Enabling Participatory Design in a Hierarchical, Tightly Integrated Setting

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Can the participatory design model be useful in the context of a traditional "command and control" manufacturing firm that purchases large, complex software from outside vendors? This question is discussed using a case study of an American aerospace manufacturer and defense contractor. Three features of this context make rethinking participatory design essential: a hierarchical work organization unlikely to support open moves towards "industrial democracy", large computer systems bought from outside vendors, and the presence of many different user constituencies that must share a common system. Expanding participatory design to include issues of organizational context and resources usually neglected in the user participation literature opens up new possibilities and strategies for participation in the design of work with and around information systems.

Keywords: Organizational Context, Participatory Design and Use, Resources for Participation

Participatory Design in an "Impossible" Setting

To be widely useful in an American context, the participatory design model of systems development from Scandinavia will have to adapt to a variety of organizational and technical circumstances. In this essay, I try to explore what new strategies and concepts will be emphasized in these new contexts by using a case study of an almost "impossible" setting where one would think, at first, the participatory design model would be unlikely to succeed. By exploring the constraints on participatory design in this setting, and the concepts and strategies available to us, I hope to further the process of adapting the participatory design model to a wide range of contexts.

The case study of AIRTECH, an aerospace manufacturer, features three kinds of constraints that make the traditional model of participatory design difficult:

- A predominantly hierarchical work organization and work culture which does not have a history of supporting moves towards "industrial democracy" (and is non-unionized).
- Large, complex, and inflexible mainframe-based software systems that are purchased "off-the-shelf" from outside vendors.
- The presence of many different user constituencies that must share a common system.

To handle these kinds of constraints, we must reduce the conceptual boundary between design and use even further and conceive of a process of evolving participatory design and use. Participatory designers have recognized that the distinction between design and use is a "false dichotomy" (Floyd, 1992), but participatory design still carries an implicit image of participation in the early pre-implementation design stage. In situations with the constraints mentioned above, where participation in the early design is impractical, the most useful and effective places and times for worker involvement with the on-going design and use process will have to be chosen more carefully, on a case-by-case basis.

The "design" work involved in what is normally thought of as the adoption, implementation, and use stage should not be underestimated. Computerization is an on-going, dynamic process (Zmuidzinas et al, 1990). Recent research of ours suggests that, for white-collar work groups, the level of participation in the computerization process is one of the important factors separating groups that report the highest and lowest gains from computing (Whang et al, 1992). Participatory designers have tried to encourage "mutual learning" by involving users explicitly in the design process, and immersing designers the use process, but this

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may not be enough, or even possible, in certain contexts. We may have to change our emphasis to supporting participation in the systems that surround the software package—the reporting systems, the data gathering procedures, systems maintenance and infrastructure, and the surrounding organizational situation in which this work takes place.

At the previous participatory design conference, (Fischer et al, 1990) asked the provocative question: does participatory design only apply in the case of custom designed software? Even if specific software and hardware systems are bought "off-the-shelf" from outside vendors, the process of assembling the technologies and fitting them to existing organizational practice is never a mechanical process; it requires design work. Expanding our concern to include the process of participatory design and use opens up new participatory strategies.

In the next section, I present a framework that I have found useful for understanding the different kinds of user participation in system design and use in the MIS, software engineering, and participatory design literatures. This very brief review points to the relative neglect of contextual and resource issues that are so important in the case of AIRTECH. Then, I will discuss two episodes at AIRTECH which highlight the dilemmas of participation in contexts not usually considered as appropriate for participatory design.

A Simple Framework for Understanding User Participation

User participation, or involvement, in the system design process is a concept that has been around for a long time in the MIS (e.g., Ives and Olson, 1984), participatory design (e.g., Greenbaum and Kyng, 1991), and software engineering (e.g., Ould, 1990) literatures. These literatures can be very different in their basic assumptions and intentions—for example, the emphasis on improving acceptance and commitment in the MIS world vs. promoting workplace democracy in the participatory design world—but there is also quite a bit of overlap in their topics and advice. And particular user participation issues, such as who exactly should participate, are better developed in one body of literature than another, often suggesting that the issue may be important to the other bodies of literature as well.

After a very brief review of these literatures[1], I have come to the tentative conclusion that the essential issues of user participation can be summarized in a way understandable to both researchers and practitioners. Inspired by the general model of social action in (Burns and Flam, 1987), my framework for understanding user participation is summarized by the six questions listed in figure 1. Under each of the main questions are only a few examples of the specific participation issues and alternatives that fall under each main category.

- **Who participates and makes decisions?**
  Direct vs. Representative
- **Why, for what aims?**
  Promote satisfaction and commitment
  Provide arena for bargaining and conflict
  Improve requirements elicitation
- **What activities and techniques?**
  Concrete: specific tools and techniques
  Abstract: (in)voluntary, (in)formal
- **For what kind of problem?**
  Structured vs. unstructured
  Localized vs. extensive
- **With what resources?**
  Rewards for participating
- **In what context (when and where)?**
  In which stage of the development process?
  In what organizational climate?

Figure 1: Six User Participation Issues

The question of **who should participate** has been widely discussed, with differing opinions about whether the direct participation advocated by participatory design or representative participation should be used. Less discussed are practical issues of how many participants to include, and who to exclude if the system affects many groups. The issue of **why** users should participate is important because different theories of why participation works—for example, to restore a perception of control over the work environment—lead to different participation strategies. Many different suggestions have been put forth for specific participation **activities and techniques**, from software prototyping tools to unstructured observation techniques (e.g., Byrd et al, 1992). These activities can also be described more abstractly: formal vs. informal, for example, or voluntary vs. involuntary. The importance of **what kind of problem** the system is intended to solve is another factor often mentioned, whether the system is extremely technical and "complex" or not, or whether the scope of the problem includes many different people or just a few.

Less mentioned in general are the remaining two questions, the issues of context and resources. The question of **context** includes **when** and **where** participation takes place. The when usually refers to the stage in the development process, whether in the initial requirements, the

[1]Because of space limitations, and because my main goal is not to write another review of the user participation literature, I do not cite the materials reviewed nor explain in any detail the different dimensions suggested by my preliminary framework. Please contact the author for more information about this research (Allen, 1992).

final testing, or after the system has left the development organization. The where can refer to any number of aspects of the organizational context, such as the history of management style, but also highlights the potentially important difference between participation where the system was originally developed, and where it is implemented and modified for use. The question of the **resources** required for participation to take place is the one aspect of the Burns and Flam model that is, in my view, almost never addressed.

For each of these six user participation questions, there are large gaps in our understanding of the choices and conflicts involved, much less which choices are most associated with the outcomes we desire. Many practical issues and alternatives, such as the number of participants, or the difference between participating in the interface design versus the underlying functionality, have yet to be explored. For the participatory design world, however, I feel it would be especially valuable to concentrate more seriously on questions of context and resources. A discussion of participation context (when and where) could point to the value of participatory design strategies, perhaps slightly different from what we are used to, in common situations where it had not previously been considered. The resource question is also particularly important because, as an "alternative paradigm" not yet in widespread use, participatory designers have to mobilize support for their activities. One place to begin is to discuss the constraints and opportunities for participatory design and use at AIRTECH, an aerospace manufacturer.

Constraints at AIRTECH

AIRTECH is the largest of five divisions within the Aerospace group of a large industrial conglomerate (Beuschel and Kling, 1992, contains more details of the study and methodology). Located in Southern California, AIRTECH employs about 1,200 people. It produces control equipment using mechanical, electromechanical, hydraulic, and electronic technologies. Designs of incredible complexity, as well as manufacturing requirements that push existing technology to the limits, are common. AIRTECH has around 10 product lines, and the factory is organized as a large job shop (as opposed to an assembly line). AIRTECH makes products to order for the U.S. Department of Defense and several major airplane manufacturers. Like many aerospace firms, AIRTECH has recently been hard hit by declining demand in the defense industry which forms half of its market.

For our purposes, I will concentrate on one of the largest computer systems in use at AIRTECH, the MRP2 (Manufacturing Resource Planning) system. The MRP2 system is used to schedule the purchasing and delivery requirements of the parts and subassemblies used to assemble AIRTECH's finished products. Ideally, the MRP2 system can compute a reasonable purchasing and production schedule given a master production schedule of what finished products are needed, the parts and subassemblies needed to build each of these finished products and how long it takes to build or purchase each one of them (the lead times), and the existing production capacity of the factory. Many different functional areas use the MRP2 system: production controllers for scheduling jobs, purchasing for the timing and quantity of procurement, shop floor workers and supervisors for checking work schedules, design engineers for monitoring production problems and design feasibility, quality assurance to check for production problems, and by finance and higher management for accounting and control purposes.

The design and use of the MRP2 system at AIRTECH takes place under the three constraints mentioned above. AIRTECH has a culture of hierarchy and strong functional separation, which is reinforced by the tight military and government regulations they are subject to in their day-to-day operations. Even the spatial arrangement of the main building reinforces the hierarchy: as one program manager described it, management and finance are on the third floor, design engineering on the second floor, operations on the first floor, and the "[human waste] flows downhill." Many of the employees and managers have either been in the armed forces, or working in defense-related environments (or both) for most of their lives. AIRTECH is non-unionized, in a politically conservative area, and does not have a history of supporting open moves towards "industrial democracy."

Another constraint on participatory design is the fact that the MRP2 system is bought from an outside vendor. MRP2 systems are huge, mainframe based programs that are notoriously inflexible: a recent study claims that the most successful adopters of MRP2 changed their company to fit the software package, rather than the other way around (Roberts and Barrar, 1992). AIRTECH's parent corporation has decided to standardize all of the Aerospace Group divisions on a particular MRP2 package known as AMAPS/G. Besides from updates, bug fixes, and general technical support, there is no continuing relationship with the vendor after the purchase. What limited modifications take place to the MRP2 system (mostly for report generation) are done by the Aerospace Group's computing staff. AMAPS/G is run on the mainframes at the Aerospace Group's centralized mainframe center rather than at AIRTECH, further reducing the amount of say they have over design and implementation. In fact, many AIRTECH employees have been complaining about the poor responsiveness of the Aerospace Group Information Systems (IS) department for some time (programming request backlogs of 30-100 weeks are common).

Finally, the MRP2 system is used by a number of functional areas, each with their own preferences and agendas. These conflicting preferences can sometimes be seen in the daily use of the shared information system, as in the case of design engineers who want the freedom to quickly change parts requirements versus purchasers who seek long-term, stable purchasing agreements (for further examples, see Kling and Iacono, 1988). The resolution of these conflicts is then at least partially mediated by the capabilities and constraints of the shared information system. Local modifications to the system are difficult, as the production controllers have said again and again, because any changes they propose would affect so many other areas of the company.

The effects of these three constraints—tight integration, hierarchical work environment, and purchased software—on participatory design strategies can be seen in the following two episodes. Episode 1 is an example of one group trying to create and modify their own reports in the face of a tightly integrated, inflexible system. Episode 2 shows an example of how a strategy of unilateral control over the information system by upper management has, grudgingly, given way to a more participatory strategy.

Episode 1: A Report of One's Own

The MRP2 system at AIRTECH produces an incredible volume of reports. To production controllers and capacity planners, the MRP2 reports form the main interface to the shared information system that coordinates many factory activities. A large set of already programmed reports exists which can be turned on and off fairly routinely, but the ability of an individual production controller to create a new MRP2 report is severely constrained for a number of reasons. The slow response time of the Aerospace group centralized mainframe center—where programming requests for new reports take a minimum of 6 months and sometimes 2 years—has already been mentioned. The rather inflexible MRP2 system bought from an outside vendor appears resilient to even the most basic changes. For example, a production controller has not been able to change the number of digits in the "days of lead time" (length of time to make or order a part) field from two to three, even though lead times regularly exceed 100 days. Requests for report changes have to be approved by managers above his direct supervisor because, again, the MRP2 system is shared by many functional areas and proposed changes affect their work as well.

Participation by a single group of workers at the design stage of the MRP2 system is impossible in this context. But we should not give up on the participatory design ideal so easily. Instead, we should search for areas of meaningful participation in the design *and use* of the MRP2 system and the organizational systems that surround it. The use of the MRP2 program is highly dependent on many of these surrounding systems—reporting structures, data collection in a particular area, or computing support practices, for example—and participatory changes in any one of them may result in substantial workplace change. One important strategy is to choose important areas where a decoupling of activity can temporarily be accomplished, and the freedom to explore and experiment with design parameters in a participatory way can be achieved.

One strategy used by the production controllers at AIRTECH to maintain their autonomy and flexibility was to try to anticipate all the different kinds of MRP2 reports they would need and order them from the Aerospace Group IS department ahead of time. Reports that have already been programmed can be turned on and off relatively easily and quickly. Soon, however, the Aerospace Group IS department complained about the programming effort going into reports that were turned off most of the time.

Their other strategy was to reformat the finished reports from the central MRP2 system without telling the Aerospace Group IS department. AIRTECH production controllers hired a PC programmer to download finished reports from the MRP2 system, strip all the formatting, and import the raw data into a PC-based database program to create new reports. The PC programmer now answers to their immediate report requests.

Though not "globally optimal" in a systems analysis sense, these strategies are important for creating locally autonomous subsystems where participation and experimentation can take place with the kinds of reports generated, and how this information is distributed. The resources required to set up an environment that allows participation in this case are substantial. Participatory design-like activities do not follow automatically, but they are at least made more possible without requiring the approval of many other actors and groups at AIRTECH.

Episode 2: Who's In Control of the Schedule?

The MRP2 reports provide work scheduling, part ordering, and inventory information not only to the production controllers closely associated with shop floor operations, but also to AIRTECH's upper management. For the operations manager, the director of materiel management, and even the general manager of the division, the MRP2 reports are a major source of information about the status of the factory floor, particularly the work schedule. Sometimes, however, the temptation is to use it as the only source of information.

The basic elements of the model used by the MRP2 system to schedule work on the factory floor is shown in figure 2. The factory consists of a number of interconnected work centers, each with its own queue of work waiting to be processed. The most crucial scheduling parameters for a particular station are the assumptions about the time it takes a job to move between work centers, the average queue time spent waiting at each work center, the setup time to prepare for a new job, and the run time it takes to perform the manufacturing operation. In addition, each work center has an efficiency factor, which describes at what percentage of full capacity the work center is operating under.

Upper management at AIRTECH are continually being pressured and encouraged to reduce the total amount of time it takes to produce a final product, which they call the *lead time*. New foreign competitors with lower lead times and higher quality are threatening AIRTECH's markets, and AIRTECH's recent financial performance has not been good. Major customers are demanding lower lead times from AIRTECH which, for complex products, can total up to 2 years from initial order to shipment. And the new Japanese-inspired methods of manufacturing scheduling (often referred to as World Class Manufacturing, e.g., Schonberger, 1986) which are now celebrated by U.S. professional organizations such as APICS (American Production and Inventory Control Society) consider reduced lead times as a major goal, even perhaps as the best measure of manufacturing success.

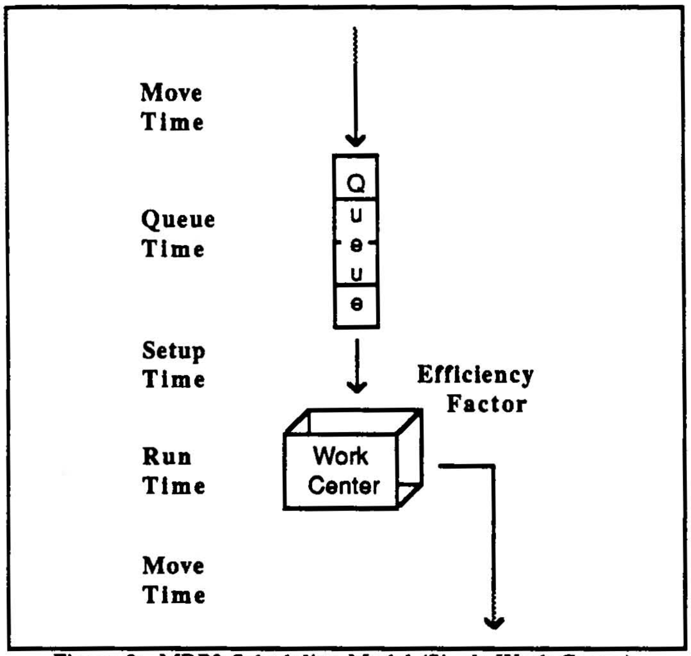

Figure 2: MRP2 Scheduling Model (Single Work Center)

In the face of all these pressure, and their desire to meet their own performance goals, the manufacturing operations upper management at AIRTECH decided to unilaterally reduce the move times and queue times for all work centers in the MRP2 factory scheduling model to zero. This shrank the lead times in the MRP2 model considerably. Whether they expected to get away with this redefinition of reality, or were simply "putting the heat" on the factory floor in order to reduce the amount of "fat", is unknown. What is known is that the new schedules created by the system caused massive confusion and mistrust on the shop floor. Shop floor supervisors complained about AIRTECH's "visionary" management. Shop floor workers were disoriented by the constant scheduling changes to adjust for slips, working overtime on a part one day only to be told the next by the MRP2 system that it was unimportant. No time was allowed in the schedules for quality inspection, or to rework damaged parts. The close interconnection between shop floor activities and the information system meant that the actions of one group had tremendous implications for many others.

A year later, both the operations manager and the director of materiel were fired, and the general manager of AIRTECH was reassigned to another position. In the meantime, another aspect of the Japanese-inspired World Class Manufacturing philosophy, an increased emphasis on "worker empowerment" and cross-functional teams, had caught on at AIRTECH. Though these initiatives to increase teamwork and empowerment have yet to substantially restructure AIRTECH's work organization, taking advantage of initiatives such as these can be an excellent pragmatic strategy for enabling participatory design and use.

The new operations manager has recently allowed shop floor supervisors to set up more participatory activities under the banner of World Class Manufacturing. For instance, floor workers are now beginning to be consulted and asked to suggest realistic move and queue times on the shop floor. It is too early at this point to tell how far shop floor participation will go. This move does not represent the kind of dramatic gains found in Scandinavian labor union projects, but it does suggest that the potential for participatory design-like activities, and the potential for *value* to be placed on these activities, can be found even in a hierarchical defense contractor such as AIRTECH.

Strategies and Resources for Participatory Design and Use

All three of the contextual constraints which appear to make participatory design impossible—tight integration, hierarchical organization, and software purchased from an outside vendor—complicate user participation at AIRTECH. In both episodes, tight integration through a shared information system makes changes in one area impossible without affecting others. In neither episode was greater industrial democracy an explicit goal, though there was some mention of "worker empowerment". And end users did not have the opportunity to participate in the initial development of the AMAPS/G MRP2 system. Yet, even in this "impossible" setting, meaningful participatory design-like activities are possible. The particular context at AIRTECH highlights these different resource and strategy issues.

An important step towards creating the conditions for participation and experimentation in these tightly integrated, bureaucratic environments is to create some measure of autonomy which makes changes to the system possible. This autonomy is usually assumedn in participatory design accounts, but must be explicitly created in organizational contexts like AIRTECH. This freedom to play can be hard to attain, especially in the face of strong systems ideologies that advocate one organization-wide information system. Some Computer Integrated Manufacturing advocates even go so far as mandating that there should only be one central database in the entire organization (Melnyk and Narasimhan, 1992). Despite this ideal, manufacturing firms typically have a difficult time justifying or carrying out the electronic integration of their major information systems (Beuschel and Kling, 1992), so the opportunities are there.

The system autonomy which enables participation requires resources in the form of equipment and staff support. For this potential to develop into participatory design and use, further supporting resources are needed to for basic skill building and education. Machinists don't automatically have enough knowledge about the MRP2 system to design alternatives, but even production controllers and managers are sometimes unsure of how the system works. For example, at AIRTECH there was confusion about the meaning of "shrinkage" in the MRP2 model: controllers believed that 50% shrinkage meant using 20 units of raw material for every 10 finished products, when it actually meant using 15 units for every 10 finished products. Because discussions of autonomy and skill with respect to information systems are rarely legitimate, obtaining these resources can be particularly difficult. Especially at AIRTECH, where where the vice president of the Aerospace Group sets a limit of 2% of sales to be spent on computing, and called PCs a "cancer" on the bottom line.

Organizational contexts such as AIRTECH also require us to be more pragmatic about choosing the most useful areas for participation. Participatory design usually assumes early involvement in software development is the most useful strategy. This early involvement may be impossible, or early design decisions might be overshadowed by particular work arrangements or configuration choices in the implementation and use environment. In either case, we must evaluate, rather than assume, where the most promising areas are. And we should take advantage of popular ideological and political movements that call for greater user participation. There is rarely any shortage of "improvement" programs in American factories. American industry has given at least lip service to the goal of employee involvement since the beginning of human relations research in the 1930's (have you ever seen a company put up huge banners on the factory floor calling for less employee involvement?). We should be more explicit about taking advantage of these new ideals, particularly under the newest labels—World Class Manufacturing, Total Quality Management, and Computer Integrated Manufacturing.

Could better end-user tools have helped at AIRTECH? Better end-user report generators, and the skills and support to use them effectively, would be very helpful for report-intensive workers such as the production controllers. Perhaps less obviously, simulation and learning tools that help workers understand the assumptions and design choices in these large systems could open up new participation possibilities. Research into how to keep systems as visible and modifiable to the user as possible should continue (see Henderson and Kyng, 1991, for important continuing use concepts), but without losing sight of the autonomy and resources that make the use of these tools possible.

The insights of participatory design can be made much more widely applicable if we include the on-going design activities in what are normally considered use contexts. There is a much stronger case for the use and diffusion of participatory design methods and theories if we can move beyond the image of a small number of users involved in a custom software project.

Conclusion

There are many opportunities for participation in the on-going process of design and use of large, integrated, software systems purchased from outside venders such as MRP2, even within the culture of an aerospace firm and defense contractor such as AIRTECH. The model of participatory design as involving a single group of users in the pre-implementation stage of development has to be supplemented by an understanding of the on-going, evolutionary process of fitting and modifying large software systems in existing technological and organizational contexts. Supporting participation almost always requires some measure of autonomy and resources—obtaining these may prove to be the most crucial step towards participatory computing.

I have used the example of the MRP2 system at AIRTECH to explore participatory design in an "impossible" setting. By showing where participatory design and use are possible in this context, I hope to expand the possibilities of the participatory design model to include settings such as AIRTECH. These examples at AIRTECH illustrate the importance of context and resource issues for user participation research and practice. I also hope to open up the on-going, evolving process of information system use to the participatory model as well.

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