The Integration of Computing and Routine Work

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Most computing serves as a resource or tool to support other work: performing complex analyses for engineering projects, preparing documents, or sending electronic mail using office automation equipment, etc. To improve the character, quality, and ease of computing work, we must understand how automated systems actually are integrated into the work they support. How do people actually adapt to computing as a resource? How do they deal with the unreliability in hardware, software, or operations; data inaccuracy; system changes; poor documentation; inappropriate designs; etc.; which are present in almost every computing milieu, even where computing is widely used and considered highly successful? This paper presents some results of a detailed empirical study of routine computer use in several organizations. We present a theoretical account of computing work and use it to explain a number of observed phenomena, such as:

—How people knowingly use "false" data to obtain desired analytical results by tricking their systems.
—How organizations come to rely upon complex, critical computer systems despite significant, recurrent, known errors and inaccurate data.
—How people work around inadequate computing systems by using manual or duplicate systems, rather than changing their systems via maintenance or enhancement.

In addition, the framework for analyzing computing and routine work presented here proves useful for representing and reasoning about activity in multiactor systems in general, and in understanding how better to integrate organizations of people and computers in which work is coordinated.

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1. INTRODUCTION

This paper addresses three focal questions:

—What is the character of computer use for the mainstream user?

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—What makes it like it is?
—How do people in complex organizations integrate computing into their work on a routine basis?

Most studies of computing use question the problematic aspects of computing (e.g., "Why do errors (or some other problems) *exist* in computer systems and what can we do to eliminate them?") or try to demonstrate the advantages of new technologies. In this study, we have taken a different tack. We focus on the long-term, routine use of computing in organizations. Instead of studying how to eliminate problems or characterize advantages, we are attempting to describe and explain the dynamics of computer use over time. This leads us to focus on how circumstances *persist and evolve*, rather than why they exist in the first place. Some problems with computing *persist* over time, while others are easily and quickly eliminated. Why? For some users, *high-quality computing* persists over time, while for others, data accuracy, DP service, or some other aspect of computing repeatedly *degrades* as time goes by. Why?

We approached these questions by studying the individual and small-group-level interactions that drive computing in specific organizations. We sought to understand the low-level dynamics of computing use and how computing fit into the work ecology within the organizations we studied, rather than developing broad but less qualitatively particular generalizations. As it turned out, this detailed focus led us to findings that sometimes contradict the assumptions of those who overlook or assume away the importance of the microlevel social dynamics of computing (e.g., [20]). (In this respect, this research is similar to Kusterer's studies of manufacturing work[1] [26].) We discovered a fluid world where users try to sustain control over scarce resources, changing work demands, and evolving technologies. Existing treatments of computing work rarely account for episodes like the following:

—Engineering analysts working in WESCO, a large firm which designed and constructed chemical plants, learned which analyses could go wrong in the package of complex analytical programs they used, and how to correct for untenable results. For example, they routinely input temperature coefficients for pipes carrying hot fluids as though the pipes were intended to operate cold, causing the analysis program to disregard certain heating stress calculations. Over years of experience with this program, the engineers had learned that entering the "correct" information would lead to erroneous results and the pipes would not work properly in the final design. They worked around the technical problems of the program by "running the hot pipes cold" when using it [008-031-A][2].

[1] Kusterer found that "unskilled" or "semiskilled" workers (e.g., operators of machines making paper cones for cotton candy) brought surprisingly intricate and detailed knowledge and management skills to bear in their work. There were numerous low-level contingencies and variable conditions impacting the work (e.g., variable wetness of the raw paper for cones). Since workers worked at piece rates, their effectiveness at managing these contingencies helped them earn more and work more easily.
[2] Interview code numbers represent the organization, respondent, and number of the interview in which quoted data were gathered. See [12] for details.

We are interested in (1) how routine computing work tasks—producing reports, generating data, programs, and analyses, fixing bugs, etc.—come about; (2) how the actual work of producing computer-based information and analyses takes place, treating the very existence of some organized process for the production of computing as the central research issue and (3) how this process works and sustains itself.

Our contributions are two: First, this paper develops and demonstrates the usefulness of several theoretical concepts, namely, *task chains, production lattices*, and the concept of the *work situation.* Task chains and production lattices have already appeared in the work of Kling and Scacchi [25], though in a much less developed form. The concept of work situation is an outgrowth of the work of Lofland on social situations [27], Strauss on negotiation contexts [36], and Gerson [15, 16].

Second, this research exposes some of the microlevel processes that integrate computing into work and sustain the operation of computing over the long term in organizations. These basic processes, which we term *Fitting, Augmenting*, and *Working Around computing*, serve to take up the slip between the static or slowly changing, fairly rigid work procedures associated with computing, and the fluid, rapidly evolving, contingent demands of daily work which computing supports. The ease or difficulty of fitting, augmenting, or working around computing in given circumstances makes computing easier or more difficult to use. Understanding these dynamics allows us to better integrate computing by giving us theoretical bases for when and how to freeze work routines (perhaps in a new technology), and when to allow for the flexible adaptation of ad-hoc, perhaps manual, operations.

2. METHODOLOGY

The findings presented here are based on data that were gathered during field research in ten organizations. These comprised six manufacturing firms, a land management firm, an academic and administrative computing center serving three community colleges, a multinational engineering firm, and one university research organization. The most intensive investigations were conducted in two manufacturing organizations, which we shall call PRINTCO and LA COSTA ELECTRONICS.[3] Data from these case studies will be reported here anecdotally as needed to illustrate and support our findings. Data from the case studies are reported systematically and in detail in [12].

In LA COSTA, PRINTCO, and three other manufacturing firms studied, we investigated the use of manufacturing computing systems built around a core called a *material requirements planning* (MRP) system [32, 40]. An MRP system is a complex, demand-driven inventory control system. MRP systems typically integrate the work of 2 to 30 departments, and embody significant programming and processing complexity. Typical full MRP executions take 8 to 16 hours of elapsed time on a dedicated IBM minicomputer.

[3] These names are pseudonyms, used to assure the confidentiality of the respondents and their organizations.

We collected three types of data. Our primary data were collected during intensive, directed, unstructured interviews, which lasted from 1 to 3 hours. We interviewed a total of 59 respondents in the two major organizations. In addition, we collected several types of documentary data in each firm. Last, we directly observed the operations of each firm by attending meetings and via informal guided plant tours.

3. THEORETICAL PERSPECTIVE

In order to analyze the integration of computing into routine work, we need a framework for approaching it. The framework presented here is drawn from the Symbolic Interactionist tradition of sociology, especially the work of Strauss, Becker, Gerson, and others, augmented by our own insights, developed through this empirical study.

The focus of this research is upon computing as it is used in real work settings. This requires a definition of "computing use." We define computing use to be any employment of computer-based information or analyses in the performance of other tasks. Thus, computer use presumes the existence of other work—namely, the *primary work* of the computer "user." A materials analyst, for example, tries to schedule materials for manufacturing and uses a computer-based MRP report. The report is a resource for the analyst, but his or her primary work is to handle problems in the scheduling of materials—not to use a computer-based report per se.

A computer specialist is a special type of computer user. The specialist, too, employs computing in the service of his or her primary work. A PRINTCO systems programmer, for example, who is trying to build a new software component, uses the RPGII compiler as a resource for the development work. The programmer is not running the compiler for the pleasure of doing it. The primary work of *developing a report module* (which entails many other tasks as well) is intertwined with other computing work: running the compiler.

On the basis of this definition, the use of computing is embedded in a context of many other tasks. Computing itself is usually a resource which supports the other tasks. It is difficult to imagine (or to locate in an organization) uses of computing which exist for their own sake. (Computer games may be an important exception.) In most cases it is fair to say that at least a component of most computing is a rational attempt to employ computing as a resource for action.

3.1 Assumptions about Organizations

Our theoretical perspective rests upon several basic assumptions about the nature of organizations, borne out in our observations of organizational behavior.

First, all organizations have some limits to the resources they can bring to bear on particular needs (e.g., finite dollars). This means that people in organizations need to make decisions about how to allocate resources, which may produce conflict.

Second, actors in organizations have bounds to their rationality [30]. It is impossible to consider all possible alternatives in carrying out a given decision-making or production process because resources are limited, not infinite.

Third, knowledge in organizations is distributed unevenly. This is partly a result of variations in skills, and partly, again, a result of the limitations on the resources of any individual actor or group.

Fourth, meaning is created through the interactions among people and groups, and during the process of performing work. The meaning of events and artifacts is not static or constant across participants or groups.

These assumptions about organizations have important implications for understanding action in organizations. Taken together, they led us to assume that conflict almost certainly will exist. In the words of Crozier and Friedberg,

> Organizations are . . . developed . . . by man to solve problems of collective action, and above all the most basic of these—cooperation for the production of some collective good by relatively autonomous social actors pursuing diverse and always, in a certain sense, conflicting interests. [6]

Thus some of the activity in organizations must be addressed to preventing and ironing out destructive conflict.

3.2 The Work Situation

Computing work in a complex organization comprises a highly interlocked and coordinated system of tasks. The most basic unit of analysis we wish to consider is therefore the work *task*. A task presumes some *agenda*—that is, some program for what the task is supposed to accomplish. Each work task requires *resources*, which may take several different forms, including information, time, attention, budget, computing cycles, skilled support staff, particular technologies, and so on. Each work task is carried out by some *person or group*—which executes the task. Each person or group executing a particular task brings to it a set of orientations and values, which impinge upon the task performance. These include the persons' skills, their beliefs, other commitments they have, the power they wield, the accountability they bear for the outcomes of their work, the discretion they have over their work [28], and the important social meanings of actions and objects in their work. Finally, each work task takes place *over time*, and happens in some *place*. Work is a process, not just an event, and so it has a temporal organization. Some work occurs cyclically, while other work is unique in form and function. The physical location where work occurs, the arrangement of work apparatus, the proximity of colleagues, the "working conditions" (e.g., lighting, noise, amenities) all conspire to influence the particular character of work tasks [1, 31].

3.3 Task Chains, Lines of Work, and Production Lattices

Each task, considered alone, has a place in the larger system of tasks, and has some connections and relationships with other tasks. Each task is part of the *division of labor* in the organization. The particular organization of tasks *is* the division of labor of computing work in the organization at a given time.

Some aspects of the division of labor are relatively static over long periods of time—the same people do about the same things over and over again. They can be expected to do so, and indeed, the coordination and functioning of the organization require such stability [39]. This is another way of saying that coordination of activities requires the *commitment* to a certain character and organization of work tasks [2, 15, 37]. Work organizations can be seen as a complex structure of organized commitments, which serve to coordinate tasks [11]. Thus the degree of certainty of commitments influences how smoothly the entire task structure functions. If task commitments break down, additional work must ensue to reinstate them or to accommodate the new arrangements.

Ordinarily, complex artifacts are produced by many people doing numerous things. If we organize our view of work along a particular axis in this vast array of tasks, we can pick out a sequential *chain* of tasks, called a *task chain*, which describes the production sequence for an object or event. For example, in producing this report I am using a text processor. The chain of tasks for producing this report includes

(1) having an active computer account,
(2) getting access to the computer (e.g., finding an unoccupied, working terminal),
(3) possibly dialing in on telephone lines,
(4) logging on to the computer,
(5) typing the document,
(6) running the document through SCRIBE (a text formatting program),
(7) getting the formatted document printed (usually on a laser printer),
(8) distributing the document to my readers.

With the report itself as the axis of analysis, the task chain is clear. Of course, several steps in this chain may be executed repeatedly. Thus the *actual* task chain is different in each case from the simple abstract task chain represented here, and in general will be different each time in some respect. *In any particular instance, the precise structure of the task chain is unpredictable, because it depends upon the contingencies of the work process, including intersecting task chains.*

Many resources and other activities of other people are taken for granted in this formulation. For example, someone maintains the computer I use, and I depend upon this maintenance. "Getting the report printed" probably means that the operators will reload the laser printer with special paper; this is a part of their job, and I assume that it gets done when I issue a print request. Viewed from the axis of the work done by the computer operator, printing my report was just *one task* in a long series of activities he carried out. His own task chain occupied his time and his efforts. Thus, task chains *intersect* and must be coordinated for the production of work. A complex, coordinated structure of intersecting task chains we call a *production lattice.*

Like the individual task chains which comprise it, each production lattice has some sections or elements of its basic structure that are stable and routine; this is what gives organizational work and production its stability.

We now distinguish among several types of work found in the production lattice in computer-using organizations: primary work, articulation work, and computing work. *Primary work* directly addresses the specific agendas of the work situation. For example, the primary work of a programmer may be developing a report-generation module for the MRP system. As contingencies of primary work change, pressure is exerted upon the production lattice.

Commitments may go unfulfilled, necessitating some reorganization of work to meet the principal agendas of the work situation. The reorganization of the commitments that stabilize the production lattice *is itself work* and is a special part of maintaining the production lattice. Similarly, when conflicting forces exist, some trying to change the production lattice while others press to keep it stable, *work is required to iron out the conflict.* These two types of work, the work of reorganization and maintenance, are the *articulation work* of the production lattice. Articulation work serves to establish, maintain, or break the coordinated intersection of task chains, and is found in all organized social settings [3, 12, 37].

It should be clear that the distinction between primary and articulation work in a given setting rests partly upon the needs of the researcher. Work that articulates the intersection of task chains is the primary work of some actors (e.g., managers). Thus we can envision the production lattice as a cascaded network of primary and articulation work (e.g., managerial articulation work may require its own articulation work, such as ironing out disputes among managers).

Orthogonal to these dimensions is the notion of *computing work.* Computing work comprises any activities that are part of the task chains that produce computing, or activities in which computing or computer-based information is employed as a resource. For some actors, notably computer specialists, computing work is primary work. For others, working with computing may be articulation work, necessary to keep some primary work going smoothly. We must distinguish computing work from noncomputing work to emphasize the supportive role of computing work in other work, and to explain how similar supporting functions are often carried out by means that do not involve computing when the need arises.

In summary, we describe the work in an organization that uses computing as a collection of interlocked and coordinated tasks. Tasks may involve primary or articulation work, and both types of work may or may not involve computing. Each of these tasks takes place in a context, and we term the task along with its context the *work situation.* Following Gerson [16] we note that, over time, task chains are organized into lines of work ("all the activities needed to address a particular problem in a particular style"). For purposes of analysis, we conceive the structure of tasks in a line of work as a production lattice for the line of work.

Each person has a variety of roles to play, each role involving a different line of work. He may be father, materials analyst, union representative, and organizer of the departmental softball team. Each of these roles may demand his attention and activity in the course of his work. Thus each person has a number of distinct lines of work he is pursuing simultaneously, in general, and the interaction among these intrapersonal lines of work may be analyzed using the framework presented here.

4. COORDINATION ACTIVITIES

Computing activity is coordinated through numerous commitments among actors to carry out task chains that deliver products of a particular type, in a particular time, for a particular cost. But the performance of each task, and thus the fulfillment of individual commitments, is contingent upon the organization of the work of numerous other actors (the production lattice). Each task in a production lattice is shaped by the arrangement of the work situation in which it occurs. Thus the orderly flow of work depends upon the consistent *alignment* of resources and commitments in the workplace.

The resources obtaining in each work situation may be misaligned with the demands of work in three ways: They may be oversupplied, undersupplied, or qualitatively misaligned. We assess misalignment with relation to both (1) the resource *requirements* of the task, and (2) the *conventions*[4] under which key participants expect that task to be performed. When resources are oversupplied, we say there is *slack* in the resource supply. Slack may become problematic either by moral definition (e.g., "waste is bad"), or because it means demands upon time and attention (see, e.g., [8]).

Resource *slip* is the undersupply or qualitative misalignment of resources needed or expected for carrying out a task. Slip may occur in any resource dimensions in the work situation, such as when there is too little time, technology, budget, attention, etc., or when the quality of resources is inappropriate, such as when data representations do not precisely reflect shop conditions.

When slip or slack occurs in the computing resource which is supporting some primary work, we can say that computing is *misfit* to the work it is intended to support. Misfit may be the result of some planned change in the work situation, as when work has been reorganized and the required computing resources have not been implemented, or the early implementation bugs have not been "shaken down." This was the case in LA COSTA when data-entry tasks were shifted from DP to other departments (such as Engineering) that provided data. Data accuracy in computer-based reports such as bill-of-materials reports degraded until people with new data-entry responsibility were trained and gained experience.

The fit of computing is a *negotiated* dimension of the work setting; there is no perfect alignment between computing and work processes. In each case, computing is judged to be socially acceptable or unacceptable according to the demands and contingencies of the work situation, including the ability to perform the articulation work required (cf. [3]). It may change over time and be redefined as the work situation evolves. Thus it is never possible to completely align computing with a work setting, once and for all, because the work setting will change in unforeseen but important ways. This means that the work of sustaining the fit of computing is ongoing, not static.

4.1 The Ubiquity of Anomaly

Work is a contingent process [2, 6, 7, 10, 26, 33, 38]. In general, it is impossible to predict the entire range of contingencies that people will face in daily work. However, not all activities face the same degree or types of uncertainty [38]. Although there is a great deal of literature concerning how organizations adapt to uncertainty, there is much less which focuses on the contingencies faced by individuals in their work, and the strategies they have created for addressing them. Examples can be found in [4], [5], [19], [26], [33], and [37]. However, none of these addresses the contingencies of computing work, and thus it has been unclear how computing work is managed day-to-day by those involved in it.

[4] The notion of performing work under a structure of *conventions* is taken from [2].

Although people who use computing face numerous types of contingencies in their daily work, here we shall focus primarily on the contingencies that involve the use of computer-based information. In particular, since we have defined computer use to be the employment of computer-based information in the accomplishment of other primary work, we shall focus upon the contingencies of computing work that affect the work it supports. This is the import and meaning of computing work, in the final analysis.

What types of contingencies do people face? Since work consists of organized commitments and expectations (assumptions) about how they will be carried out, important contingencies of the computing workplace are the disruptions in commitments and expectations which involve computing. Any *unmet agenda* has the potential to cause disruption, because it leaves a commitment unfulfilled and work elsewhere in the production lattice may be affected. The wider the proliferation of effects from the unfulfilled commitment through the production lattice, the more serious the disruption. Similarly, any *change in the attributes of the work situation* has the potential to cause disruption, as it may require the shift of commitments and expectations because of added constraints or increased opportunities.

Contingencies arise because the organizational settings of computing work are *open systems* [18]—systems in which all possible behaviors are not inherent in system descriptions. Planning using automated systems (a prime goal of MRP and many other computer-based information systems) will not eliminate all contingencies. Moreover, even planned solutions require negotiations over resource commitments, sometimes under conflicting demands. Once established, particular resource allocations may not fit emerging contingencies, and reallocation must occur. For example, Bob Elliot reported:

> You don't have the key caps for the production you need for all next month for the keyboards. What are you going to do if you don't have key caps? You can't deliver them if you don't have key caps. That's not saying you didn't plan well. The vendor's machine broke down, or he's moving his plant to Mexico. All the planning worked perfect but the parts aren't there—now what do you do? All the solutions mean increasing your inventory, and that's what you try not to do [027-002-A].

Computer-based planning performed as designed, but the world did not comply. Existing, planned MRP reports are only partially useful here in scheduling production, as they do not reflect the actual shop conditions. In order to proceed with work and reintegrate MRP reports into the process, reports will need to be updated to reflect new conditions, and other work adjustment (e.g., expediting, schedule shifting) will need to be done.

Overall, we found that computing slip was ubiquitous in the organizations studied. Every respondent in our sample reported *some* incidents of slip. Examples of the kinds of misfit reported to us include:

—*Inaccurate data.* Shortage reports are only 50 percent accurate at LA COSTA.
—*Late reports.* The materials planning department at LA COSTA had difficulty getting several reports on time. In addition, while reports may be timely, data in those reports may be out-of-date.
—*Reports produced too seldom or too frequently.* A production foreman at LA COSTA reported that the main disadvantage he faced was that the MRP

was only run on Wednesdays. "They only order on it one day a week. If you're out of something, you wait another week. The delay time throws you too far behind" [027-011-A].

—*Technical inadequacies in the MRP system.* The MRP systems at both LA COSTA and PRINTCO could not handle multiple bills of material or product "revision levels."

—*Inadequate computing resources.* Both users and computer specialists at LA COSTA faced long delays, poor turnaround time, and restrictions on running jobs because of computing resource constraints.

—*Response to software maintenance requests too slow.* Sales Department personnel at LA COSTA reported that they no longer requested new or revised reports because they could not get a response from the DP department.

—*Lack of expertise in the DP department.* Two successive DP managers at PRINTCO were charged with managing conversion projects for which they did not have the expertise or experience.

—*Bad MRP explosions.* Participants at both LA COSTA and PRINTCO encountered bad MRP explosions caused by inaccurate input data, poorly written operations procedures, etc. This meant late or nonexistent reports and rescheduling or postponement of other jobs competing for computing resources.

—*System response time too slow.* Users in LA COSTA reported waits of up to 10 minutes for system response during on-line terminal use, which they regarded as impeding the progress of their work.

Of course, not all slip is critical or even problematic for the organization or the individual. But each form of slip does entail some readjustment of work to accommodate it. We shall turn our attention to the variety of strategies people have adopted to deal with computing slip, and discuss the process of applying those strategies, and their implications. In this way we expose the full range of work that goes on in making use of computing, and lay the groundwork for later assessments of the actual effects upon such topics as the costs and benefits of computing and productivity measures.

We have unearthed and classified three strategies for accommodation to computing slip: fitting, augmenting, and working around. The following sections define and discuss each of these in turn.

4.2 Fitting

Fitting work is the activity of changing computing or changing the structure of work to accommodate for computing misfit. Several types of fitting work have appeared in our data.

Making Changes to Computing Arrangements. Fitting work may consist of planned changes in computing, or ad-hoc readjustments to accommodate short- or long-term misalignment. We unearthed numerous examples of fitting work at LA COSTA. For example:

> Participants at LA COSTA kept track of multiple revisions to the bills of material by implementing the WSOU scheme. But this created confusion among customers who received replacement parts they did not

expect. A second programming change was made: If "Replaced By" was found in the description, the computer looked up the replacement part number and inserted it in the invoice.

Adjusting Work Schedules and Commitments. When slip occurs, people adjust the routines of their work, and shift commitments made to others, to accommodate the anomalies or misfit. For example:

> The LA COSTA DP manager, Carol Lynch, instructed the data-entry personnel to avoid entering job tickets during certain periods, though entering job ticket information was a high priority. She did this to avoid interfering with manufacturing personnel who were trying to enter job tracking information on a heavily loaded system.

Fitting work is often done in concert with others, and sometimes requires elaborate justification. Decisions about what changes are "justified" are grounded in the ecology of power relations in LA COSTA. The types of fitting work that occur are not random, but a function of complex negotiations between those who control resources and those who face anomalies and misfit.

4.3 Augmenting

Augmenting work is undertaking additional work to make up for misfit. In relation to our theoretical discussion of work, augmentation is adding additional tasks to a task chain, complicating the production lattice, and at least potentially increasing the need for articulation work. We have discovered several types of augmentation work.

Verifying and Revising Data. When errors or other anomalies are expected or frequently experienced, additional work of verifying and revising data is important adaptation work. This is especially true as the consequences of errors rise, as they did at LA COSTA for military jobs with delivery delay penalties. Examples of these activities include the following:

> Errors in purchase requisitions were caused by highly volatile production scheduling and many product revisions. In response, one materials analyst spent more than half her time verifying all purchase requisitions and fixing mistakes.

Assessing Causes and Effects of Anomalies or Misfit. For significant errors, people must do the work to track down the causes and mitigate the consequences. We gathered data on several such episodes, for example:

> In one case, it took LA COSTA personnel three weeks to track down and eliminate the problems caused by a change in labor accounting programs. In the interim, a cost accountant had reportedly "gone bonkers" trying to accomplish his work which depended upon these programs [027-001-D].

Consolidating Data Sources. Some respondents reported that they combined data from several sources to understand MRP-related conditions. The multiple sources may include other computer-based reports, other people, manual reports, or visual inspection of conditions. For example:

> Pam Warner, the materials analyst, used several reports in concert to verify purchasing requisitions: the generation requirements report and the shortage followup report.

Training. Many respondents at LA COSTA reported that, when new personnel arrived, data accuracy plummeted, and mistakes were found on reports and in the ways reports were used. Training was a way of handling this sort of anomaly and reducing its occurrence.

Archiving Programs. When storage capacity must be conserved, one approach is archiving. Archiving programs or data takes work and is a potential source of error. To reuse those files or programs, users, operators, or programmers expend additional effort to restore them to working order. Both archiving and restoring programs lengthened the task chains of computing production at LA COSTA. For example:

> Both the DP manager and the VP of finance coped with the undersupply of disk capacity by archiving files and moving infrequently used programs around on the existing disks. Moving programs and data was necessary, reported the DP manager, because otherwise, "we'd be handicapped, we'd be stopped every night" [027-018-B].

4.4 Working Around

Working around is a third strategy for accommodating to misfit. Working around means intentionally using computing in ways for which it was not designed or avoiding its use and relying on an alternative means of accomplishing work.

Advocates of the formal automated, MRP systems we studied did not like workarounds—especially *manual* workarounds. Workarounds are typically adhoc strategies to solve immediate and pressing problems. They often conflict with the formal ideology of system use. Workarounds we have discovered take three forms: data adjustment, procedural adjustment, and backup systems.

Data Adjustment. In several cases we have found participants "gaming" their computer systems by entering data that they knew were "inaccurate" or that did not reflect the spirit of the input data expected by the programs. They did this in order to get desired, usable, and in an important sense, "accurate" results. For example:

> LA COSTA materials analysts sometimes entered "bogus" lead times for military jobs, because of the high penalty for delayed production [027-021-A].

> The production manager and his staff at PRINTCO made up a "phony" composite bill of materials each week as input for the MRP run, because PRINTCO's MRP system could not handle multiple bills of material. The design changes in PRINTCO's products came frequently enough that, without the manual bill of materials, the MRP output data would have been unusable.

Procedural Adjustment. Another way of working around formal computing arrangements is to reverse organizational procedures for getting service or making changes. The ability to work around established procedures depends upon having the power to create and exploit flexibility in work routines, a close working knowledge of the procedures and the particular division of labor in the organization (one must know whom to trust and whom to ask for favors and speedups) and having the access to key actors who can do the work one needs in the way one needs it done. Our examples of reversed procedures include:

> Service Department personnel often worked around the delay in computerized ordering procedures by going straight to the purchasing manager and having him handwrite a requisition. The requisition was entered into the computer *after* the order had been placed, and served to track the order.

The ability to work around the MRP system often requires substantial knowledge and experience with the organization of work at LA COSTA, and how parts are procured, received, entered into MRP, and stored. Working around the formal system depends upon great skill *with* the formal system (cf. WESCO engineers in Section 1).

Backup Systems. A third type of workaround is the use of alternative or backup systems, manual or automated. Alternative systems have been reported by Dery [8], Kling [21], and Malvey [29], among others. Some backup systems are manual, involving duplicate records, additional data not kept in the computer system, notes on computer-based reports, etc. Other alternative systems are automated—users buy time on outside service bureaus, or buy their own microcomputers for their own analyses. Examples include:

> In the absence of a system to handle multiple bills of material and the changeover from one to the next, LA COSTA personnel implemented a complex manual notation system on their MRP BOM reports: the WSOU scheme. The WSOU notation cued analysts to manually change the MRP part numbers when current stock of an obsolete part ran out.

4.5 The Role of Adaptation

These three types of adaptation work, Fitting, Augmenting, and Working Around, account for numerous small but crucial details of problem solving and action related to computing. Fitting, Augmenting, and Working Around were not necessarily gross phenomena in all of the computer-using organizations we have studied. But every respondent in our studies reported facing some anomaly and performing some adaptive work.

In many cases, Fitting, Augmenting, and Working Around are so important to the integration of computing that, without them, computing services and performance would degrade very rapidly, at significant organizational cost. If Pam Warner did not verify data in the MRP system, data errors would have proliferated rapidly, MRP reports and purchase requisitions would have been inaccurate, the plant could have become loaded with unusable inventory, and many needed parts would have been short, impeding production. The potential organizational costs for *not* being able to adapt flexibly to numerous work contingencies are large. Thus Fitting, Augmenting, and Working Around are central to integrating computing into work.

4.6 Adaptation as Organized Work

To use computing, people must cope with the misfit they encounter, and still accomplish their primary work as best they can. They may apply several of the above strategies (Fitting, Augmenting, or Working Around) at various times. Each of these strategies takes work, and thus may be conceptualized under our theoretical notions of work: task chains, production lattices, and lines of work. Each time an actor works around a particular inappropriate computing arrangement or problem, he or she is creating and executing tasks in a task chain, and most likely these tasks intersect with the work of others, embedding his or her work in a production lattice. The ease or difficulty of fitting, augmenting, or working around computing is linked to the execution of the task chains comprising that work. Accommodation work is like any other work in this respect. Over time, it may comprise both primary and articulation work as well. We may examine several examples from the LA COSTA case which illustrate how adaptation work depends upon the coordination and intersection of tasks in production lattices.

Fitting: Making Changes to Computing. The sales administrator, Babs Turner, needed a change to a freight number on invoices. She could not do the programming herself, nor did she have access to the computing resources she would have needed. Instead, she sent a memo to the VP of finance, detailing the request and asking for the computing change. There was no response, and she next went to her supervisor, Bill Blake. He negotiated with the VP of finance, who finally agreed to the change, which was implemented by the DP manager. The action of making this two-digit change involved four people over three months' time. In this case, the coordination of the fitting work was difficult to achieve; she had to wait 3 months and make two attempts. Final negotiations over the work took place between her supervisor and the VP of finance. The outcome of the negotiations affected her work, but it was carried out by others, upon whom she depended.

Augmenting: Verifying Purchase Requisitions. At LA COSTA, Pam Warner, the materials analyst, spent much of her time verifying purchase requisitions which were generated by the MRP system. Some purchase requisitions were incorrect because of changing requirements due to engineering changes or schedule changes. The engineering changes and schedule changes were the products of the work of others. Thus the specific content of the verification work she did was shaped by the work of others; her task chains intersected theirs.

Warner consolidated data from a number of reports, in order to verify requisitions. Some supplementary data for verification work came from the shortage followup report and the generation requirements report. Thus Warner's verification work depended on the production of these two reports. She reported that 98 percent of the time she knew when to expect something odd, because others have notified her. Someone in the Engineering Department may have called her with notification of a part number change, or a planner may have changed a purchasing lead time. Thus, the knowledge gained by others at LA COSTA, communicated through the action of a phone call or visit, supported her verification work.

When Pam Warner went to the Receiving Department to check the validity of orders, she depended on the fact that the Receiving Department retained the appropriate shipping documents, and could explain discrepancies. Thus her verification work, whether at her desk or out in the shop floor, relied on others doing their work. She needed to be coordinated with them.

Working Around: The WSOU Scheme. When the LA COSTA MRP could not handle multiple simultaneous bills of material with changeover dates, LA COSTA materials planners implemented the WSOU scheme. They added a remark to the component description field of the bill of materials. But the simple change meant that WSOU descriptions began to appear on customer invoices. DP personnel reprogrammed billing programs to recognize and accommodate the "WSOU" and "Replaced By" notations. Planners tracked the changeover dates manually, and did not place requisitions for out-of-date parts. They depended upon shared knowledge of the WSOU scheme, as well as the appropriate bills of materials, parts descriptions, and change reports from the Engineering Department. Finally, the planners received a weekly report on all parts that had changed over. Thus planners depended on the accurate production of the changeover report as well.

In the WSOU episode, the work of a wide variety of people intersected. Materials planners implemented manual workarounds and checks, customer liaison personnel reported invoice errors, DP personnel made computing changes, materials planners and others shared knowledge about the meaning of WSOU and educated others, etc. The WSOU scheme depended heavily on the coordinated work of many actors.

Other examples of coordinated adaptation work were plentiful in the LA COSTA case. From justifying computing changes to inventing manual backup systems such as hot lists, the work of adapting to misaligned computing is interlocked among many people.

4.7 Coordinating Work across Work Situations

Each computing work task takes place in a particular milieu. Above, we termed work in its context the work situation. Again, this is true of both primary work and computing work, as well as the Fitting, Augmenting, and Working Around that accommodate for computing misfit so that primary work may proceed. The task chains of accommodation work may traverse different work situations: For example, a software anomaly such as the appearance of WSOU notations on customer invoices may be discovered by a customer, reported to a customer liaison, repaired by a systems analyst or programmer, and verified by a materials analyst. Each of these people has other demands on his or her work, each has a particular mix of resources to use, a particular degree of responsibility and accountability for his or her portion of the work, etc. In other words, the work of each person in the production lattice for adaptation work is embedded in a

Table I. Analytical Dimensions of the Work Situation

- Work task: Action being performed
- Agenda: Program, goal, or intended outcome of the task
- Actors: Persons or groups performing the task, having
  Skills, Personal Agendas, Meanings, Sentiments, Attention
- Resources: Supporting resources with which the task is performed, including
  Information, Time, Attention, Budget, Computing cycles, Support staff, Special equipment
- Temporal organization of work
- Place and spatial organization
- Division of labor
- Power
- Discretion
- Accountability
- Actual products or outcomes

different work situation (see Table I). The coordination of work across different work situations is central to the accomplishment of work that accommodates to misfit, and keeps computing integrated into work. If the resources, agendas, and commitments of the respective work situations are not well aligned, adaptation work, like other work, becomes difficult or impossible.

When Babs Turner, the sales administrator in the Sales Department, requested a change to a two-digit freight number, she was making a request to the VP of finance. He worked in a different building, in a different department, and, most importantly, in a different work situation. His agendas and priorities did not match those of the sales administrator, and he did not act upon her request. Turner did not have the resources or access to control the change herself, and called upon her supervisor, who had greater power to negotiate. Changing a two-digit freight number required the work and negotiating effort of four people across three work situations, and took 3 months.

When participants face computing anomalies or misfit in their work, they choose what responses they can, given their work situation. How they adapt depends on how they are able to coordinate work around them given the available resources, agendas, skills, etc., of people in the work situations involved. Coordinating work across work situations can be difficult when the work situations are misaligned, with the result that adaptation work becomes more difficult to manage. When the pressure of primary work is great enough and people do not have the option of performing "legitimate" adaptations (e.g., software maintenance), they rely on locally effective alternatives—other types of Fitting, Augmenting, and Working Around—to keep computing integrated into their work, and to keep computing marginally usable.

5. CONCLUSIONS

5.1 The Nature of Computing in Complex Work Organizations

The mainstream, routine user of computing often faces numerous low-level problems. Kling and Scacchi were the first to point out the pervasive nature of such problems in [24]. Our study corroborates theirs. The nature and severity of these low-level problems vary with the nature of opportunities and contingencies faced in work, such as the relative temporal organization of work, the level of resources participants can draw upon to correct problems, and the relative organizational power they wield. In other words, the nature of recurrent computing problems that users face depends on how easily they can fit, augment, or work around computing, given the contingencies they face, the resources they control, and the place of their work in the production lattice of computing.

The fluid organization of work around computing, and especially the relationship between computing and the primary work of users, is the key factor shaping the character of computer use—not the technical design of a system, per se. Addressing computing problems or adapting computing to work contingencies using the strategies of Fitting, Augmenting, and Working Around depends on the organizational relationships among users, specialists, and key actors—how computing work is organized in a production lattice.

Substantively, we have shown how people manage to use systems that are technically inadequate. Computing remains useful and intelligible to staff through constant informal interaction and communication, and through continual work of maintaining accurate data and integrating computing by adjusting work routines. Here, we have helped to flesh out a portrait of computing activity, showing how the highly variable details of action, not formal structure or technical design, provide the glue that integrates computing into work. Existing formal models of computing and work are insufficient to explain the numerous and contingent adaptations that integrate computing into work. Instead, we need fluid conceptions of practical, adaptive work—people responding to the contingencies they face using the resources and strategies they have available at the time. Deterministic, structural accounts of computing activity are useful only at a gross level, as a first approximation of what goes on in routine computer use.

We begin to build a picture of computing integrated into work through the complex, coordinated action of people and groups in different work settings accommodating to the varying misfit of computing as the contingencies of their daily work evolve. This leads us to the insight that the ease or difficulty of integrating computing into work depends on the ease or difficulty of accommodating the misfits and taking up the slack between computing and the demands of particular work contingencies. This in turn is shaped by the coordination of work across work situations of varying character.

A corollary to this theory is that the reasons people choose a particular accommodation strategy depend upon how they are able to coordinate and balance the demands of their work with the resources they have. Locally, working around computing by using a manual system may provide greater leverage in primary work than going through the bother of getting a system changed. In another instance, calling a well-known programmer to make a quick format change in a report may provide an easier route than keeping an auxiliary manual log. In either case, the choice made and its outcome are situation specific and linked to the ecology of working relationships (the production lattice) in the organization at a particular time. Thus we cannot analyze a user's behavior in the face of computing slip without reference to the other participants in the production lattice for his or her computing work, their choices, and their actions. Accounts of computing that focus on the interaction between person and machine or on the abstract capabilities of the equipment miss the organizational interactions that shape the nature and quality of computing products routinely produced (cf. [23]).

These findings differ from those presented in much extant research literature. A fundamental assumption of design-oriented literature is that managers, designers, and system proponents define what are "rational" actions in dealing with a computing system—rational procedures for using a system, getting problems fixed, etc. From this viewpoint, workers in our study who worked around formal systems were "escaping" from the constraints of the system, and acting "irrationally" with respect to system goals and managers' expectations. But here we have discovered that, far from acting irrationally, the informal practical actions of participants actually make systems *more* usable locally. Informal fitting, augmenting, and working around are essential and locally rational parts of system use. Some local adaptations spread, and eventually become redefined as standard ways of using a system, rather than as adaptations. Appropriate and rational action is defined by the demands of the work situation and the institutional arrangements surrounding computing, not by the ideologies of managers or the presumed necessities of system structure.

Second, computing systems are not perfectible, technically or organizationally. With limited resources, resource allocations are not uniform or complete. Some groups have better access to resources, fewer problems, and greater control. The continuous evolution of work demands means that no complex technical system can be aligned with work for long. Organizational participants always negotiate *acceptable levels* of computing—data accuracy, timeliness, service, etc.—which are socially agreed upon, but not technically or formally perfect.

For many analysts, computing anomalies (errors, data inaccuracies, etc.) originate because of poor designs, inattention of users or support staff, or irrational actions of workers. In the view we present here, anomalies result from misalignment in the production lattice of computing, and from conflicts among locally rational actions. Even the definition of what constitutes anomalies is open to negotiation across work situations, making it difficult for some participants to recognize or respond to anomalies.

5.2 Designing, Maintaining, and Understanding Systems

This research has several implications for designers, implementors, and managers of systems. Although we need more research to identify the distribution and patterns of system workarounds and other articulation work, it is clear from our study that implementors and maintainers must focus attention on the institutional arrangements of system use in order to make systems more maintainable and to assure that implementation goals are met. Users find difficulties fixing problems when there is conflict between aspects of their own work situations and those of other people involved in repair. They institute workarounds as locally appropriate solutions to these problems. To address the systemic difficulties of implementation and maintenance, we need better to align the social contexts of the people involved so that their interests, agendas, and resources match. This means continually paying attention to the evolving ecology of working relations surrounding the system.

The costs and benefits of computing must be assessed in the light of the totality of computing-related work in the production lattice—not just the "legitimate," formal ideals of development and maintenance activities. Without ad-hoc and informal adaptation work, computing would break down in many settings—thus its cost is part of the cost of doing business with computing.

5.3 Extensions to This Research

We and others are extending this line of research in several ways. First, this research points to the need for new conceptions of work processes and decision making if we are to understand how to integrate computing in dynamic, multi-actor settings. Studies of technical work organization such as those reported in [3], [12], [16], [17], [22], [23], [34], and [37] provide a foundation for understanding work as a product of complex, historically grounded, negotiated agreements among participants. The bases and import of this negotiated-order view need further elaboration, but it is clear that a conception of computing work that focuses on the rational uses of computing and the formal structures of organization, and excludes the opportunistic and pragmatic local action of participants, is woefully incomplete.

Second, the knowledge of integrating and organizing processes gained in this study provides a basis for representing and reasoning about concerted action in multiactor systems in general. We are extending the notions of task chains, production lattices, and negotiations in open systems as a framework for representing and building multiagent intelligent systems [9, 13, 14, 35]. For example, we believe that the production lattice and work situation concepts provide a representational basis for a "cognitive map" of the terrain of events, processes, expectations, and commitments faced by an intelligent actor in organized interactions with others. Analytically and practically, we are pursuing a vision of computing integrated into organizations where both people and machines are members of a production lattice, each is embedded in a different work situation, each has models of other actors, each can negotiate resolutions to conflicts, and each can reason about the all-important "social terrain."

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