Application of Collaborative Conflict in System Design: The Case of the New Millennium Program

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HETEROGENEOUS SYSTEM DESIGN PROBLEM

Most organizations do not develop systems from scratch. Instead, to deal with economic constraints, organization demands, and customer needs, they often: a) identify possible problems that represent customer demand [10, 16], b) consider which possible technologies are useful to address these problems, e.g. commercial off-the-shelf software (COTS) [8] or open source software [12], c) select which problems to address, and d) implement a project to solve these problems. The initial choices for problem selection, in turn, involve a process of balancing and negotiating requirements from multiple sources [11, 13, 14, 17].

In some views, the hardest part of project design is identifying the problem to be addressed [9, 10]. As March (1994) [16] describes, there is rarely only one clear problem to choose to address. Indeed, problems, and their respective technology choices, co-exist in competition with one another. A problem-technology choice can be viewed as a prospective project for possible funding by an organization's principals. Principals are those who have the power and resources to authorize and fund a project [4]. Each problem-technology set represents a different (yet sometimes overlapping) group of stakeholders. Each stakeholder group has its own set of requirements that underlie their project choice. This set may overlap with other stakeholder groups' sets, but usually not with all of them. Each project represents one or more choices of technologies. Based on the requirements of all of the stakeholders, there are hundreds of different project possibilities. How does an organization choose which project to do?

Bergman and Mark (2002) [5] conducted an empirical field study to examine in detail the issues faced by practitioners in forming and stabilizing requirements during project selection and the procedures they created to overcome them. In this paper, we examine how the practitioners applied collaborative conflict as part of the process by which they selected system projects.

THE NEW MILLENNIUM PROGRAM (NMP)

The New Millennium Program (NMP) was started in 1994. It is located within the Jet Propulsion Laboratory (JPL). The Jet Propulsion Laboratory has been in existence for over 40 years. It had been involved in the design and development of technologies used in nearly all of the NASA (National Aeronautics and Space Administration) outer space and Earth based missions during that time, including landing on the moon and the Mars rover.

The main mission of the NMP is to perform space flight validation of new technologies [15]. It was created to address a problem of the lack of new technology utilization in space science missions. The primary reason science missions need new technologies is to reduce mission cost, allow a measurement, or enable a new function or capability. However, new technology is considered too risky for space use, and hence off-limits to science missions. By performing space flight validation on new technologies, these technologies become available for use in future space missions.

We studied the "NMP Formulation" process. This process deals with how the NMP selects the technologies for space flight validation. We found the formulation process to be in fact a *project selection process*. There are thousands of possible technologies that need space flight validation, hundreds of which are considered important by NASA directors and science mission technologists at any one time. The technologies tend to cluster into sets of related functionality, such as propulsion, communications, sensors and control systems. Each new technology was viewed by the NMP as a possible project choice. The NMP selection process has been developed and evolved over the last nine years to address this issue of project-technology choice.

COLLABORATIVE CONFLICT AS SYSTEM DESIGN SENSEMAKING

The general results of the study are presented in a variety of papers from Bergman and Mark [5-7] and Bergman and Buehler [1-3]. In this discussion, we focus on how the NMP applied reflective methodology during initial system design.

The NMP customers are called NASA theme technologists. They represent different ongoing space programs, such as studying the sun-earth connection, planets and other heavenly bodies. They represent a variety of diverse missions that want to use new technologies. Specifically they want the new technologies for their capabilities and, when possible, reduced costs. The missions they represent and work on have very diverse needs. All of these needs cannot be satisfied with a single or small set of technologies. There are ongoing needs for hundreds of different technologies. In addition, the relative needs of the different theme technologists are organizationally equal. Hence, there is no easy answer as to what technology to choose. Indeed, the NMP found they could not apply quantitative decision support methods due to the complexity of the problem [1]. They had to create and implement a repeatable method of selecting technologies that all of the stakeholders would support or the NMP program would fail.

The observed NMP selection process is quite complex. It is performed in two distinct phases: Pre-phase-A and Phase A. Pre-phase A focuses on determining what the NMP customers want, what new technologies are being developed and which of these technologies can address a subset of the customer requirements. Phase A is used to first gather external (to the NMP) technology and project proposals, review and rate them, and then select which proposals move on to implementation.

In both Pre-phase A and Phase A, we observed the application of collaborative conflict as a key methodology used in the selection process. We define collaborative conflict as 1) isolating specific, reoccurring predictable conflicts that occur during the selection process and 2) letting those either most directly affected by the conflicts or impartial to them engage the conflicts in a procedurally bounded manner. It is the application of preplanned, procedurally bounded, same-time conflict analyses in order to determine hidden or "tacit" information about technologies and their related project plans. We observed this information if difficult to obtain because is tends to represent the negatives (i.e. downsides) of a technology or project proposal. This is the information proposers do not include since it would very likely compromise their chance of the proposal being accepted.

Applied Collaborative Conflict Analysis

The NMP broke down and isolated repeatably observed conflicts in their processes. The main conflicts that needed to be addressed in the NMP selection were: customer demands as expressed through requirements; technology selection during a) technology concept areas (TCA) development b) external technology proposal review and selection, and c) project review and selection; application of the NMP filters to the technologies in a TCA; and authority level (organizational, project, technical) disagreements over which TCAs (and their technologies) to support.

In Pre-Phase A, the NMP focused first on the framing technical issues: determining customer requirements and finding available technologies. With this information, the NMP technologists pulled formed viable system designs to address common sets of requirements. They call the resulting early system designs technology concept areas (TCAs). At the end of Pre-phase A, the NMP selects which TCAs are going to be supported for an open technologies call.

Phase A begins with the technology call. It contains the requirements of the various TCAs that are being funded for the current NMP selection cycle. Any United States base supplier of technology (industry, government, university) can submit a technology proposal to the call. This is similar to a call for papers to a conference. Phase A uses review panels to rate and rank each proposal, first technical, and then project proposals. It ends with a final project selection and hence, selection of the technologies included in the project.

We now discuss how the NMP applied collaborative conflict in addressing their issues. We focus on there specific applications of collaborative conflict: 1) theme technologists and their requirements, 2) NMP technologists and the NMP filters, and 3) the technology and project proposal review panels.

Theme Technologists – The NMP technologists gave their customers, i.e. the theme technologists, proposed TCAs to examine. Each theme technologist was given a week to review and initially rate each TCA. The ratings were based on how well or poorly an individual TCA fit their perceived needs. After that time, the theme technologists were brought together in a meeting to discuss their ratings with one another.

These meetings were procedurally bounded by time, activity and outcome. The meetings were only one to two hours long,. They met once a week until they finished the task of considering all of the TCAs. They used a 1-3 rating system (3 being highest). They added a "silver bullet" to a specific TCA indicating each technologist's highest importance. They also stayed confined to the technologies presented to them, although suggestions about other technologies were allowed. Discussion was quick, detailed and precise. The whole task never took more than 3 meetings.

During these meetings, the theme technologists learned about each other's ratings and enquired as to each rating's rationale. They made sense of each other's positions and in so doing, improved their own sense of their ratings. This is seen by their working together to change ratings on various TCAs based on newly discovered mutual interests or lack thereof. The theme technologists used their a priori positional conflicts over requirements and technologies to discover more about each other positions and the technologies themselves. They applied and clarified their own (technical, economic and political) requirements as they worked through the various different technologies. In so doing, they addressed their own as well as the groups' technical, economic and political positions, which are represented in the final ratings. Furthermore, some of the feedback from this process was used to modify the TCAs to make them better fit the theme technologists' needs.

NMP Technologists – Another application of collaborative conflict was performed by the NMP technologists themselves. Each NMP technologist is an engineering expert within a specific domain. These domains include sensors, propulsion, communications, software control systems, and so forth. They oversee the technologies and proposals that fit their area of expertise. Over the years, they have learned to trust the expertise of the other technologists when discussing technologies that are not in their engineering domain.

The NMP has a set of "filters," i.e. ongoing requirements that are used to determine which technologies are appropriate for space flight test validation [1]. The NMP technologists apply these filters to each proposed technology to determine whether it can be consider by the NMP from selection. These filters bound the discussion about the technologies, i.e. a determination about how well each technology met or failed these filters.

These discussions occur in formal meetings or informal gatherings (especially over lunch) of the NMP technologists. A technologist presents his or her rationale to the colleagues and then they intensely engage the issue. The presenter describes how a technology they are considering should be accepted by the NMP, often by comparing the technology with similar technologies selected by NMP in the past. If there is not a general quick consensus (which we rarely observed happen), the other NMP technologists would point out specific instances in which the technology fails one or more filters. The most observed filters discussed were a) did the technology have to be space, or could it tested on earth, b) was the technology mature enough in its development to merit consideration and c) why this technology deserved consideration over other competing technologies. These discussions can last for days or weeks, especially on those technologies that may be testable on earth.

By considering each TCA and its component technologies against the NMP filters, the representing technologist must reaffirm their views as to why this technology should be tested. These discussions usually uncover new underlying issues about a technology that was not originally considered. These issues lend further insight to the strengths and weaknesses of the TCA system designs. Hence, the NMP filter discussions produced a better understanding of the TCAs (and the technologies therein) by the NMP technologists individually and as a whole. It helped to produce NMP team consensus on which technologies pass the filters as well as fostered better system designs.

Review Panels – In Phase A, the NMP forms independent review panels to rate and rank the technology proposals. At this point in the selection process, there has been a general call for technology proposals, based on the requirements set forth for each selected (in Pre-Phase A) TCA. Those proposals that survive the initial technology review process are invited to submit project proposals. These are also reviewed and ranked by another independent panel of space system design experts.

There are many procedural boundaries for the review panels. First, the review panels are made up of technology and system engineering experts. They are selected to cover the different engineering areas defined by the TCAs in the call for technologies. They cannot be part of any active proposals. Next, each proposal is first only considered against other proposals in the same technical domain, i.e. addressing the same TCA. The best of these are selected for the project proposal stage. The, the project proposals are compared at the level of full NASA missions, i.e. at a project level. Technical specifics are only discussed at this level if they have a direct impact on project execution and outcome. In addition, there are specific rating and ranking forms for each technology the panelists need to fill out. This standardizes the comparison results per panel.

The technology panels consider first how well each proposal meets the stated (TCA) requirements. Those that fail this are dropped from consideration. They then discuss the relative weaknesses of each proposal. They look for unwanted, yet unavoidable issues with the technologies. Examples include high cost, uncertain support, excessive mass, power, size, chemical or biological hazards, insufficient shielding to work in space, and so forth. We call these *negative requirements*. In other words, what stakeholders want, need, or desire to constrain are positive requirements, while that which they do not want, need, or cannot or overly constrain are negative requirements. No technology is perfect. Each has positive (wanted, desired, need) and negative capabilities and constraints.

Upon reflection, we assert the panels mainly exist to allow the managed, bounded conflict of engineering expert opinions on each technology to be expressed a rapid, focused manner. There was a desire to learn as much about a technology as is possible without seeing the technology first hand. This is based on a combination of examining what is written in the proposals in conjunction with the history of the technology and the reputation of the business team producing it. All of this was taken into consideration during the panel discussions. Individual panelists often shared insight on the history of a specific technology and its project team, which gave added depth to a proposal.

The outcome of these panel discussions was deeper and richer insights into the positives and negatives of each proposal. The panelists were able to compare and contrast proposals to find even more strengths and weaknesses. We found that proposals tend to focus on the positive, i.e. how the met stated TCA requirements and their technical capabilities within constraints. The panels tended to balance these proposals by identifying the negative requirements and undesired technical attributes and constraints. Altogether, collaborative conflict fostered an improvement in the information accuracy and dept of each technology and project proposal.

CONCLUSIONS

Proponents present the positive view of their technologies, requirements and project specifications. Via conflict, an informed opposition uncovers the negative aspects of the technologies, requirements, and projects. During planned, procedurally bounded collaborative conflict, the proponents and opponents are afforded a space to work together to defend the strengths and uncover weaknesses of their positions. This is performed in an attempt to better understand all of the issues that are part of initial system design.

Collaborative conflict in system design is similar to other proceedings, for instance legal trials, journal peer review, and quality assurance. Key similarities are a) the existence of known or expected conflicts (during a process), although the specific nature of the conflicts is not known in advance, b) predefined rules and procedures by which these conflicts are addressed, c) an expectation that bringing in opposing view will produce hidden and tacit "truths" about the situation, d) an acceptance of the outcomes by the involved parties, and e) only those parties with direct interest or organizationally endowed power are part of the process. The main difference is that the outcomes of early system design are far from concrete. Whereas a trial's outcome is (reasonably) clear, systems design can change as the development process progresses. Much of the activity in initial design is making sense of the choices available and the implications of each choice. Also, the early rules and procedures of conflict engagement are as not well defined.

The NMP incorporates collaborative conflict in many aspects of its selection process. This indicates that it is a useful tool for reflective design practice. Yet, the challenge is to determine in general where collaborative conflict is useful throughout the system design and diffusion process. We propose that further research needs to be done to determine and understand how these apply in other system design situations, such distributed software systems, information systems, collaborative work systems, and alike.

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