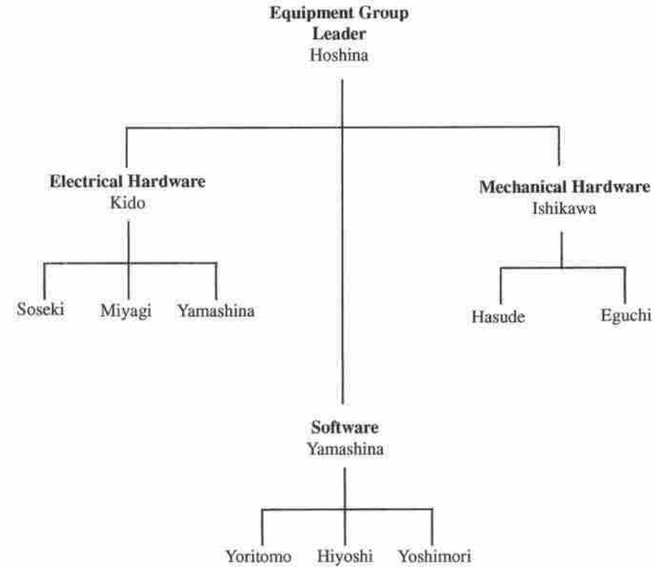
Experience in organizations is structured, therefore, by the ritual repetition of events. But activity unfolds in space as well as time. Choices concerning the physical layout of the factory or office can significantly affect the way in which participants organize their experience. For example, physical space in the organization can be divided so as to maximize or minimize interaction activities (Hatch 1987). Open-plan offices tend to increase supervision and interdepartmental contact while decreasing confidential conversations and friendship opportunities (Oldham and Brass 1979, Sundstrom et al. 1982). Individuals located far from each other tend to communicate less than individuals located close to each other (Hatch 1987, p. 337). People can be pulled together or pulled apart by the presence or absence of communal activity centers such as bulletin boards, coffee rooms, and cafeterias.

The process of identity construction and reconstruction may be particularly evident in organizations competing in high-technology industries. The importance of such technology is that it "generates a great deal of raw data" (Weick 1979, p. 168), thus providing organizational participants on-going opportunities for analysis and sensemaking. This sensemaking is the way in which organizational members discover who they are. As Weick (1979, pp. 133–134) says: "Organizations are presumed to talk to themselves over and over to find out what they're thinking. . . . The organism or group enacts equivocal raw talk, the talk is viewed retrospectively, sense is made of it, and this sense is stored as knowledge in the retention process." An important aspect of our analysis of technology, then, will concern organizational sensemaking and how this contributes to group members' identity.

In this paper, we investigate the technologies that create and sustain workplace identity. The specific questions that the present paper tries to answer concerning the structuring of organizational identity are two. First, are individuals "cultural dopes" (Garfinkel 1967), automatically enacting technologies of control through habit, socialization, or cognitive programming (Ashforth and Fried 1988)? Or are these technologies part of the tool kit of cultural competencies (Swidler 1986) actively used by interacting individuals and groups to structure their worlds of work? Second, what are the latent and manifest functions of the structuring of daily life, and what are some of the unintended consequences of such structuring for personal identity? These two sets of questions get to the heart of structuring processes (cf. Garfinkel 1967, Giddens 1984, Merton 1964), but have not been posed in connection with identity creation in organizations.

Our findings emerged from an intensive interaction with ethnographic data collected over an 11 month period and are presented in two parts: the analysis of how daily work is organized in time and space is followed by an examination of the development cycle of one particular high-technology project. Perhaps the most interesting discovery we made was that the engineers in our sample consciously and continuously promoted an isomorphism between the structure of the work group and the structure of the high-technology machines they were producing. The engineers looked to the products they were creating for clues as to how to structure their interpersonal relations. Further, we found that engineers were active and engaged participants in the daily structuring of activities, both in time and in space. In this high-technology factory, where even small reductions in defect rates disproportionately increased profits, the engineers continuously monitored group activity. Unlike the aircraft personnel described by Weick and Roberts (1993), however, the engineers' intensity of heedful interrelating occurred not in the context of ever-present danger but in the context of the fierce competition characteristic of the global electronics industry.

Figure 1 **Hierarchy of Responsibilities in the Wire Bonder Equipment Group**



The Setting

The focus of this research was a group of engineers who were known as the Wire Bonder Equipment (WBE) group and who worked for a major electronics manufacturer at its Fukuoka Works in Fukuoka, Japan. Until 1980, the Fukuoka Works produced mainly industrial equipment such as hoists, cranes and motors. Due in part to the two energy crises in the 1970s, however, the sales of these products began to decline. The company began producing semiconductor chips at the Fukuoka Works in the early 1980s. By 1989, semiconductor manufacturing represented more than 90% of the Fukuoka Works' 700 million dollar annual sales, and the Works employed about 2,500 people.

As core employees of one of the largest of the Japanese business groups (or *keiretsu*), the wire bonder engineers were at the heart of the Japanese economic system, modern-day samurai with considerable status outside the factory. The group consisted of 11 engineers, all male, whose ages ranged between 24 and 43. Their job was to develop, build, and service the wire bonding machines necessary for production of semiconductors. An organizational chart for the WBE group is shown in Figure 1.

Hoshina, the group leader (age 43), and Kido (age 37), an assistant group leader, spent some of their time representing the group in regularly scheduled meetings with external entities such as laboratories, suppliers and customers, but both were very involved with day-to-day operations within the WBE group. Kido, Ishizuka (age 33), and Yamashina (age 30) shared responsibility for developing and integrating the electrical, mechanical, and software systems for each equipment design. In addition, each of these engineers took lead responsibility for specific equipment orders, handling duties typically covered by a program manager in a U.S. firm.

The other engineers tended to be younger (ages 24 to 30) than the more senior engineers, and provided support for the activities directed by their seniors. The electrical engineers shared responsibility for the electrical aspects of the wire bonder; the mechanical and software engineers operated in a similar manner. In addition, responsibilities were often shared between these electrical, mechanical, and software groups. For example, the wire bonder's new bonding head required specific electrical and software efforts with which two of the young engineers (Hiyoshi and Soseki) were familiar. Therefore, these two engineers from different subgroups shared responsibility for the final development of this bonding head with very little guidance from the senior members of the group.

As well as the 11 engineers in the WBE group, two other important individuals were Nakamoto, the section manager (*kachoo*), with authority over both the wire bonder and die bonder groups; and Itoo, the department manager (*buchoo*) of the Semiconductor Equipment Department (SED), with authority over six sections including Nakamoto's section. Nakamoto spent most of his time in departmental meetings and teams helping to standardize and integrate technology across the different equipment groups. He spent little time managing the section's day-to-day operations. He rarely attended the weekly equipment meetings or any of the smaller meetings that involved only one equipment group. He stayed in touch with his section's activities by attending his section's daily standup meetings (described later), by reviewing various documents such as schedules and equipment orders, and by taking advantage of the open layout of the office, which enabled him, he said, to hear almost everything that went on.

Itoo, like Nakamoto, was primarily involved in managing external relations. When Itoo was at the SED office, he spent most of his time as a facilitator. He was minimally involved with individual equipment design projects (usually only in terms of budgets), but he was heavily involved in defining the technological future of the semiconductor equipment and the processes used to design and manufacture the equipment.

Itoo spent a great deal of time walking around the office speaking with employees. He did not have an enclosed office. His desk was located at one end of the department's open office, which made him very accessible. According to a senior member of the SED, Itoo had in-depth individual conversations with over 70 percent of his engineers (there were about 70) in his first year as department manager. Like many other managers at the company, Itoo lived away from home: his family resided in Osaka, about 570 kilometers (360 miles) distant.

Methods: The Ethnographic Approach

To uncover the day-to-day sensemaking of organizational members requires an immersion in the daily life of the collective under study. The researcher must "be grounded in the organization's culture" in order to produce a first-order analysis framed around the dominant themes expressed by participants (Gioia and Chittipeddi 1991, p. 435). The theoretical explanation of these first-order findings comes later by means of a second-order analysis, and as Gioia and Chittipeddi (1991, pp. 435–436) pointed out, the ethnographer who becomes completely involved in fieldwork risks "losing the dispassionate view required for more theoretical analysis" (p. 436). Following Gioia and Chittipeddi, therefore, we employed both a participant observer (hereafter "PO", who spent 11 months as a full-time member of the wire bonder equipment group; and two outsiders, who helped provide a second-order, retrospective, more objective analysis of the data (cf. Gioia et al. 1994).

The PO trained intensively in Japanese before joining the WBE group. His local knowledge and expertise markedly improved over the course of the first few months, and much of the data we report derives from the last eight months of his tenure in the group when his understanding of technical conversations was fluent.

The PO joined the WBE group in February 1989 with a mandate from the department to pursue open-ended research on management processes. The PO was employed as a software engineer, but all members of the department were informed of his research interests. In his first two months, he spent most of his time in training sessions and plant tours. His training was similar to the training provided to new departmental employees. He learned about each type of equipment, its purpose, design and technology, with particular emphasis on wire bonding equipment. This training enabled him to meet key people in the department and the WBE group and to learn some of the key technical aspects of the equipment.

As with engineering companies the world over, to be accepted by the engineers in this group the PO had to demonstrate his technical competence. He was accepted as an equal because of his advanced training in robotics and other engineering fields, and his experience as a manufacturing engineer in a U.S. semiconductor chip factory.

The PO participated in all of the WBE group's regular activities. He attended their meetings, social events, and he sat in the same area of the office as the other employees of the group. He listened to their conversations and watched their activities. His work involved performing various engineering activities associated with the design and development of a new vision system for the wire bonding equipment. These activities required him to interact with all members of the WBE group, both in the office and in the factory, members of other groups in the department, and personnel in the central laboratories.

The primary sources of data for this paper were the notebooks kept by the PO over the 11 month period. We treated the PO, then, as an inside member of the WBE group, one who could provide us with what Geertz (1983, p. 57) called "experience-near" concepts. The PO's notebooks recorded interviews and systematic observation of departmental activities. The notebooks were written primarily in English, with numerous technical and specialized terms inscribed in both English and Japanese. The PO conducted over 200 in-depth interviews with WBE engineers and personnel in other departments with which WBE interacted. The PO also made systematic notes of daily, weekly, and informal meetings of WBE engineers. Notes were also made of intergroup meetings with managers from other equipment groups.

The PO started attending weekly wire bonder equipment meetings and daily standup meetings almost as soon as he arrived in Fukuoka. He spent more than 150 hours in these meetings learning about the WBE group and department activities. Equipment development projects, their schedules, equipment problems, customers, suppliers, and laboratories were discussed in these meetings. The PO took detailed notes at almost every meeting.

Our descriptions of WBE group activities and reports of interviews with engineers were derived directly from the PO's notes without added theoretical interpretation. These narratives present the view from inside the organization, both in the accounts of the structuring of daily activities and in the account of the Kochi project. The aim is to convey something of "the vitality of everyday life encountered by the researcher in the field setting" (Golden-Biddle and Locke 1993, p. 599).

The second-order analysis represents an interpretation of the data by the PO and the two outside researchers. This second-order framing emerged from an intensive interaction with data and with existing relevant research. Following Geertz (1983, p. 58) the emphasis was on "searching out and analyzing the symbolic forms—words, images, institutions, behaviors—in terms of which, . . . , people actually represented themselves to themselves and to one another." In other words, we tried to capture the everyday observable actions of the engineers, and to link these actions to relevant theoretical concepts. Given our interest in how identity related to the structures of time and space and the production of technology, our data sampling focused on routines, spatial arrangements, and the everyday work of high-technology production. The combination, then, of ethnographic detail and second-order framing attempted to retain the sense of lived experience within the limits of theoretical explanation. The aim here, as in most ethnography, was to complete the hermeneutic circle, to tack back and forth between local detail and global structure "in such a way as to bring them into simultaneous view" (Geertz 1983, p. 69).

For this particular department, the work consisted primarily of projects to supply semiconductor equipment to other units within the *keiretsu.* We focused on one particular project to see how the engineers dealt with the process of placing a new machine in the customer's organization. This process generated raw data that WBE employees spent a great deal of time worrying over. We investigated the process by which employees made sense of this raw data.

Temporal and Spatial Ordering

A typical day began with a standard set of exercises in response to a tape that was broadcast over the entire factory. Interestingly, the same tape (known as "*Rajio Taisoo*" or "Radio Calisthenics") is used in schools and companies all over Japan. Further, an early morning run by the PO often found retired people exercising to the same tape in parks and other public places. In the factory, a few minutes after the exercises were completed, a bell would ring signalling the start of the day. Employees bowed to each other in unison and said "*Ohio gozaimasu*" ("Good morning").

Bells were also used to signal the beginning of lunch, the end of lunch, and the end of the regular day. Because all the departments at the Fukuoka Works ate in one rather small cafeteria, the lunch bells signalled when each department had access to the cafeteria. The lunch break was short: 15 minutes. People sat in the same seats, they ate with the same people each day, and they rinsed their own dishes.

Weekly Meetings ("*Renroku Kaigi*")

The WBE group met weekly at the same time and place. These weekly meetings were highly structured. First, the group leader summarized key information and key problems for about 30 minutes. Second, senior members of the group summarized key projects using detailed schedules for another 30 minutes. Third, junior members of the group summarized their activities using standard forms that described their activities for a specific month in terms of expected duration, percent completion, and revisions to expected duration. Fourth, the group leader asked detailed questions about these individual schedules in order to ensure that the project schedules could be met. The project and individual schedules were discussed for another 30 minutes (see Funk (1992) for more details on these meetings).

The standardization ("*hyoojunka*") of equipment, software, and procedures was a constant theme in meetings and conversations with the engineers throughout the 11 months of participant observation. The main problem, according to Soseki, was that there was very little standardization of parts and assemblies across the die bonder and wire bonder equipment groups. Standardization was important, according to the PO's informants, because the department needed high volumes in order to have lower prices. The dilemma was that customers always wanted different things, so it was necessary to understand their requirements. The problem with standardization was that if you standardized too much you couldn't innovate, but you needed to standardize some in order to cut costs. This idea was summed up in the epigram: "*Obi ni mijikashi tasuki ni nagashi,*" or, "It can't be too long or too short." There needed to be a balance between the goals of standardization and innovation ("*innobashin*").

Standup Meetings ("*Churei*")

Short, "stand-up" meetings occurred every work day immediately following lunch. These meetings lasted between 5 and 15 minutes, during which employees stood near their desks and formally provided information to their colleagues. The meetings were chaired by each group member in turn, and began with the equipment group leader summarizing the daily performance of newly installed equipment, providing information on the percentage of defective chips or type of equipment stoppages. The engineers brought up issues they felt were important, such as the outcome of business trips, the status of an important equipment project, or an upcoming social event. Meetings concluded with the day's chairman summarizing for the group the main aspects of his current work.

Information about meetings and trips accounted for almost half the average meeting time with reports about current projects occupying a further quarter of the total time. Attendance at these meetings was considered important by the engineers in the Wire Bonding group. On several occasions engineers could be seen running to attend the meeting as the bell rang to signal the end of lunch.

A sense of the usual, rather technical, content of these meetings can be gleaned from the PO's description in his notebook of the August 8 meeting, at which current projects at the Kochi factory and the Kumaden factory were discussed.

> Hoshina discussed Kochi results. Three magazines worth of frames flowed with minimal problems. Some recognition give up, 2-axis problem once. In general, sounded like good news. Hoshina said that every time Yoritomo leaves Kochi, the problems go away. Yoshitomi [the meeting chair] said he is writing external specs for the Kumaden stand alone, next he will work on the timing chart for the feeders.

As can be seen from this example, Hoshina, the WBE group leader, began the meeting by summarizing the latest results from the Kochi project (described in more detail below). Hoshina then joked that the problems at Kochi seemed to disappear when Yoritomo left the factory. To put this joke in context, it is important to understand that Yoritomo traveled four times to the Kochi factory (500 kilometers distant) looking for software bugs, and striving to help reduce machine errors. He commented to the PO that "if you're unlucky it [the machine] only jams when you're not there." Because the machine took five or six hours to process a batch of chips, and there were very few errors, it took a long time to collect data. Therefore, for the machine to produce errors when Yoritomo was actually on-site was helpful rather than the reverse. The meeting concluded with the day's chairman summarizing his current work.

Although the content of the meeting was quite standardized, occasionally the format was disrupted. For example, the PO's notes for the standup meeting of November 15 follow.

> Nakamoto made a rare speech about the lunch meeting. He mentioned the amount of information being communicated concerning customers and working groups and how it was becoming too disorganized. He asked die bonder and wire bonder members to come up with a better way; perhaps to assign a day to Kochi, Kumamoto and each working group. Hoshina then discussed the elemental technology meeting which is trying to standardize technology in the department. They are now writing up a data sheet of technologies; they will register the technologies, standardize them. Soseki is apparently the WBE representative at the meeting, but he's not here today. Ishi (in charge of the meeting) summarized work he is preparing.

This meeting was unusual in that it focused on the actual format of the meeting itself, and featured an appearance by Nakamoto, the section head. The Kochi project had not been going according to plan, and Nakamoto had traced the delay to coordination problems across equipment groups. As head of the section that contained both the die bonders and the wire bonders, he asked for some ideas about how to better coordinate these two groups. This theme of coordination is maintained by Hoshina in his comments about the ongoing struggle to standardize technology across groups. Finally, the day's chair summarized his current work.

The daily standup meetings kept everyone informed of important events. Everyone learned the goals, problems, and strategies of their own group and of the section and department at large. Each employee was given a chance to summarize his own work on a regular basis, and employees heard a summary of almost every meeting in which even one of their members had participated. Social events were announced and workers encouraged to participate.

The younger engineers appeared to be less bonded to the meeting as a social ritual, just as they were less enthusiastic participants in other organizational rituals such as compulsory morning exercise. Soseki, for example, was one of the youngest of the engineers, a recent graduate of Fukuoka University. He was notorious for forgetting to display his location on the status board (see description below) when he was absent from the office, thus causing Hoshina to frequently chastise the group in the standup meetings concerning the importance of always keeping people informed of your whereabouts. These lectures were understood by everyone to refer to Soseki, who was thus the shamefaced target of much chuckling by the other engineers.

Business Trips ("*Shutchoo*")

Engineers in the Wire Bonding group frequently travelled on group-related business to other factories in Japan and elsewhere. These trips were, of course, announced frequently in advance, and reported on in detail upon return.

A good example was reported to the PO in a conversation with Miyagi on June 2nd. He said that he was going to the Sanken Laboratory in Osaka for a month, although he would return to Fukuoka each week on Friday or Saturday and return to Sanken on Monday. The PO asked him why he couldn't produce the design at the Fukuoka Works, phoning to Sanken for information as needed. He replied that the engineers at Sanken had designed the new recognition algorithm method and knew it well, so he needed to go there. He admitted he would be lonely because he was going by himself.

The same engineers who travelled to distant factories as representatives of the group appeared alarmed at the prospect of taking private vacations unrelated to group activities. The management of the Fukuoka Works sent around a memo in October asking employees who had not taken at least 10 days of holiday (of the 40 days available) to arrange to take the extra days. The assistant group leader, Kido, told the PO over lunch on October 31 that he was very worried about this requirement. He didn't know what to do ("*nani o suru ka zenzen wakaranai*"), and without experience he couldn't decide where to go, how to find a cheap place to stay, or how to find a hotel that didn't require reservations months in advance.

On July 26, the PO asked Kido over lunch if he was planning to take the following Friday off; it was an official holiday. He replied that no one planned to take the Friday off. Unless everyone took the day off, no one could take it off. This was not because of the managers. In fact, he said, the workers felt uncomfortable working with the managers around, because they disliked being watched, so the managers tended to go home. The engineers set the work load themselves, so they really had no one else to blame. No one could take the day off because there might be a problem which only a particular person could fix. In any case, the engineers were so accustomed to working that they wouldn't know what to do if they had free time.

This devotion to work was partly structural: those engineers who lived away from home found it difficult to pursue leisure time pursuits. For example, Ishizuka mentioned to the PO that he was interested in interior decoration, but his house was located far from the factory in Kita Itami (near Osaka), so he couldn't pursue his hobby.

The same engineers who found it difficult to contemplate or arrange private vacations were ready at a moment's notice to leave for business trips to distant cities if required by their work in the group. For example, on one occasion, Kido, who was apprehensive about the prospect of taking a private vacation, left on a two-day business trip within 30 minutes of hearing about an equipment problem at one of the company's semiconductor chip factories.

Spatial Layout

The office seating arrangement for the Semiconductor Equipment Department was arranged according to the organizational chart. Employees who were part of each of the three engineering sections occupied adjacent seats in the same row. Although the department manager, Itoo, had five-foot walls surrounding his desk, the other employees sat in an open office containing 16 rows of desks. Section managers such as Nakamoto sat at the end of the rows facing the rest of the desks, which were arranged by hierarchy, with the higher level employees sitting closer to the section managers.

The organization of the desks approximately matched the department's organization chart. Employees in the same group sat in two rows with their backs to each other. Desks within groups were separated by 12-inch-high dividers, whereas two foot partitions separated different groups so that employees did not have to look directly at each other.

The open-plan office facilitated both formal communication, such as took place every day after lunch in the standup meetings, and the informal conversations between engineers both within the group and across groups. With no private place in the office, all talk was public and accessible to other engineers as well as supervisors.

Engineers were frequently absent from the office, but their whereabouts were monitored by the employee status board. This was a white magnetic board that indicated which employees were in on a particular day, and where they were currently working. When employees arrived at or left work, they moved their markers accordingly. When employees left the office to visit another part of the site, they were supposed to indicate where they were going. In many meetings attended by the PO, information was needed from an employee who was not at the meeting. Usually, by checking the employee status board, the absent employee's location was found, and it was possible to contact the person for the required information.

The degree to which the spatial ordering of organizational space was consciously maintained by employees was indicated by the PO's experience on two occasions when he was in the lunch line ahead of his colleagues and sought to sit at an empty table in the cafeteria not usually occupied by him and his WBE lunch companions. The reaction was amusement at the PO's obvious mistake, combined with a quick rearrangement of the usual seating practices. His companions joined the PO, while the group that the PO had displaced, spontaneously occupied precisely those seats that the PO's group had on this occasion vacated. The displaced group was careful not to occupy any of the other vacant tables in the cafeteria. The interaction boundaries were thus maintained by adapting to the newcomer's change of table. There was considerable laughter, however, at the PO's violation of the understood spatial etiquette.

The engineers also maintained the spatial boundaries between groups by changing the organization of the office each time the department's organization chart was changed. Each time a new employee joined a group the desks were rearranged to make room for the new employee in the group to which he belonged. For example, a supplier representative on temporary loan to the WBE group sat for two months at a desk that blocked the aisle, thus forcing group members to make a lengthy detour in order to move around the office. There was no other place for the temporary worker to sit and still be physically connected to the WBE group. No one ever suggested that the worker move.

According to systematic observations by the PO over a week, engineers in the Wire Bonding group spent over half their work time with others rather than working by themselves. Over 75 percent of this communal work consisted of informal conversations, with the remaining one quarter consisting of scheduled meetings. The more senior members of the group spent significantly more time with others: approximately 75 percent of their time in the office was spent talking with other people.

Second-Order Analysis

We have described the technologies that structured the work time and work space of the engineers, technologies that provided continuous opportunities for repeated and ritualized interactions within the group. To what extent was this structuring of time and space consciously reproduced by the engineers themselves? The answer appears to be clear: engineers were active and engaged participants in the daily structuring of activities. They were engaged in heedful rather than mindless interrelating (cf. Weick and Roberts 1993). This conclusion is supported by the active efforts of the engineers to reinforce the interaction boundaries in cafeteria and work group seating. The members of the WBE group were not cultural dopes, but knowledgeable agents of cultural maintenance and transmission. Newcomers, like the PO, who transgressed against prevailing norms, were regarded not as innovators with new ideas (e.g., Louis 1980), but as neophytes in need of cultural training.

One arena for cultural training was the group meeting. The manifest function of the weekly and daily meetings was clear: they provided the group members with information about events. Members heard summaries of almost every meeting in which even one of their members participated. Everybody was kept informed about what everyone else was doing.

Apart from the purpose of sharing information, the meetings also appeared to serve as vehicles for collective sensemaking. Even when a piece of information was widely known, the information was often repeated in the meeting so as to make the interpretation of the information a part of the collective experience. The engineers were constantly searching for ways to reduce error rates on high-technology machines. As Weick and Roberts (1993) have shown, in systems preoccupied with failure-free performance, the members continually trade detailed, disparate information in order to discover, as a group, higher-order themes.

Business trips by WBE engineers served as an expression of group purpose, and were validated and interpreted in group meetings. But as an expression of individual liberty, the prospect of trips (such as vacations) to distant locations became, for some WBE engineers, reminders of individual fallibility and weakness.

Group members sacrificed holidays, family life, and hobbies to the interdependent tasks of the group. Cross-cutting membership in different groups was sacrificed to the demands of the work group. Ishikawa was unable to pursue his decorating hobby because his job required him to live far from home. Holidays with family members were routinely sacrificed because no one could afford to skip a day's work. So intense, indeed, was the commitment to the group's work, that some of the engineers claimed they wouldn't know what to do with free time.

As agents of the group the engineers were flexible and efficient decision makers with respect to such activities as business trips. Stripped of a group purpose, however, an individual undertaking, such as a personal holiday, became a fearful and threatening prospect for some. One unintended consequence of the reproduction of work group identity for the individuals concerned, then, appeared to be the weakening of nonwork identities, so that individual projects, such as personal vacations, hobbies, or higher education, became in some cases difficult to initiate or sustain.

In addition to the meetings, the spatial layout of the work area also played an important role in structuring the work environment. The open office encouraged group interactions, thus promoting group sensemaking. Talk within the group was easily monitored by others and therefore tended to concern company rather than personal business. Each engineer's seating location was determined by his precise level in the hierarchy of control. Every movement away from the office was supposed to be recorded on the status board. Thus, the engineers' movements and conversations were under constant surveillance by others. In this regard, the spatial layout resembled a Panoptic cage, "in which the individuals are inserted in a fixed place, in which the slightest movements are supervised, in which all events are recorded" (Foucault 1979, p. 197). Not surprisingly, the PO was told that the engineers preferred to work when the managers had left, and when, therefore, the Panoptic gaze was reduced in intensity.

Social interactions within any particular setting were monitored and controlled, however, by the engineers themselves, as the incident of table-swapping in the cafeteria showed. The engineers were vigilant in preventing the structures of everyday life from unraveling. Bestor (1992, p. 34) described a similar experience when he and his wife disturbed the spatial representation of hierarchy at a Tokyo festival banquet by sitting together: "We stayed in place as geography was rearranged. Men moved so that my seat became the end of the male chain of hierarchy now wrapped around both sides of the room, and women scrunched together to assure that my wife, although by my side, was clearly seated within women's territory!" The WBE engineers, like Bestor's neighbors, were prepared to go to great lengths to maintain the interaction boundaries that sustained group identity. As Weick and Roberts (1993) have emphasized, in organizations that emphasize high reliability, interaction patterns that promote heedful interrelating are maintained as necessities rather than luxuries.

The Kochi Project: An Example of Engineers at Work

Background Information

During the period of observation, the WBE group designed and installed more than 20 wire bonding machines. Several of these machines were part of a new generation of assembly equipment that consisted of a die bonder, three wire bonders, a mold machine, and a quality control station. Whereas the die bonder glued the chip to a metal frame, the wire bonders bonded wire from the pads on a chip to the leads on the metal frame. In operation, a wire bonder resembled a sewing machine, stitching wires to packages. Finally, the mold machine sealed the chip by putting a plastic package around it. The company's semiconductor business unit had ordered the new equipment for a new factory dedicated to the production of small volumes of a wide variety of special purpose logic chips (as distinct from the more familiar commodity chips found in personal computers).

The project for the WBE group, then, involved linking all three wire bonder machines to each other and to the die bonder and mold machines in a seamless manufacturing effort. This required cooperation among three groups—the die bonders, wire bonders, and molders—that previously had worked independently. The challenge was to improve the performance of three different types of machines while integrating their hardware and software.

In April, the three wire bonder machines were connected to each other on the factory floor at the Fukuoka works. The three machines were referred to collectively as the Mark II. The process as it evolved over the coming months involved taking a cut-up wafer from the customer's works at Kochi (500 kilometers distant), putting it in the die bonder and observing what happened as it moved through the three machines making up Mark II. The engineers could inspect each machine's process through a microscope built into each machine. Also, they could inspect records of how often the equipment stopped and how often the finished product appeared visually acceptable.

In the May 30 lunch meeting, the ship date for the Mark II prototype was set for June 3. On June 2, Kido confirmed that, *"Ashita Mark II shukka shimasu"* ("Tomorrow Mark II will be shipped"). He suggested that it would take one week to set the machine up, and that a trial run and adjustment would be made on June 12.

Installation and Testing at Kochi: Early Problems

Mark II was installed at Kochi on June 5. The installation and checking was expected to go smoothly, but already in the early days difficulties began to appear. During the WBE lunch meeting on June 5, Ishizuka discussed a few of these such as the third wire bonder shutting down and concerns with the quality control station. He asked Yoritomo to fix these problems. On June 6, Kido expressed alarm because the work schedule of one group member was not detailed enough for an important project like Kochi. By June 7, one of the engineers told the PO that the documentation for Mark II was being shipped a little late, but that this should not be cause for concern since Kochi was very familiar with the equipment, and installation should go smoothly. Trips to Kochi by Yoritomo and Kido were planned for June 8, and visits by WBE members to Kochi became a regular part of the schedule.

By June 14, the news from Kochi discussed in the lunch meeting was more grave. Nakamoto described a fax he had received from Kochi that morning concerning a large variation in bonding force and voltage. Nakamoto also speculated that there must be a glitch in the second wire bonder because the engineers at Kochi were not saying much about it. He asked team members for a good plan. On June 15, Hoshina reported in the lunch meeting that the Mark II vision system had problems with misrecognition. During this meeting, the PO also overheard the Die Bonder group in its lunch meeting discussing communication between machines at the Kochi installation.

The problems with the Mark II machines at Kochi continued to be discussed in lunch meetings throughout June. By June 26, in both the lunch meeting and in a private meeting between the PO and Kido, the pattern recognition/matching problems at the Kochi installation were discussed. Kido pointed out that, "We need a 100% working recognition system for all equipment. We have not been improving recently. We're stuck at 90 to 95%." In the lunch meeting, there was a plea for people to think about how to make the pattern recognition perfect. The dilemma, as Kido pointed out to the PO, was the conflict between speed and yield: "If we increase the number of checks, we'll have a slower speed, but we need more checks in order to eliminate misrecognition."

On Friday and Saturday (July 8 and 9), the entire semiconductor equipment department held a retreat at which problems of coordination between the wire bonders and other groups surfaced, according to one of the engineers present at this meeting. The WBE engineers traced the coordination problems to (1) no communication between *kachos* (section managers); and (2) no communication between group leaders.

A visiting American engineer familiar with the Mark II installation at Kochi suggested to the PO that the Kochi installation had been rushed and this had led to lots of problems including: the installation and later replacement of the wrong gear motors; and the imperfect operation of the vision system that was designed to detect faulty chips.

The PO noticed at this time much evidence of the dedication of the engineers. On July 13, there were water problems in the factory so that no hot water or cold water was available. Further, the soft drink machine was broken. But there were no complaints from the engineers about the absence of liquid refreshments. The PO commented in his notes: "Nobody seems to care—they'll work until they drop." On July 15, Yoshitomi told the PO that during his visit to the Kochi installation, he and his colleagues worked 16 hours a day in a 27 degree Celsius (81 Fahrenheit) room, wearing full suits. Despite this intense level of activity, Yoshitomi in the July 20 lunch meeting admitted he was unsure about the source of the problems at Kochi.

Second-Order Commentary

One of the puzzling aspects of the story so far is the apparently fanatical dedication of the engineers to reducing defects. In fact, as Fruin (1997) has pointed out, knowledge factories specialize in improving process yields, and such improvements dramatically affect company profitability: "A five percent increase in yield results in much more than a five percent increase in profits" (Fruin, 1997, p. 54). As we will see in the next part of the Kochi story, the engineers were seeking to reduce defective chip production to below 0.1 percent.

The engineers' constant monitoring of machine performance appeared to affect their thinking about the group itself. The problems of communication between machines produced by die bonders and wire bonders led to discussion in the departmental retreat about the lack of coordination between section and group leaders: the engineers appeared to accept an isomorphism between technological communication on the one hand and human communication on the other. The engineers seemed to view relations between groups as mirrored in the relations between the technological products of those groups.

Commercial Production: Continuing Quality Problems

On July 25, Hoshina announced that the first Mark II line at Kochi had started commercial production on that day. In the morning, only two of the three wire bonder machines had operated, because of problems with pins fitting into holes. By July 31, Nakamoto in the lunch meeting was looking forward to the completion of the Mark II installation, asking people to please check details and solve problems for the customer even after the job was finished. By August 7, Hoshina in the lunch meeting reported that three magazines worth of frames flowed with minimal problems through the Mark II assembly machine. Hoshina also joked that every time Yoritomo left Kochi, the problems went away. However, the problems at Kochi continued to occupy the WBE team throughout August, with frequent visits by engineers to work on the refinement of the Mark II assembly. By August 30, Itoo, the department head, was reported by one of the engineers to want to develop mechanical, electrical, and software designs in parallel rather than in series. Such parallel development would help avoid the system coordination problems evident during the Mark II installation.

On September 1, quality reports from Kochi summarized the frequency of "severe problems" such as ball inaccuracy, poor ball shape, sagging loops, and short loops. Several engineers planned to go to Kochi the next day, including Hoshina and Nakamoto. The PO gained some insight into the continuing problems at the Mark II installation during a conversation with Miyagi and Ishizuka on September 5.

Ishizuka reported that the machines at Kochi were still producing one to two percent bad chips, whereas the goal was to reduce defective chip production to below 0.1 percent. Further, the rate of machine stoppage needed to be ultimately reduced by a factor of 10 to a target of one stoppage every 2240 chips, or approximately one stoppage every five to six hours. These targets were going to be very difficult to achieve, said Ishizuka, and the Mark II installation was now undergoing its fifth design revision. The pin position error was the biggest problem, and Ishizuka laid the blame for this continuing problem on the department head, Itoo. It had been Itoo who, against the advice of Hoshina and Ishizuka, had ordered an innovation in the operation of the heater block on the wire bonding machine to help eliminate vibration. This decision, they said angrily, had been taken without proper discussion, and they felt the resulting problems were Itoo's fault. (As a side note, another engineer at a later date expressed irritation with Itoo because he was pressuring everyone to visit factories and solve problems without waiting for the factories to pay the department.)

On September 7, Hirayama told the PO that the technology transfer between the groups was bad, and that there was a need for a more similar use of technology for quality and cost reasons. Hirayama was part of a two-person group responsible for developing a standard controller for all of the equipment types. Therefore, his job required effective cooperation between the various equipment groups.

Problems with the Mark II machine at Kochi continued through the fall, with WBE engineers continuing to undertake trips related to software problems, vision recognition, ball size, and so on. Nevertheless, during the September 11 lunch meeting, a fax with the latest results from Kochi was read out, with the good news that level 1 (less than 1.0% defective chips, less than 1 equipment stoppage per 500 chips) had been achieved, level 2 was expected by the end of October, and level 3 by February. On September 13, the three installed Mark II lines at Kochi were reported to be working well, according to Hoshina. Only the third wire bonding machine in the third line was experiencing slippage. Despite these encouraging reports, Ishizuka was reported by Kido (during a conversation on September 25) to be talking with the people at Kochi almost every day, and the engineers were described as spending a great deal of time at Kochi looking for problems, returning to make changes in software, and then going back to Kochi to install the software.

The continuing problems at Kochi prompted Hoshina on October 23 to comment during the weekly Wire Bonding meeting that the Mark II installation had taken too long. During the November 8 lunch meeting, Hoshina summarized the latest results from Kochi, which indicated a stoppage rate still twice as high as the level 2 target.

During the November 15 lunch meeting, Nakamoto, the section manager in charge of both the wire bonder and die bonder equipment groups, made a rare speech focusing on the lack of communication between the two groups. He asked for members to come up with a better way to organize projects such as Mark II, and suggested the possibility that a day could be assigned to each such major project. Nakamoto made another rare appearance during the November 17 lunch meeting of the die bonder and wire bonder equipment groups, and called for better communication with suppliers. He also mentioned a few problems that had occurred recently, and one of his remarks caused Ishizuka to laugh nervously at an apparent reference to a mistake he had made with the wrong screw in a clamper. Nakamoto asked people to develop a better system.

As a result of Nakamoto's intervention, the daily meeting was changed so that first, the whole section met (including Nakamoto), and then each equipment group met by itself (without Nakamoto). Subsequently, after the period of observation covered by this paper, representatives from each of the equipment groups responsible for the Kochi project were combined into one equipment design group that was dedicated to the design of assembly equipment.

The Kochi Story: Second-Order Analysis

During the Kochi project, machines were placed in the customer's facility, and debugged, tested, and modified by both the equipment groups and the customer. The apparent chaos of the installation masked a process of continual interpretation of data produced by machine prototypes. The frustrating process of continual adjustment and redesign was managed through daily group meetings that served partly to communicate progress, and partly to keep the group together. In fact, there was little scapegoating of group members. However, attributions of blame were levelled at one person outside the immediate circle of WBE engineers: Itoo, the department head, was singled out for criticism. Itoo was not part of the work group, and his interventions were sometimes met with anger. As well as being blamed for the machine redesign problem, Itoo was also criticized, for example, for pressuring engineers to solve problems in customers' factories without first being guaranteed payment. The continuing sense of crisis surrounding the Kochi project prompted a change in the regulation of the group's daily activity, with meetings modified to increase coordination with others outside the immediate group who might have an impact on the realities the group was trying to enact.

The extended drama sketched in the description of the Kochi installation parallels, then, the process of crisis in other arenas such as the financial markets, where a similar cycle of enactment, attribution, and regulation can be modelled (Abolafia and Kilduff 1988). At Kochi, the engineers created a new entity, a state of the art Mark II piece of semiconductor equipment, found their expectations of smooth production repeatedly disconfirmed, attributed blame to a highly visible and plausible outsider, and accepted a regulatory change in their self-governance.

However, at the Fukuoka Works the enactment process was different in one respect, and this involved the high degree of self-reflexivity encouraged by the production of a piece of high-technology equipment. Because the group as a whole in cooperation with other groups produced and monitored a complex piece of machinery, this machinery became a symbolic representation of group identity and process. Just as the WBE engineers were able to inspect the workings of the Mark II by observing through microscopes its internal processes, so the operation of the machinery served as a microscope by which to inspect their own internal relations, and their ability to coordinate with other groups.

Looking back over the data for the development of the Kochi project, there is a discernible parallel between talk about the machinery and talk about group problems. The early problems with pattern recognition and matching in June are traced in the July retreat to problems of coordination between the wire bonders and other groups. Thus machine coordination problems are linked to and blamed on group coordination problems. Further, machine problems seem to inflict machine-like endurance demands on the engineers, who find themselves working 16 hour days in 81 degree heat in full suits, in some cases without access to liquid refreshment. It is almost as if the engineers were testing not just the machines, but themselves, to find out if they could work under extreme conditions of temperature and pressure.

The continuing difficulties with machine coordination resulted in a continuing series of comments about the need to restructure group activities, showing very clearly the degree to which the technological output of the group came to symbolically represent group process. Itoo wanted to prevent future machine problems by restructuring the software design process. Hirayama pointed to poor technology transfer between groups. Nakamoto made a point of attending group meetings to ask for a group restructuring to prevent future technological problems. All of these interventions point to a conscious and continuing effort by the engineers to promote an isomorphism between the structure of the group on the one hand and the structure of technological design on the other hand: the group was mirrored in the high technology it produced.

Conclusion

This analysis of one department in a Japanese factory has focused on how technology reproduces identity. The technologies of routinization and spatial order combined to offer group members continuous opportunities each day for heedful interrelating and sensemaking, promoting an intense social community that enclosed the individual in numerous obligations and dependencies. The individual engineer's allegiance to cross-cutting groups inside or outside the factory was weakened by the interdependent nature of tasks within the group, by the daily rituals of togetherness, by the shared social space within which all activity was publicly visible, and by the joint production of new machinery. If, from a Simmelian perspective, individuality is defined by the number of overlapping social groups to which the individual has allegiance (Simmel 1923), then these WBE engineers appeared to be under-individuated in their commitment to a work-group identity that left little time for family, hobbies, or other interests.

The phenomenon of the overcommitment of engineers to work groups, is, of course, not confined to Japan. The very different accounts of Kunda (1992) and Kidder (1981) are similar in one respect: they both chart the dangers (in a U.S. context) to individuals of involvement in cohesive teams working at technological boundaries. These dangers include burnout and suicide as a result of individual identities being used up by projects that come to an end.

The main possibility for changes in the technologies of control that guarded and shaped the WBE group's solidarity derived from the interpretation of the progress of the complex machines produced by the group. Evidence that problems with machines offer opportunities for restructuring social relations at work has been offered by Barley (1986). At the Fukuoka Works, in contrast to the radiology departments investigated by Barley, the high-technology equipment was created by the group members, and served as a visible, tangible representation of group identity. The failure of high-technology equipment created by the WBE group implied failings in group process or structure. As a result of machine coordination problems during projects such as the one at Kochi, the WBE group members were eventually assimilated into a larger circle that included the adjacently situated group of die bonders. The organizational self, then, proved mutable rather than fixed, proved capable of assimilation into a larger concentric circle within which the same processes of routinization, spatial segregation, and technological production prevailed.

What, then, of alienation? These engineers defined themselves in terms of the products they produced, and their relationship to these products was intense and continuous. There was no evidence of a classic Marxist separation of worker from output. The wire bonders' attachment to their work came at the expense of other possible attachments, however, other possible selves. The danger for these engineers, from an alienation perspective, was that the technologies of control that bound them so tightly to the work group and to the products they created left them unprepared to negotiate the freer social spaces outside the factory in a rapidly changing Japan in which norms were no longer fixed.

Also, to the extent that workers look to the commodities that they produce for insights into their social relations with other groups, the danger arises that social relations themselves become reified. Marx (1976, p. 163) coined the term "commodity fetishism" to describe how relations between producers of commodities become transformed into relations between the commodities themselves: the products of the human brain become endowed with life. In the case of the engineers, the performance of the machines in customers' factories came to symbolize the success or failure of relations within the production facility, thus removing the social relations from the immediate arena of human contact and control. To paraphrase Weick (1979, p. 133), it was as if the engineers monitored the machines they made in order to discover who they were. Social relations, from this perspective, tended to be objectified in ritualized meetings, in prescribed and monitored spatial settings, and in machine performance. The technologies of time, space, and production, it could be argued, maintained collective identity by objectifying it beyond the control of any individual engineer.

Did the group members realize how bound up their professional identity as engineers was with the team production of expertly functioning high-technology equipment? In the similar context of a high-technology U.S. factory, one commentator suggested that such consciousness was absent. Tom West, the department head of the team of engineers who produced, against considerable odds, the Data General Eclipse mainframe, said: "These guys don't realize how dependent they are on that thing [the Eclipse] to create their identities" (Kidder 1981, p. 232). At Data General, the team broke up once the project was finished. At the Fukuoka Works, the group reformed, in a different configuration, to tackle new projects. In West's language, the WBE group earned the right to play pinball: "You win with this machine, you get to build the next" (Kidder 1981, p. 228). What was unusual at Data General was routine for the WBE engineers: the same group pushing the envelope of design possibilities over and over again.

Another similarity between the process by which group identity was maintained at Data General and the Fukuoka Works was the role of the department manager. Tom West at Data General, like Itoo at Fukuoka, was minimally involved with the actual design or implementation of new technological products. These department heads operated outside any of the groups of engineers under their command, and therefore became easy targets for blame when things went wrong. This blame-taking role may, indeed, be an important part of the responsibility of the outside manager. One of the engineers under West at Data General opined that West was just far enough away to "lay blame on" (Kidder 1981, p. 229) and in this way prevented the team's members from turning on each other or on their immediate managers. To preserve group identity, the department manager of a high-technology unit may need to act as a receptacle for blame, a strategic scapegoat for anger that could split the group.

This paper was written at a time of unprecedented attention to the writing up of field research (e.g., Clifford and Marcus 1986, Van Maanen 1988). We have tried to separate our own interpretations from the accounts of what the wire bonders did. Inevitably, even the apparently factual accounts reflect our choices of what to include and exclude, choices limited by the written notes made in the field. What is included here is the result of a series of choices: what site to study, who to talk to, what to record, what to select for attention, and so on.

The veracity of this account of what happened in a Japanese factory depends, however, not only on how credible our own writing is, but also on how much what we describe is compatible with other accounts of factory routines and behaviors. By selecting "an ordinary place," to use Bestor's phrase (1989, p. 6), similar to other development factories in Japan, we invite commentary from others within the interpretive community familiar with the technologies of Japanese work life, and the ways these technologies sustain the crafting of selves.

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