Paper 5

**Turn to the material: Remote diagnostics
systems and new forms of boundary-
spanning**

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Abstract

To learn and adapt, organizations engage widely in Information Technology (IT)-mediated boundary-spanning. This involves making sense of a swath of peripheral information made available by digital means so as to expand local knowledge. Prior research on boundary-spanning has paid scant attention to material differences between IT systems in enabling or constraining such activity. In this article, we argue that material features do matter: features afforded by IT systems have a significant impact on the form and content of boundary-spanning. We analyze material features and related affordances provided by remote diagnostics systems – a family of ubiquitous IT systems. These features

allow remote diagnostics systems to collect, store, and continuously analyze data about the state of machinery and related production processes across space, time and organizational boundaries. Organizations use these systems to determine when maintenance intervention is needed, or to improve their production processes. Often, these systems are run by external service providers at remote sites, which become the new ears and the eyes of a focal organization's production processes. Building on a longitudinal multi-site case study of two organizations, we explore the impacts of remote diagnostics systems on boundary-spanning. We observe that material features afforded by the remote diagnostics led the organizations to change their boundary-spanning in contradictory ways. On one hand, they reinforced existing boundaries. On the other hand, they crossed or cut down others, or created new ones. This suggests that the material features of these systems, when combined with new knowledge creation and sharing practices, within and between the local and the remote sites generate richer, multifaceted inter-organizational knowledge flows. We surmise that IT's new material features will continue to significantly shape organizing logics that determine where and when organizational boundaries are drawn and crossed. Future boundary-spanning will increasingly be shaped by socio-technical assemblages brought together by increasingly pervasive IT capabilities.

1. Introduction

The ability to protect knowledge within organizational boundaries, or to allow it to flow across them, has long been recognized as a critical element of organization design. It affects, among other things, innovation and organizational transformation (Grant, 1996; Kogut & Zander, 1992; Nonaka, 1994; Von Hippel, 1988). When the members of an organization cross boundaries to attain external knowledge, the activity is called boundary-spanning, and the actors involved are called boundaryspanners (Leifer & Delbecq, 1978).

Information Technology (IT) eliminates the problem of distance, increases speed, provides universal access, and cuts down on communication costs. Not surprisingly, for some time IT has been viewed as an important mechanism that contributes to boundary-spanning in that it: (1) renders heterogeneous internal information resources more transparent and thus integrate diverse knowledge (Ross, Beath, & Goodhue, 1996) and (2) helps assimilate external knowledge through virtual exchange and collaboration (Bharadwaj, 2000). Evidence for the positive influence of IT on boundary-spanning is, however,

mixed. On one hand, IT has increasingly enabled ‘cross-over’ practices within and between organizations (Hayes, 2001). On the other hand, it has reinforced existing boundaries (Levina & Vaast, 2006). One reason for these mixed findings is that the extant research has paid scant attention to material differences between IT systems that underlie boundary-spanning (Lindgren, Andersson, and Henfridsson (2008)). Clearly, an inter-organizational transaction system within a supply chain (Malhotra, Gosain, & Sawy, 2005), and a collaboration system supporting inter-organizational design work (Majchrzak, Rice, Malhotra, King, & Ba, 2000) will have different effects on boundary-spanning. This calls for more careful consideration of how the material and social become “entangled” in the process of boundary-spanning (Orlikowski, 2007).

In this study, we address the significance of such material differences by investigating how a family of inter-organizational Information Systems (IS), denoted remote diagnostics systems, enables and constrains boundary-spanning. Remote diagnostics systems—an application family within ubiquitous computing (e.g. Lyytinen & Yoo, 2002)—collect, store and continuously analyze data about the state of production machinery and processes and help, for example, to determine when maintenance or other types of intervention are needed. In transmitting digital representations over space and time for extensive analysis, these systems have the potential to transform localized, manual practices into complex, digitally mediated, organizationally and geographically distributed socio-material practices.

To date, studies of remote diagnostics systems have focused on the benefits of timely and extensive information-handling in hostile, capital-intensive, and time-critical environments (Jonsson, Westergren, & Holmström, 2008). No studies have been conducted on forms of boundary-spanning that follow these systems as they extend the flows of information and knowledge across boundaries. We posit that remote diagnostics have the potential to spawn new forms of boundary-spanning involving novel interactions among previously unconnected actors, both inside and outside a given organization. In this paper, we will address, in particular, the following questions: (1) do practices associated with remote diagnostics create new forms of distributed maintenance, drawing new organizational boundaries? and (2) do remote diagnostics systems generate and support new forms of boundary-spanning in these distributed arrangements? To address these questions, we will examine *in situ* boundaryspanning associated with remote diagnostics systems in dispersed work settings.

Because remote diagnostics systems are deeply intertwined with material practices, they offer a fruitful arena to examine how material and increasingly embedded features afforded by IT shape boundary-spanning and re-organize the social and the technical elements at the boundary (Leonardi & Barley, 2008). The distilled theoretical insights can also be used to formulate guidelines for system design in terms of how to transform existing boundaries and/or erect new boundaries when introducing remote diagnostics systems. The study also adds to the stream of research an interpretation of remote diagnostics systems as an inter-organizational information system affecting boundary-spanning.

The remainder of the paper is organized as follows. We will next discuss boundary-spanning in organization theory and the IS. We then describe remote diagnostic systems and clarify their material features. This is followed by a multi-site field study on the evolution of boundary-spanning associated with the adoption and use of remote diagnostics systems in two industrial organizations. We conclude with a discussion of the implications of our findings for studies on boundary-spanning, notions of the organizational boundary, and how such boundaries will be generated and ‘managed’ in the future.

2. IT and boundary-spanning

2.1 Definition of boundary-spanning

Contemporary organizations are designed with multiple boundaries in mind so as to demarcate non-compatible tasks and systems (Leifer & Delbecq, 1978). Such divisions are necessary to create separation of concerns, which permits organizations to enjoy economies of scope and scale. As employees engage in separated tasks, languages and cognition diverge, logics multiply and boundaries are erected. At the same time, an organization’s ability to create, transfer and integrate heterogeneous knowledge across boundaries is viewed critical to its continued adaptation and learning (Kogut & Zander, 1992). Consequently, organizations need to develop competencies to engage in both internal and external boundary-spanning, defined as the activity of collecting and making sense of peripheral information so as to expand an organization’s local knowledge (Lindgren et al. (2008)).

2.2 Organizational boundary-spanners and boundary objects

A boundary-spanner is traditionally defined as a person located at the ‘boundaries’ of an organizational (unit) and engaged in a task relating the unit with its external elements (Leifer & Delbecq, 1978). Boundary-

spanning is connected to a person's field of practice, and boundary-spanners transform their practices as to accommodate the interests of their external counterparts (Levina & Vaast, 2005). Behaviors that make boundary-spanners effective have received considerable attention (Allen, 1971; Levina & Vaast, 2005; Walter, 1999; Williams, 2002). Williams (2002), for example, identified as boundary-spanners' critical abilities to be effective personal relationships, ability to manage in non-hierarchical environments, and entrepreneurial policy-making. The weakness of these studies is, however, that they largely neglect the design and impact of information flows and/or related artifacts that affect boundary-spanning.

To address this gap, Star and Griesemer (1989) introduced the notion of boundary objects as a complementary approach to viewing knowledge transfer at the boundaries. In contrast to approaches that focus solely on boundary-spanners' behavior, the boundary objects approach places in the foreground a broad range of artifacts and their material properties as a means to enable knowledge transfer between social worlds. Such artifacts include prototypes (Carlile, 2004), drawings (Bodker, 1998), scenarios (Bodker, 2000), engineering sketches (Henderson, 1991), and various ISs (Ackerman & Halverson, 1999; Briers & Chua, 2001; Harvey & Chrisman, 1998; Pawlowski, Robey, & Raven, 2000). The boundary objects do the "knowledge transfer" work because of their flexibility and robustness—i.e., they are "both adaptable to different standpoints and robust enough to maintain identity across them" (Star & Griesemer, 1989, p. 387). To become both flexible and robust, boundary objects must be tangible (Carlile, 1997), concrete (Bechky, 2003; Henderson, 1991), accessible and up-to-date (Carlile, 1997).

2.3 IT and boundary-spanning

As noted, ISs form one class of boundary objects when they are shared across two or more organizations, units, or social worlds. They enable or constrain boundary-spanning as they permit or prevent the efforts of organizations' members to share information across functional, geographic and temporal boundaries (Hayes, 2001). When information becomes increasingly digitized, it can be shared instantly; geographic distance becomes irrelevant, enabling distributed collaborations; and improved access generates new forms of boundary-spanning (Fountain, 2001). Therefore, most studies emphasize IT's enabling or enhancing capabilities with regard to boundary-spanning. For example, digital 'capabilities' such as e-mail, Internet web sites, and groupware provide access to multiple sources of information over a distance, and consequently expand boundary-spanners' capabilities (Yan & Lewis,

1999). Several studies show such positive enabling or enhancing impacts on boundary-spanning. For example, Levina and Vaast (2006) found that e-mail, phone and intranets allowed actors to share new information across boundaries. Likewise, Clemons and Row (1993) showed how inter-organizational systems improved boundary-spanner's coordination in a supply chain. Finally, Barrett and Walsham (1999) illustrated how the introduction of a computerized trading system offered opportunities for flexible work and access to new markets. The overall impact of IT on communication and knowledge-sharing across boundaries, however, has been mixed, as it has also been found to reinforce prevailing boundaries (Goodman & Darr, 1998; Schultze & Boland, 2000). In a study of a global bank's intranets, Newell, Scarbrough, and Swan (2001) for example found that introduction of intranets reinforced existing functional and national boundaries.

One reason for these mixed findings may be that little attention has been paid to material features of different IT systems and to the extent to which they either constrain or enable distinct forms of boundary-spanning across contexts. For example, transaction systems used for supply chains differ significantly from groupware systems facilitating teamwork. The question is then: how does one account for the varying impacts of different material features of IT for boundary-spanning in its social context (Leonardi & Barley, 2008)? This issue has represented a long-standing challenge in IS research (Leonardi & Barley, 2008). For example, Orlikowski and Barley (2001) contend that there can be "a fusion of perspectives, a fusion that is more carefully attuned to explaining the nature of techno-social phenomena" (p.147). They aspire to "bridge" (ibid, p.149) the physical and the social in ways that supports two-way interactions between technology, institutions, and their change. On one end of this two way-analysis, social constructivists address the bridge and "theorize over the IT artifact" (Orlikowski & Iacono, 2001) by shifting away from the materialist conception of technology towards a conception where technologies are viewed as socially constituted objects, so as to show how the same technology has different impacts in different contexts (Leonardi & Barley, 2008; Walsham, 1993). While this avoids one element of the dilemma—technology determinism—it also allows the scholars to sidestep the question of the changes in IT's materiality and whether these material differences matter (and if so, under what conditions). In order to overcome this myopic view, scholars need to bridge the material and the social such that material change in technologies is recognized to have an effect in the same or similar ways across social contexts. Likewise, changes in boundary-spanning need to

be placed in the context of theorizing about material features of mediating technology enabling boundary-spanning calling for a “material turn” (Orlikowski & Scott, 2008). Clearly, we need to look at how material features offered by IT enable or constrain new forms of boundary-spanning across contexts. To this end we will next analyze how IT systems have featured capabilities over time that enable or constrain forms of boundary-spanning.

2.4 Inter-organizational systems and boundary-spanning

Inter-organizational systems (IOS) literature characterizes shared IT functionalities as enabling faster and more efficient sharing of richer information sets across boundaries (Kumar & van Dissel, 1996; Robey, Im, & Wareham, 2008). These functionalities include shared database access, communications support, shared application functionality, transaction messaging (EDI), and so on (Kumar & van Dissel, 1996). They allow more quickly participants to share states of organizational processes or resources (e.f. inventory levels, design status). In the earlier IOS research (Hart & Saunders, 1998; Robey et al., 2008), electronic data interchange (EDI) systems formed the primary focus, but recent interest has shifted to electronic business interfaces founded on XML-based standards that allow for mutual and many-to-many real-time information exchange and application integration (Gosain, Malhotra, El Sawy, & Chehade, 2003). These functionalities are adopted to facilitate communication, coordination and collaboration between organizations’ interfacing processes (Premkumar, 2000) in supply chains (Kumar & van Dissel, 1996; Malhotra et al., 2005), or in design tasks (Argyres, 1999; Majchrzak et al., 2000). Combined in diverse ways, these functionalities allow for more intense and broader boundary-spanning (Kumar & van Dissel, 1996) for joint group tasks (document-sharing and integration) or about automated transactions (EDI, supply chains). The main impact of these processes is on setting up and sharing digital forms of process information at the organization’s new “digital boundaries”.

2.5 Ubiquitous computing and boundary-spanning

Developments in sensor technologies and related IT features have opened up vistas for new forms of boundary-spanning where IT can become the ‘ears and eyes’ of organizations (Fano & Gershman, 2002). In these systems, data sensing, responding and analysis capabilities are embedded in the organization’s material environment, which allows for expanded analysis and response from a distance. Yet, only a few studies have examined these forms of boundary-spanning. Recently, Lindgren et

al. (2008) conducted a case study of a mobile road transportation system that coordinates services for road haulage firms. They observed how the system facilitated new boundary-spanning forms as it altered the organizations' understanding of their external environment by re-defining the contextual cues with which the organizations made sense of that environment (Lindgren et al., 2008). While this study adds insight about new forms of boundary-spanning, ubiquitous computing systems offer a richer variety of features. A mobile road transport system involving human agents at both ends of system differs significantly from a remote diagnostics system that uses sensors for automatic data creation and involves high levels of data analytics. Therefore, next we will describe the main components of these systems, and their material features.

3. Remote diagnostics systems

The use of ubiquitous IT capabilities in production environments enables continuous condition-based machinery and production process monitoring. When the monitoring takes place at a distance, we call these systems remote diagnostics systems. These systems rely on the accuracy, timeliness, volume, multi-dimensionality and extended time-span of new forms of digital data representing production states and objects. They not only can automate significant portions of component-based performance monitoring, but can also help diagnose problems or provide early signaling for potential problems (Biehl, Prater, & McIntyre, 2004). These systems are organized around rich forms of digital data gathering and exchange (Simmons, 2001) that allow for extensive, real time, and model-based computations. In addition, the data can be gathered across multiple organizational boundaries at a distance using multiple networks (Brax & Jonsson, 2009).

These systems are made up of collections of heterogeneous technologies; sensors that collect data, (mesh) networks (Bluetooth or Zigbee) that transmit it into a centralized repository; and analytics and operational rule systems that store and retrieve the data, analyze it, visualize it and make recommendations, generate alarms, or launch responses. The sensors are distributed among critical physical components throughout a plant, or an industrial network (Han & Yang, 2006). With these capabilities, remote service centers can be organized globally, and they can monitor and diagnose a large number of distributed production systems and their components across multiple organizational boundaries.

These systems have led to unprecedented centralization of maintenance services that were previously locally arranged. They have generated new services like brokering leading maintenance practices data, or new maintenance rules. Finally, they increase the information and knowledge intensity of maintenance work, as centralized centers can analyze multiple data sets in complex ways with small additional cost. Technicians in the centers can also focus on proactively diagnosing problems by learning from the past cases. They provide knowledge-intensive value-adding services like learning from failures through rule-based decision-making, or statistical sampling and data mining (Kuschel & Ljungberg, 2004; Tolmie, Grasso, O'Neill, & Castellani, 2004). Not surprisingly, industrial organizations have widely adopted remote diagnostics systems as the cost of sensors has decreased and their networking capability and environmental adaptability has increased.

Overall, remote diagnostics systems are an example of new ubiquitous inter-organizational IS. As with earlier IOSs, these systems are shared among organizations, and they connect organizational processes (Robey et al., 2008). Like earlier IOSs, these systems facilitate collaboration between organizations so as to improve the uptime of the monitored equipment (Kumar & van Dissel, 1996). In contrast to traditional IOSs, the remote diagnostics systems are not based on standard interfaces at “digital boundaries”, and their use is not coordinated with that of other systems in the monitored organization. In contrast to earlier IOSs, remote diagnostics systems contain proprietary technical architectures, and they do not offer mutual access to shared data “on the frontier”. They also embrace highlevel data analytics and knowledge generation at the remote site that is not found in earlier transaction- based IOSs. Finally, only members at the remote site have direct access to all the system data and analytics, while the members of the ‘monitored’ organization are not aware of the details of the data or the analysis creating information asymmetries.

Remote diagnostics systems can be viewed as harbingers of a new distributed and networked knowledge-intensive industrial organization that re-organizes production functions and their control geographically and by expertise based on the creation and distribution of new knowledge-based operational skills. They foster untried ways to organize production and its maintenance that separate local information from its origins and make it travel so as to permit centralized operators to act from a distance. They establish unprecedented knowledge-based routines that separate technicians in time, space, and industrial context from the components they monitor.

To summarize, these systems deeply influence how organizational boundaries that are drawn as ‘cross-overs’ are now less limited by constraints of time, space or the type of data shared (Jessup & Robey, 2002). These systems permit workers at remote sites to gain access to information about external dispersed objects and production processes. They also create new boundaries between entities that were not connected before and cross previous boundaries with new information and knowledge. Overall, the systems create unprecedented challenges to how various local and remote work practices and their knowledge are expected to interact. To understand the impact of new forms of boundary-spanning enabled and fostered by remote diagnostics, we conducted a multi-site case study.

4. Research setting and approach

4.1 Study aims and setting

We will use the term “remote work” to describe work conducted in a centralized location. Local context refers to the locale where the monitored components are situated—in this study, an industrial plant where local maintenance units manually inspect and repair equipment. Likewise, the concept of remote diagnostics systems refers to the IT application and its capabilities, while the concept of remote diagnostics services refers to the services offered by centralized facilities organized around these systems.

A qualitative study aimed at gaining an in-depth understanding of the impacts of remote diagnostics systems on boundary-spanning among local and remote maintenance work groups was carried out in four industrial organizations. These organizations were selected for several reasons. First, all utilized remote diagnostics systems for maintenance, either as providers or as customers. Second, the organizations represented both the remote and the local work settings, enabling the study of both ends of the boundary-spanning. The remote workers are represented by service providers offering maintenance services and operating remote diagnostics systems. Their customers represent local work settings. Other criteria for selecting the organizations were their willingness to cooperate, the availability of multiple sources of data, and the possibility of purposeful sampling (Peppard, 2001; Yin, 1989).

4.2 Maintenance work

Maintenance forms a critical issue to manage in many industrial settings, as uptime is crucial, lowering production costs or avoiding

environmental hazards. The equipment will eventually break down; the challenge is to manage maintenance in a way that balances the maintenance cost in relation to the equipment's potential uptime value. Depending on the equipment's value for production, maintenance strategies can vary from reactive (i.e., using fault-based maintenance) to proactive (i.e., using preventive maintenance). With a fault-based maintenance strategy, the companies deploy a run-to-the-failure approach where components are replaced after a failure. This approach requires limited planning and minimal information-handling (normal inventory control and maintenance manuals). In contrast, the preventive maintenance approach seeks to replace components before the failure (Tsang, 2002) and minimize losses in production and environmental hazards. However, this exponentially increases the need for information-handling as failures must now be predicted and fixed proactively (Armistead & Clark, 1991). Two suggested approaches to preventive maintenance are scheduled maintenance and condition-based maintenance. In the former, maintenance is performed at scheduled intervals based on plans and manuals regardless of the item's actual condition. In the latter, maintenance is performed when failure is deemed to be imminent based on information and model-based prediction. Performance-parameter analysis, vibration monitoring, thermography, and oil analysis are typical condition-monitoring techniques that can be used to detect the threat of failure. The challenge involved in condition-based monitoring is that to achieve low cost means to observe such conditions, to maintain the history of collected data and to build a model to predict when a failure is imminent, as well as to communicate this to the relevant parties.

In contrast to the fault-based maintenance approach, preventive maintenance is information-intense. The scheduled maintenance strategy needs to co-ordinate information on the maintenance intervals for the different components. With a condition-based approach, maintenance becomes even more complex and information-intense as it demands vast amounts of data to be collected from the equipment and production processes and model-building to determine the appropriate maintenance interventions. With the shift to condition-based maintenance comes a drastic increase in IT use and a new work organization that can deal with the new information-rich maintenance.

4.3 Research setting

Two organizations providing remote diagnostics services were selected: Monitoring Control Centre (MCC) and PowerDrive. Their customers are

represented by two organizations denoted here as Alpha and Beta. We use fictitious names to preserve confidentiality. All organizations are located in Sweden. Table 1 lists the organizations and outlines their internal relationships.

Organization	Activity	Local/remote maintenance work
PowerDrive	Manufacturer of motors, remote diagnostics service provider	Remote
MCC	Remote diagnostics service provider	Remote
Alpha Customer to PowerDrive and MCC	Mining industry company User of remote diagnostics services	Local
Beta Customer to PowerDrive	Pulp and paper industry company User of remote diagnostics services	Local

Table 1. Organizations involved in the study

PowerDrive is a manufacturer of motors that offers a remote diagnostics service to enhance maintenance for motors. Their system uses sensors embedded in the motors to collect data about their condition. Data are collected every 30 s and temporarily stored in the system before they are transferred once a day to a server at PowerDrive for analyses. If something abnormal is detected, an alarm is automatically sent out to technicians via SMS or e-mail, with information indicating the problem. A report that summarizes the condition of the motors and any problems detected is also put together every month and sent to the customer. PowerDrive had a long history in maintenance services before the use of remote diagnostics services. The company has several service divisions, which assist with local maintenance by producing written guidelines and giving help desk services. Moreover, they perform selected repairs that require detailed knowledge of the machines involved, and they also perform periodic manual inspections to verify their condition.

MCC is a “pure” maintenance service provider that offers condition-based maintenance monitoring and other industrial services for the mining industry: operations analysis, implementation of infrastructure for condition monitoring, and collection and analysis of measurement data. This study focuses on their remote diagnostics service, in which MCC takes responsibility for implementing remote systems for their customers’ equipment, analyzing the collected data and informing the

customers. The company began operation in 2002, and by the time of this study, their largest customer was Alpha. MCC was established as a remote diagnostics service provider, so it had no organizational structures developed previous to its use of remote services.

Alpha is a large mining industry company with a number of plants where remote diagnostics systems are used. The company is a customer of both PowerDrive and MCC. Alpha recently decided to re-organize maintenance so as to cut down some boundaries between their different plants and create a more risk-aware culture. As a part of this re-organization process, condition monitoring was delegated primarily to MCC but also to its equipment suppliers, including PowerDrive.

Beta is an organization in the process industry that uses remote diagnostics systems in its plant. Beta has only one plant, which has a well organized and functioning maintenance system. The company has created its own group responsible for condition monitoring. The management of Beta considers it important that maintenance knowledge remain within the company and is more reluctant to allow external providers to exclusively perform maintenance services. However, PowerDrive was allowed to install remote diagnostics on the plant motors. In addition, Beta has allowed other providers to perform select maintenance services when Beta does not have the required competence in-house.

4.4 Data collection and analysis

We employed semi-structured interviews as a primary data collection technique. In all, the study included 22 interviews, which are summarized in Table 2. All interviews were conducted on-site at the respondents' workplace, which enabled the researchers to gain some insights into their work. The interviews were conducted by the first author and a co-researcher, and they lasted between 45 min and 3 h, with an average of about 60 min. The interviews were recorded, which allowed the researchers to focus on the respondent and formulate follow-up questions. The interviews were transcribed for content analysis. As recommended by Miles and Huberman (1994, p 278), a preliminary copy of the results was both presented orally and circulated among the respondents to ensure the credibility and authenticity of the research.

Service providers		Customers	
<i>MCC staff</i>	<i>Date</i>	<i>Alpha staff</i>	<i>Date</i>
Manager	2004-04-27	Technician	2003-10-09
Manager	2006-01-31	Maintenance/production manager A	2003-10-10
Team leader	2006-01-31	Maintenance manager B	2004-04-27
Technician A	2006-01-31	Maintenance technician	2004-04-27
Technician B	2006-02-01	Maintenance technology manager	2004-04-28
Technician C	2006-02-01		
Developer	2006-02-01		
		<i>Beta staff</i>	
		Technician A	2003-11-06
<i>PowerDrive staff</i>		Technician B	2003-11-06
Design manager	2003-08-21	Maintenance manager	2003-11-06
Service/Maintenance manager	2003-08-21	Maintenance inspector A*	2003-11-07
Technical engineer	2003-08-21	Maintenance inspector B	2003-11-07
After-sales manager*	2003-08-21	Maintenance engineer	2003-11-07

Table 2. Interviews conducted in the study (interviews marked with an * were not recorded)

When choosing interviewees from among the members of these organizations, we sought to include people in managerial positions, technicians developing the technology and people with experience using the services. From the user organizations, we included both individuals in managerial positions and maintenance technicians who are in contact with the remote services.

The remote diagnostics systems had already been introduced in the beginning of this study so that the interviews were retrospective in nature. In the interviews we asked the respondents to characterize their work processes and related interactions with other stakeholders before and after situations as a way to find significant differences between these two. The focus of the interviews was to probe the effects of remote diagnostics systems on work organizations and also new forms of boundary-spanning. Based on the literature, we identified three key areas of inquiry to recognize these impacts: (1) the context and overall change

in work settings, (2) changes in boundary-spanning and (3) the impact of these changes on work organization and process. The first area directs attention to the industrial context and the range of technologies in use. These are important to consider, as the previous research has devoted little attention to the specific features of IT applications supporting boundary-spanning. We asked to what extent remote diagnostics systems enabled or prevented boundary-spanning. We also asked for the effects of these new boundary-spanning practices on maintenance.

The interview materials and field observations constitute the major corpus of the empirical database. The data analysis involved reading the data set and organizing the data into themes corresponding to the three identified areas. During the first reading, the material was grouped into two main categories—remote and local activities—affected by new forms of boundary-spanning. Next, we analyzed these two categories based on observed changes in boundary-spanning by sorting the data into three categories: (1) what boundaries had disappeared, (2) what new boundaries had emerged and (3) what boundaries were reinforced. Examples of coding data into these categories are listed in Table 3. Finally, we analyzed data in each category separately to find out interactions between material features of the remote diagnostics and forms of boundary-spanning.

Category	Spanned boundaries	New boundaries	Reinforced boundaries
Remote activities	<p>“If we ask the sales person we get one answer; if we ask the customer, well they might not even know that it is a one of our motors. The technician has another answer. The real answer we get if we install monitoring technology that measures [the status of the equipment]. How many hours has the motor been used? What was the temperature? The pressure? Has the oil been dirty?”</p>	<p>“You will miss the feeling for the equipment [with remote diagnostics] [...] But on the other hand you can’t have a person at every machine, that doesn’t work.”</p>	<p>“It was good to be present in the plant [...] then I could get a sense and talk to people. I tried to listen to the local technicians and account for their opinions when I tried to diagnose a machine.”</p>
Local activities	<p>“With the remote service provider we feel safe, we have better control of our equipment. If we remove the monitoring of the vibrations of the bearings the breakdowns would increase. “</p>	<p>“With more monitoring, you can work more and more online and fewer people will be out among the machines. You won’t get the same feel for the machines. The only things you see are, for example, temperature, pressure, and flow. You don’t know how it sounds.”</p>	<p>“If I have this equipment, if I’ve bought it, they [the suppliers] shouldn’t care about how we use it [...] they want to interfere, make changes [...]”</p>

Table 3. Examples of data coded in each category

5. Changed maintenance practices

5.1 Current work settings and the existing boundaries

Figure 1 illustrates the organization of the maintenance firm and its knowledge flows and boundaries before the use of remote diagnostics systems. As MCC did not exist before the use of remote diagnostics services, the supplier side in the figure is represented solely by PowerDrive.

Figure 1. Maintenance organization before the use of remote diagnostics systems.

We could identify several boundaries that affected knowledge flows. The equipment being maintained was situated in large plants run on the 7/24 principle. Therefore, the plant had their own maintenance organizations that performed repairs locally for immediate needs. As both companies in this study had adopted a preventive maintenance approach, the work also included external services on a regular basis, where external inspections sought to avoid unplanned breakdowns, primarily using the technicians' skills and senses to monitor and "sense" the machines' condition. The employees at PowerDrive described that over time, the external service technicians had become indirectly responsible for their "own" customers. They knew the equipment, the customers' plants, and the people. When they visited the customers' plants, they received information from the local staff, and they also could give advice regarding how to use the product. The technicians served as boundary-spanners who collected information about products and local conditions in customer organizations and distributed the maintenance knowledge. The boundary between the service technician and the customer sites was porous, as they had regular and intensive local contacts.

In addition to the ad hoc local information, some longitudinal information could be collected from the products' control systems. These control systems carried out limited data-logging functions and the data could be retrieved with a laptop. The technicians could then analyze the data at the site, or bring it to their office. They learned over time about the products they were responsible for, but foremost by observing how the machines behaved during breakdowns. The technicians served as boundary-spanners by collecting information about the products and forwarding it to the rest of the organization. However, this information was mainly ad hoc and based on what could be collected during visits and easily documented. The visits were irregular: as long as the product was running smoothly, there was no need for repairs. As a result, the service provider had limited knowledge of how the products worked in different settings. The walls between the service organization and the utilizing organization remained high, though the information technicians collected was deemed valuable in product development:

We don't have basic data on how our motors work in operation around the world. We know what happened in our own tests, but not what happens out there. What are the most common problems? How do we get information about that? Should we listen to the guy who calls out most or the one who can give the best overview? It varies what information we get from the after-sales division and our technicians around the world. Most often it is the guy who calls out most who gets what he wants. (Technical engineer, PowerDrive)

The information collected by technicians mostly stayed with the individual or within his/her service division. The log files and reports of the service visits were stored on a central server within each service division. PowerDrive did not have routines for the centralized integration of data for further analysis, learning and development. Knowledge remained localized, immutable and immobile:

The data is available within each service division, on a server. Somewhere. . . (Service/Maintenance manager, PowerDrive)

Current maintenance practices in PowerDrive generated internal boundaries and blocked data flow between the divisions. On the customer side, there were additional boundaries due to the irregularity of visits and the customers' dependence on technicians' skills.

The field service technicians occasionally collected "narrow band" information through their interactions with the customer technicians and the equipment. They could also give information to the customer technicians and change the parameters of the equipment. However, this boundary-spanning depended highly on technicians' personal

relationships with the staff and the regularity of their interactions. Moreover, the service technicians did not always get a chance to talk with the “right” local people who had knowledge about the product. These issues hindered the transfer of information and gave rise to boundaries between the local and remote work settings.

5.2. Changed work settings and boundaries

The remote diagnostics systems generated new connections between service providers and the equipment, as real-time performance and status data was now transferred to a central location. As noted, depending on which types of sensors are installed, the remote diagnostics systems can, for instance, collect data on vibrations of bearings or temperature, pressure and speed. By monitoring such data, the system can find problems in the machines early on. Fig. 2 depicts the maintenance organization and its boundaries after the introduction of remote diagnostics systems.

For the local maintenance organization, the system remains invisible. The organization receives monthly reports where the status of the equipment is presented. Moreover, the remote technicians inform the product status via phone, especially if they detect urgent problems. The division of labor among the service providers and the plant workers is such that the local group maintains the products with the help of information gained from the remote workers.

5.2.1 Boundaries spanned with remote diagnostics services

In the new situation, some boundaries are made porous or even blurred by the remote diagnostics system. Three such boundaries were identified: (1) the use pattern boundary, (2) the divisional boundary and (3) the contextual boundary.

Spanning the use pattern boundary refers to how the flow of data between the local and the remote site enables the service provider to gain access to a continuous stream of information and see what happens between the service visits. These capabilities help span the use pattern boundary that had previously hindered the remote actors from gaining continuous information about the products:

Figure 2. Maintenance organization after the use of remote diagnostic systems.

With the remote diagnostics systems we can see things between the physical visits. For example, in England we could see that one motor worked under very high temperature. When the technician was there everything was ok, but the system told us that every night the temperature increased dramatically. It was due to a regular overload of the motor and nothing that we could detect during our physical visits daytime. (Technical engineer, PowerDrive)

At PowerDrive, the ability to get feedback was one of the driving forces in the development of the remote diagnostics system. PowerDrive now receives richer information on how its products work. The boundary between the manufacturer and the product used in the local context is more porous:

If there is a problem, we can log in and see how things look right now. Have they made any changes, are the parameters of the motor the same as when it was delivered? The system gives a clear picture of the motor at the moment. (Design manager, PowerDrive)

With the remote system, it is now possible to learn how the products operate under real conditions. This knowledge is valuable for product development, but also as a way to improve the customer's use of the product. Previously, the manufacturer could inspect the product only while it was idle.

[. . .] it's easy to see how the whole drive system is being used, if it is running as planned and if it is correctly dimensioned. This will provide a useful overview of how the complete drive system is being used, helping us to understand drive applications better, improve settings and achieve better performance and more efficient utilization." (PowerDrive customer magazine, 2-2003)

Finally, the system helps customers to learn more about how their operators use the product. One of PowerDrive's customers had filed a warranty claim on one of its motors. PowerDrive then installed the remote diagnostics system to monitor how the motor was operated. When they presented the results, the customer realized that the work routines had to be changed.

MCC saw the same benefits with the system: the company now attains more detailed knowledge of how the products are used. The remote diagnostics system enables data collection, which helps the customers to improve their own operations. MCC, however, cannot take advantage of all the possible benefits of the data for product development, as the company is viewed as a pure and fair service provider.

Breaking divisional boundaries refers to how the boundaries between different plants and divisions can be removed with the capability to gather information centrally. Before PowerDrive developed their remote diagnostics system, most of the information about the products remained in the minds of the technicians, although some scattered information was saved within service divisions. The central operations at PowerDrive can now learn more about their products by retrieving information from the system:

If we ask the sales person we get one answer; if we ask the customer, well they might not even know that it is a one of our motors. The technician has another answer. The real answer we get if we install monitoring technology that measures [the status of the equipment]. How many hours has the motor been used? What was the temperature? The pressure? Has the oil been dirty? (Technical engineer, PowerDrive)

With the new remote system, it is possible to obtain direct measures for products. Both PowerDrive and MCC store data in a web-based system that can be accessed by all employees. The digital format allows for the transfer of all data to many individuals and divisions. Those who are interested in the data can access it and gain new insight. The technology has now created a capability that tears down internal boundaries that earlier hindered information sharing.

Breaking the contextual boundary is possible, as information is retrieved simultaneously from multiple products in many factories. While traditional product testing was done in laboratories ex ante, the new system transfers data from many settings post hoc:

Now we do tests under real operating conditions. Recently we had ten motors spread out in the USA, England, Italy and Sweden. We monitored them with the remote diagnostics system for one year. Then we took the motors back to the lab and took them apart and drew conclusions based on the results. (Technical engineer, PowerDrive)

The remote diagnostics system enhances the service provider's key competencies, as a centralized unit can follow the status of all monitored assets and learn from them. The earlier boundary between different use contexts is now crossed with the help of the global monitoring capability.

MCC works mostly with vibration monitoring, but their employees are expected to keep track of other technologies and take part in the development of new technologies useful for monitoring. Alpha, for instance, says that they have never had time to address these kinds of questions before. MCC believes that its increased focus on condition monitoring is important in the context of the mining industry. With this focus, the company can enhance its process knowledge and become a global expert. By the time of this study, MCC was introducing a new information system that would be used worldwide by suppliers to spread knowledge of vibration data from bearings. Suppliers can share their data so as to learn what levels should trigger alarms. This system makes the boundaries between different use contexts even more porous, as providers can learn from each other and not merely from their own customers. Alpha points out that this centralized maintenance competency is the reason why the company chose to hire external providers. The remote diagnostics service provider can get a bird's-eye view of not only all of Alpha's plants, but also other factories in other companies where similar products are used. This would be impossible for Alpha to achieve on its own.

5.2.2 New or reinforced boundaries with remote diagnostics services

As noted IT, often leads to the reinforcement of existing boundaries or the creation of new ones. This section analyzes such effects of remote diagnostics systems. Two new or reinforced boundaries are identified: (1) the boundary between the local and remote maintenance groups and (2) the cognitive boundary associated with the equipment.

The local-remote maintenance group boundary is reinforced with the use of remote diagnostics systems. As noted, Beta has a long history of experience with preventive maintenance, and it views in-house knowledge of this activity as crucial. Therefore, it sees an increased risk of losing competencies when external service providers are hired. This creates a distance between the service providers and the local setting:

We are afraid to lose hands-on knowledge. With the air system, we have chosen to keep one guy [even though Beta has an external service provider responsible for the system]. It's such an important system. If the air supply breaks, the whole plant stops. Therefore we have this

guy walking around on a daily basis to check the system, even though it shouldn't be necessary. (Maintenance engineer, Beta)

They [the remote technicians] monitor the values and see a decrease in a value from 100 to 95, and then they call. But is it really anything wrong with the machine? It's not certain that it is a problem. Everything works as usual, but they see a value that isn't normal. That's why I'm a bit skeptical towards too much monitoring. (Technician A, Beta)

The new distance created by the remote system increases the divide between the local and remote workers, resulting in mistrust in the remote monitoring. Only the remote technicians have access to detailed information, but they cannot know which environmental issues might be causing the monitored values. Despite the fact that both customers in the study experienced a decrease in the number of unplanned breakdowns with the help of condition-based monitoring, many local workers expressed deep skepticism about the value of remote diagnostics. These workers felt that the suppliers interfered too much in the use of the equipment and expressed that the suppliers should not mind about the use of the equipment:

If I have this equipment, if I've bought it, they [the suppliers] shouldn't care about how we use it [...] they want to interfere, make changes [...]. (Technician A, Beta)

At Alpha, the management is highly optimistic about letting external providers perform remote monitoring. Among the employees, however, skepticism is raised towards the new distance that is created between the maintenance groups.

What does he [the remote technician] know about our work? Can we trust that he will contact us? As long as they are here [in the plant] then it's not a problem. Then we can talk with them directly. (Maintenance technician, Alpha)

You need all this additional information from the environment to see if there is a problem or not. Sometimes it is not enough to just look at the certain machine; you have to look at the whole setting. Maybe something has happened earlier in the production chain that is causing the problem. (Technician, Alpha)

The use of the remote diagnostics system in fact reinforces the information asymmetry and the boundary between local and remote maintenance. The local group is excluded from the direct information flow, as the information is directed only towards the remote technicians. Mistrust prevails among the local workers, as they are unaware of what the remote technicians can see. Moreover, as the remote technicians do not have contextual data, the local workers show mistrust towards

remotely drawn conclusions and their legitimacy. Examples of this mistrust abound at Alpha, where, for example, the local workers sent a bearing to a laboratory to see if a problem that the remote technician had highlighted really existed. Sometimes, they waited to perform repairs that MCC had pointed out in order to see if the product would really break down. However, over time, most of the local workers at Alpha were convinced that remote diagnostics was valuable.

A *cognitive boundary* of the equipment emerges due to the distance created between the remote technician and the equipment being monitored. Due to the limited number of parameters/dimensions that can be collected using the remote system, the picture obtained by remote technicians is not ‘phenomenologically’ rich, but it yields a high level of abstraction regarding the operating conditions. A physical walk-around by an experienced technician who sees, hears, smells, and feels that something is abnormal can often lead to the detection of things that current sensing technology and the remote technician cannot. A technician at Beta says that:

You have to learn to know the machines individually. You don't do that remotely.
(Technician A, Beta)

This highlights a clear limitation of the remote diagnostics system that only relies on formal and explicit knowledge. Although the system can detect conditions that the local technician often miss, many respondents pointed out that there is a complex real world out there and the explicit set of data values on its own is not enough. The same technician raised both a risk and a limitation of the sensing technology:

With more monitoring, you can work more and more online and fewer people will be out among the machines. You won't get the same feel for the machines. The only things you see are, for example, temperature, pressure, and flow. You don't know how it sounds.
(Technician A, Beta)

The remote workers’ “limited” and explicit cognition of the reality is a boundary that will remain no matter how many sensors are put in place. The system will also decrease the need to physically visit the machines, and as a result, fewer people will be walking around at production sites. This will create a false sense of certainty and predictability, as something is seen to be under control when the parameter values are visible and appear normal. Overall, the remote system creates a new cognitive boundary between the service technicians and the monitored equipment.

5.3 Impact of boundary changes on maintenance work and its organization

We noted several changes in work organization. First, because remote diagnostics allow for monitoring while the products are running and in between the physical visits, they have the capability to span the use boundary. The divisional boundaries are also spanned as information is now gathered centrally and made available to all divisions. Moreover, the global monitoring capability of the remote diagnostics systems reduces geographic boundaries, as previously independent knowledge from multiple contexts can now be combined. The boundary between the local and remote groups is, however, reinforced. It reduces the opportunities for face-to-face interactions between the local and remote workers. Finally, a new cognitive boundary arises in between the remote worker and the monitored equipment.

In the new maintenance organization, knowledge flows are managed differently. A central data repository forms the heart—the boundary object—of condition-based maintenance. Its centralization helps generate an overall understanding of all equipment across the globe. The remote system enables the service providers to gain a deeper knowledge of their products so as to improve their service offerings. For the remote workers, data and representations become the key to finding problems. At the same time, the service providers observed significant challenges in making sense of the data, as they need to select the “right” parameters and time intervals for monitoring. They are therefore seduced into collecting more and more data so as to get a more all-encompassing model of their products, which would permit the cross-checking of parameters in case some unexpected problem should arise.

From the local perspective, the system helps monitor the products, but also creates increased information asymmetry between remote and local maintenance. The results of the data analysis are the only thing presented to the local side, and often these results are viewed with skepticism, as local workers can use all of their senses to detect the machines’ status.

Table 4 summarizes the boundary issues related to maintenance at the local and remote sites before and after the use of the remote diagnostics system. The results are grouped into four categories: boundary-spanners, objects, knowledge management practices and boundaries.

First, before the use of the remote diagnostics system, boundary-spanning was mainly performed by technicians, both at the remote and the local sites. With the introduction of the technology, the boundary-spanning changes at the remote sites, as centers monitor the equipment

at a distance. The boundary-spanning is no longer solely performed by the service technicians; the technology plays now a pivotal role in the boundary-spanning.

Second, the remote diagnostics system also changes the objects of work for the remote boundary-spanners. Earlier, all technicians worked hands-on with the equipment, but now the digitized information and the system's infrastructure constitute the main object at work for the remote technicians.

Third, boundary-spanning previously were rather non-organized and rested on the individual technician's skill. However, the remote diagnostics system caused major changes for the remote site as the system enabled data from many dispersed settings to be collected centrally —the creation of global knowledge view is thereby enhanced, and knowledge creation becomes systematic and disciplined based on continuous data collection. At the local site the knowledge management practices remain unchanged as the technicians in the local setting are excluded from the information flows of the system.

Finally, due to the remote diagnostics system, the boundaries themselves are also changing. Previously, when the boundary-spanning was performed by the service technicians, the boundaries were mainly defined by social relationships. However, these boundaries are now changing with the use of the remote diagnostics system, and are mainly defined by data access and “digital” distances.

	Before Remote Sensing	After Remote Sensing
Boundary-spanners	<i>Remote site:</i> Technicians visiting sites <i>Local site:</i> Local technicians	<i>Remote site:</i> Remote diagnostics system and the central control room + technicians visiting the site occasionally <i>Local site:</i> no change
Objects	<i>Remote site:</i> Machines, maintenance manuals, field visit records <i>Local site:</i> Machines, maintenance manuals	<i>Remote site:</i> Data, sensors, centralized data management and analysis, communication channels <i>Local site:</i> Machines, maintenance manuals, diagnostic reports
Knowledge management practices	<i>Remote site:</i> Hands-on created expert knowledge Individualized knowledge practices Some explicit knowledge in manuals and records Occasional & indirect data gathering <i>Local site:</i> Local, hands-on created tacit knowledge Individualized knowledge practices Some explicit knowledge in manuals Occasional & indirect data gathering <i>Little difference between local and remote maintenance knowledge management</i>	<i>Remote site:</i> Global knowledge at a distance Centralized, transferable and explicit new knowledge of machines Learning from machine samples Organized and explicit knowledge management practices Continuous & direct data gathering <i>Local site:</i> Local knowledge unchanged Tacit knowledge at the site Occasional & indirect data gathering Some explicit knowledge in reports and in contacts with remote technicians <i>Major difference between local and remote knowledge management</i>
Boundaries	<i>Remote site:</i> Defined by organizational roles, poor data availability and related local work practices <i>Local site:</i> Defined by organizational roles <i>Boundaries defined and maintained by face-to-face relationship</i>	<i>Remote site:</i> Defined by direct access to local data not seen by the local workers Defined by resulting huge differences in knowledge practices and access to new knowledge Defined by organizational and geographic distances <i>Local site:</i> Defined by local data poverty, and new organizational roles that subsume to control at distance <i>Boundaries defined and maintained by technology, related distance and arms-length relationships</i>

Table 4. Boundary issues at the local and remote sites before and after the use of the remote diagnostics system

6. Discussion

This paper has focused on the impacts of new forms of boundary-spanning enabled and fostered by remote diagnostics systems. To this end, we have analyzed whether new practices associated with remote diagnostics have created distributed forms of maintenance work with new organizational boundaries, and if the remote diagnostics systems have generated new forms of boundary-spanning in these arrangements. The investigation began with a basic premise that information technology is a critical enabler and constraint of boundary-spanning (Clemons & Row, 1993; Hayes, 2001; Levina & Vaast, 2006). While the issue of how material features of IT affect social practices has been a long-standing challenge in IS research (Leonardi & Barley, 2008), little attention has been paid to how the material features of IT affect boundary-spanning. In the boundary-spanning literature, IT is merely treated as a mediator facilitating the human boundary-spanners. Moreover, the IOS literature is limited to the study of organizational transactions systems, which differ from ubiquitous technologies like remote diagnostics systems.

Our study shows that with the use of remote diagnostics systems, boundary-spanning is no longer a mere social activity. The system is deeply intertwined in the boundary-spanning, as the sensors installed in the monitored equipment become the eyes and ears of the remote technicians. Together these two—the system and the technician—form a boundary-spanning socio-technical system. With the installed sensors, the information collection processes are so deeply, materially embedded that boundary-spanning cannot go on without the technology. However, in a similar way, the analysis competencies of the technicians are so intertwined with the monitoring process that their activities form a necessity for the boundary-spanning. This perspective differs from that of the existing research, which foremost views boundary-spanning as a human activity that can be supported by, but is not dependent on IT (e.g. Clemons & Row, 1993; Hayes, 2001; Levina & Vaast, 2006; Yan & Lewis, 1999). Remote diagnostics systems turn boundary-spanning from an activity mediated by IT to an IT-intense activity. In contrast to other forms of IT applications such as e-mail, the remote diagnostics systems do not merely transmit and store information; they also have the ability to produce and transform information that can be acquired by no other means. Such systems may not just change the work practices; “they often change the nature of the work itself” (Leonardi & Barley, 2008, p. 165). In the case of boundary-spanning and remote diagnostics systems, this

means that changes are profound and go beyond provisioning of additional means for the technicians to span boundaries.

First, the main object of work is changing for the remote technicians, as sensory information becomes their work material. Analysis competencies become more crucial than hands-on competencies like listening to the sound of the equipment. Moreover, the ability to interpret the signals from a sensor is now just as important as the competence of gaining information from the local technicians. Information transfer and boundary-spanning no longer solely rely upon human relationships. IT constitutes a crucial element, so that what it means to be a preventive maintenance technician and boundary-spanner has changed.

Second, boundary-spanning concerns collecting and making sense of peripheral information so as to expand an organization's local knowledge. Perceived changes in boundary-spanning will generate changes in the organization's knowledge management. The remote diagnostics system enables a new kind of data transfer, and "calculation" centers now emerge, where data can be collected from local and global contexts. Together, the technicians and the system can engage in knowledge creation that was not possible before. Knowledge can now be pulled out from data gained from many settings, without the need for physical travel. Moreover, data collection is now stable, systematic and disciplined instead of being dependent upon the local initiative and skill of each technician. A complex socio-technical organization emerges at the remote level, as data from a multiple external settings flow to the remote centers where they merge and create new product and analysis knowledge.

Finally, the remote diagnostics system also changes how the boundaries are defined. Boundaries are no longer defined based merely on physical means like access to a local setting and personal relationships. Rather, in ubiquitous computing, it is data instrumentation, rate and quality of flow, accessibility and analytics that shape the boundary setting. Those who can define access to data gain new boundary-spanning capabilities as they assimilate new type of knowledge. However, those who are excluded experience reinforced boundaries. Taken together, the data flow and computer environment change the foundations upon which boundaries of knowing and acting are drawn.

Looking at diverse ways in which local knowledge is collected, shared, analyzed and distributed, one could argue that the boundaries for cognitively sensing the world of the machines are now significantly expanded. Due to machine design and safety regulations, it is impossible

for humans to inspect the machines the way machines do. As a result, the sensors expand human sensing: they can monitor things that humans cannot and do this work in places where humans cannot go. Our case thus illustrates how social competencies become materially entangled, to use Woolgar's, (2002, p. 265) term. That is, human competence gets inextricably entangled with materiality as we conceive remote diagnostics as socio-technical objects. Maintenance work is now an increasingly complex socio-technical activity that fundamentally rests on the materiality of the technology. In particular, our study shows how the material and social become entangled in new forms of boundary-spanning as technology's material features in the end both enable and constrain boundary-spanning. Our case illustrates also how on one hand sensors expand human sensing, and how on the other hand technicians' competencies become pervasively entangled with the new materiality. As the entanglement deepens understanding material features becomes more important in understanding the work process.

As the use of IT changes the premises of how boundaries are defined, the traditional view of boundary-spanning as a purely social activity (Leifer & Delbecq, 1978) meant to serve as a link between the organization and its environment (Aldrich & Herker, 1977) needs to be questioned. Current research raises the pivotal issue of how IT serves as an enhanced mediator of increased boundary-spanning (e.g. Hayes, 2001; Yan & Lewis, 1999). Our analysis narrates a bolder story: contemporary IT infrastructures evolving towards ubiquitous computing environments will stretch the role of IT beyond that of mere mediator. Boundary-spanning activity has turned into a complex socio-technical activity where social and technical resources are inherently intertwined. These environments can automatically collect and analyze data, and by doing so, they expand the scope of the human senses and become active boundary-spanners. Boundary-spanning activity is no longer a social activity dependent upon whom you know and what you talk about. Rather it becomes crucial to have access to the data and knowledge of how to interpret and use it. IT thereby adds the dimensions of connectivity and competencies involved with making efficient use of digital information. As this paper indicates, these new socio-technical ensembles will re-shape organizational boundaries in both expected and unexpected ways.

7. Conclusions

We have described the impact of the use of remote diagnostics systems in maintenance with the aim of highlighting their impact on boundary-

spanning. Our contribution is twofold. First, we show not only how the remote diagnostics system has spanned existing boundaries, but also how it has reinforced existing boundaries and created new ones. These processes have re-shaped the boundaries and practices in the daily work of maintenance technicians. Second, the remote diagnostics system generates changes in the nature of boundary-spanning. Boundary-spanning is no longer an IT-mediated social activity; rather, it has turned into a socio-technical activity that rests on the materiality of the technology. This study is limited in that it presents only a single case study across four organizations and thus also only a partial view of boundary-spanning practices. So, additional studies are needed. Our findings underscore the need for more extensive research into the realm of technology-enabled (and not only mediated) boundary-spanning. The differences between forms of boundary-spanning and different types of IT capabilities need to be explored further. A deepened understanding of both technology-free and technology-based boundary-spanning will give us more detailed knowledge of the role of technology. The approach to boundary-spanning presented here needs to be further extended, and in the future, the garnered insights need to be validated by addressing a broader range of IT infrastructures. The processes of boundary-spanning should be generalized and validated in other industries where IT innovation has become a central locus for boundary-spanning.

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