FACULTY GRANTS AND AWARDS APPLICATION

Project Title:
Relocating Knowledge and Power Through Manufacturing Software

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This research plan envisions a study of the implementation of organization-wide CAD/CAM/CAE and ERP software packages such as CATIA, a software package developed by Dassault of France and marketed by IBM in the US, and implemented (among other places) at Boeing. In the large, the goal is to show how organization-wide software systems tend to relocate and reconfigure locations of knowledge and power within such organizations.

The project would, in the first instance, investigate how skill, knowledge, and power get represented and implemented within software. This in part would recognize the legitimacy of the old tacit knowledge problem, and it would be informed by the work of Lucy Suchman,[1] among others. The next step would be to investigate how software architecture implicitly (and often explicitly) remaps status hierarchies and locations of knowledge within organizations. This is, of course, the one area in which the public literature about Boeing's use of CATIA on the 777 is almost effusive—the traditional complaint was that negotiating out (and redesigning parts and processes) who had priority to put what within the proverbial slender cigar of an aircraft in the old system was finessed by CATIA, which, it is claimed, elegantly choreographed a more rational and efficient process. If this claim is accurate, I'd be mightily surprised, because in previous historical work I've done, I [Robert L. Frost] found that it was precisely that reconfiguration of status hierarchies which represented a sufficient danger for engineers and skilled tradesmen that they would often sabotage the whole process. Such was certainly the case with Taylorism and its descendants.

Another piece of the project would look into how cultural practices and assumptions get handled in the software. I've studied French engineering quite a bit and I would like to know how the fine-grained hierarchy among French engineers at a firm such as Dassault got written into CATIA and how it was received in Everett. In addition, American engineers who collaborate with French engineers often note the formers' impressive grasp of mathematics and logic, while noting as well their relative incompetence at the *bricolage* and gadget-development at which the American engineering tradition excels. Translating between these two cultures is no easy task. This piece, however, could well be conceptually elusive to pursue,

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[1] For example, "Human/Machine Reconsidered," (URL: http://www.comp.lancs.ac.uk/sociology/soc040ls.html (as of Mon, Aug 11, 2003)), and *Plans and Situated Actions: the problem of human-machine communication.* (Cambridge University Press, 1987).

but a well-defined ethnographic methodology, developed in the process of interviewing and document analysis, should offer some purchase on cultural/subcultural questions.

Perhaps a side-door entry into the cultural issues could be in looking at how CATIA and its cousins force a standardization of tools and practices between suppliers and contractors. Obviously the Australian firm doing the 777 tail parts had to use CATIA in order for the paperless design and prototyping to succeed. That would tend, therefore, to standardize not only tools and procedures but also vocabularies (and implicitly, epistemologies) across firms. Finally, given the price per seat for CATIA (though falling rapidly, it is still quite costly), et al, and the employee training expenses, such a practice would create a powerful lock-in upon the supplier (when some wonder why Delphi rarely sells to Ford and why Visteon rarely sells to GM, they might just look at the software/IT requirements of doing business with non-partners).

A further part of the study would look at how software packages like CATIA are never implemented, as it were, "out of the box;" that there are many inflections onto the stock package that have to be put in place in order to meet the needs of specific customers. This implies several important issues. First, the software in question has to be technically versatile enough to allow such adaptation. For example, when Boeing first started using CATIA, programmers at Boeing desperately wanted to link CAD/CAM objects to databases, replete with the requisite descriptors, only to discover that CATIA's data-handling was restricted by a legacy architecture based on very old "card-image" fixed fields. As a consequence, such data linkages involved serious work-arounds that vastly reduced the usability of the software. Second, the customization project requires strong, lasting, and trusting collaboration between vendor and buyer. This means that there is a strong incentive to use and enforce user/participant-design practices (cf. Balka's work on bringing the user into the design loop[2]), yet inevitable traditions of rejecting innovations "not invented here" operate on both sides in ways that hinder effective collaboration. In addition, as all such customization efforts tend to generate new intellectual property (IP) assets, the issue of which party (vendor or buyer) enjoys such IP rights is usually not well delineated and leads to a distrust that further hinders collaboration. Finally, it is clear that such projects are never really "finished," that in the daily use of enterprise-wide software, new needs emerge, new procedures are developed within the user organization (procedures that have to be implemented within the software), and other soft- and hardware systems are introduced in parallel to the existing system. Consequently (and despite the implications of versioning systems that embrace whole-number shifts in version numbers), vendors and users face constant negotiations between the need to innovate and the need to keep legacy systems and routines going. As with other such collaborative efforts, these negotiations often become clouded by institutional rivalries and jealousies, as well as by continuing friction over IP rights.

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[2] For example, "User-Centered Design as Negotiated Relationships." Proceedings, User centered design: Problems and possibilities. Workshop held in conjunction with 1998 Computer Supported Collaborative Work and Participatory Design Conferences, Nov. 14. Seattle, Washington (URL: http://www.nada.kth.se/cid/pdc98/workshop/ (as of Mon, Aug 11, 2003).

As I'm currently imagining this project, I'd like to study Boeing's experience with CATIA on the 777. The second part of the project would look at a current implementation and deployment of CATIA in a global auto firm today. That latter firm would most likely be Toyota (North American R&D Headquarters are—conveniently—in Ann Arbor's Tech Park), which is poised to implement CATIA firm-wide within the next 2-3 years. The comparison of two implementations separated by time, space, and organizational venues would permit an analysis of how organizations collaborate, learn, and adapt. In addition, it would underscore how effectively a vendor firm learns—as more and more IT services get outsourced, IT service and product providers such as IBM, SAP, and the like have to develop the organizational skills to adapt to the subtle complexities of each customer's socio-technical environment. A comparative study would allow, therefore, an analysis of how organizations learn.

So, what's it worth? What would this project offer in terms of new, useful knowledge for The University of Michigan and the world?

- In the large, it would underline the need to view software as a social "actor," as it were, something that is not merely technical, but has vast implications for the configuration and location of power and knowledge within an organization
- It would show how genuinely complicated it is to represent social and technical practice within the highly formalized world of software design; software engineering requires transparent explicitness, while the world being modeled is rife with fuzziness, tacit knowledge, and implicit rules. This study could indicate what techniques in this area show the greatest promise.
- It would indicate what works and what does not in terms of inter-organizational collaboration. Unlike scientific organizations, which ostensibly work under a social model of cooperation in the name of the greater good (*viz*, the growth of knowledge), business organizations are inherently based on rivalry and competition, thereby rendering collaboration a far more complicated endeavor.
- It would show how effective design must not only involve users, but must also embrace a large role for "translators," people who can identify the boundary objects upon which disparate intrafirm and professional subcultures can act effectively. Programmers and engineers, engineers and skilled tradespeople, and manufacturing companies and software firms all have different modes of internal social validation—the aesthetic elegance a programmer seeks and from which s/he enjoys peer admiration does not, for example, necessarily yield the operational-efficiency goals of the production engineer. What is optimal for one party might not only be dysfunctional for another, it may well be incomprehensible. A close study of the process will show what techniques work, keeping in mind that there is probably not "one best way," as the taylorists of old would have it.
- It will show how inter-enterprise innovation requires a lessening of dual institutional prejudices, that of insisting that one party receives all of the IP rights from the collaboration, and that of rejecting innovations from the

outside—the "not invented here" problem. One would hope that part of the institutional learning process that will be studied by the comparative aspect of this project will show how organizations improve their collaborative capacities.
- It will examine how "standards," formal, informal, or officialized by ISO, ASME, IEEE are developed. It is often argued that proprietary standards are a key part of the lock-in of buyers to vendors, yet at the same time, proprietary standards facilitate claims for intellectual property rights. Yet, proprietary standards inhibit flexibility and interoperability. This study will show how the terrain of standards-making can be best negotiated for all parties and for the IT community as a whole.
- Finally, it will strengthen collaboration among three very different academic units at The University of Michigan, serving, one may hope, as a model for interdisciplinary research.

Robert L. Frost is the lead PI on this project, collaborating with Malcolm McCullough (School of Architecture & Urban Planning) and Zbigniew Pasek, College of Engineering, Department of Mechanical Engineering. As demonstrated by his authorship of the path-breaking book, *Abstracting Craft: The Practiced Digital Hand* (MIT Press, 1996), McCullough is an expert on the issues of how craft, embodied, and tacit knowledge get represented in software, as well as the more philosophical/epistemological and cultural issues concerning the ways that different kinds of knowledge get validated (or not) in the process of abstracting craft. In his own research, Pasek is deeply engaged in issues of reconfigurable manufacturing, itself highly IT-driven, so he is quite well acquainted with the technical and engineering side of contemporary manufacturing processes and social relations. This project therefore represents a significant cross-disciplinary initiative amd it will, we hope, lead to closer collaboration and deeper mind-share among our respective academic/research units.

JUSTIFICATION FOR AND PURPOSE OF THIS PROPOSAL

Major funding for this project will ultimately be sought from NSF and perhaps from private foundations and Toyota—the latter for the second phase of the project. In order to author credible grant proposals, researchers need to demonstrate that they have completed significant background research for the project and have been assured access to the requisite research resources. Though Robert L. Frost has had NSF funding in the past, he has not previously dealt with CISE, nor (thanks to a major shift in his research focus) proposed this sort of project in the past. It is therefore imperative that all the proverbial ducks be appropriately aligned before a full proposal is submitted to NSF, and OVPR support would go a long way toward the goal of developing a credible proposal for NSF. Considerable background research has already been completed (a presentation based on it is available at: <http://www-personal.si.umich.edu/~rfrost/papers/CATIA.htm>), yet more remains to be done, both on campus and in the corporate libraries of Dassault and Boeing. In addition, face-to-face contact is crucial in attaining access to people and records internal to both firms. These two activities will require travel to Everett, WA (site of the 777's development and manufacture), Paris (Dassault's corporate HQ),

and Chicago (Boeing's HQ). (FYI, Frost is nearly fluent in French). If necessary, Frost can self-fund local travel to Toyota and Daimler-Chrysler (a current user of CATIA). This proposal therefore requests support for performing background research and for travel to the several venues noted above. The time frame would be fairly straightforward: perform the OVPR-funded spadework in the coming Fall term and over the brief holiday break—the late-November to early January period is much busier in France than in the US—, then write the NSF proposal for a March deadline and commence major research in the Summer of 2004.

BUDGET JUSTIFICATION

As mentioned earlier, it is imperative to complete the background research before submitting an application to the National Science Foundation on March 1, 2004. In order to complete this research, the PI needs travel to the three proposed sites for face-to-face contact with the people he wishes to work with and collect more data from them for analysis. For this reason, the budget for this proposal is primarily for travel. As Frost will be doing the major work on this part of the project and, as he's teaching in the upcoming academic term, stateside travel will occur during the term, between Thursdays at 2 pm and Tuesdays at 10 am. Travel to Paris will have to be in December 2003 due to travel durations. To minimize expenses, Frost will stay with former colleagues in both Washington and Chicago. Therefore, we are requesting funds for airfare, lodging in Paris, local transportation at each site, and food costs. Costs were determined by average cost per trip at the School of Information.
Cost breakdowns are therefore:

	Airfare or personal vehicle cost	Lodging @ $200 per day	Food @ $80 per day	Ground Transportation
Everett	$500	N/A	$240	$100
Chicago	$150	N/A	$240	$100
Paris	$650	$600	$240	$100
TOTAL	$1,300	$600	$720	$300

TOTAL TRAVEL - $2,920

In addition to the cost of travel, we are also requesting a modest sum to help cover the cost of the supplies needed for these interviews ($80).

TOTAL REQUEST: $3,000.00