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A Facilitator Method for Upstream Design Activities with Diverse Stakeholders

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Abstract

This paper presents a method that can be used for the elicitation and specification of requirements and high-level design. It supports stakeholder-based modeling, rapid feasibility feedback to marketing, and the interpersonal dynamics that are necessary to develop a product. The method centers on the role of the facilitator*, an independent agent whose purpose is to build the Integrated System Model (ISM). The ISM is the result of merging the independent system views from all stakeholders at any given abstraction level. Formulation of this method was based on the real-world experience of developing a complex, high-technology medical product with critical time-to-market pressures. It has proven to be a practical approach to the evolution of requirements definition and provides a necessary link to the marketing aspect of a product.*

1 Introduction

This paper presents an experience in which requirements engineering is performed in an adverse commercial environment. From this experience, a method called the *Facilitator Method* is derived. The term "facilitator" is used because the systems analyst in this method acts as an independent, neutral agent who promotes the joint creation of a system model by its diverse stakeholders.

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A new system's design is usually based on a combination of prototypes, including an existing product line for the company, an existing set of products in the market, and the expectations in the minds of marketing, development, and customers. One goal of the facilitator method is to use these prototypes, and the people behind them, to the fullest extent possible during requirements definition. This is in keeping with the basic philosophy of Participatory Design [2]. But rather than simply including users in the process, the facilitator method seeks to include all stakeholders and their differing viewpoints. For example, a common practice in industry is to develop a system and then "throw it over the wall" to quality, production, and service staff. This is clearly counterproductive, since those people have worthwhile contributions to make to the requirements definition. Thus, we take a broad definition of "stakeholder" to include customers, users, marketing, development, and service staff.

Another important goal of the facilitator method is to better address marketing concerns and project planning needs. Information that helps determine market feasibility is solicited from stakeholders as the system definition evolves. The method maintains focus on the risk of not meeting the market requirements for the product, including features, cost, and time-to-market. The method allows marketing feedback and decisions to be made at each abstraction or conceptual level of the requirements and design definition. This leveling approach is common to most analysis methods. When combined with market feasibility information, leveling minimizes losses while promoting incremental investment decisions and effective concurrent design efforts.

There is a growing awareness of the need to address the "intersection of the technical and the human" in the development process [9]. The facilitator method

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therefore attempts to address the human interaction element of producing satisfactory project requirements and design definitions. Most large projects involve diverse people working together to develop a product. Diverse stakeholders present a challenge to achieving a single definition that is comprehensive and understood by all stakeholders. Each stakeholder embodies a viewpoint that is derived from a tradition, a set of priorities or interests, specific training, and very often a language different from that of the others. For example, communicating face-to-face in a roundtable fashion often hides elements of the diversity that exist. Words are interpreted in the context of the listener [5, 7]. Without a means to anchor the discussion, the roundtable type of communication can be ineffective. Stakeholders require a medium of exchange and a neutral mechanism for achieving a common understanding [3]. With a concrete, yet neutral, mechanism in which all stakeholders are invested, the communication can be definitive and real progress can be made.

There are other methods that propose the use of a facilitator. One of the most popular such methods is joint applications development (JAD) [11]. The method presented in this paper differs from JAD in that there is less reliance on extensive group meetings during the elicitation and definition of requirements. While meetings are still used in our method, they occur infrequently and do not always require the presence of the facilitator. Furthermore, the facilitator in the method presented here formally uses a leveling approach to analysis and definition, whereas the facilitator in the JAD method largely uses informal brainstorming. Finally, the facilitator method presented in this paper provides an overall framework and structure for interaction with stakeholders, and relies on a more active role of the stakeholders involved to achieve the consensus that leads to completeness [1].

The notion of viewpoint was introduced as early as 1977 by Ross and Schoman [10]. They defined viewpoint as being a particular aspect of a product or product development, such as performance, rather than as being a perspective held by a particular stakeholder in the product. Interestingly, they described an "economic viewpoint", which in essence is one of the two components that make up a stakeholder viewpoint in the method described here.

Leite and Freeman laid the foundations for using viewpoint resolution as a means to validate and formulate a more complete picture of requirements during the elicitation process [6]. Viewpoint resolution for them is a process of soliciting a mental position from significant actors in a project. The discrepancies between viewpoints are evaluated and eventually integrated into a single solution or view. Leite and Freeman performed controlled studies giving preliminary evidence that using differing viewpoints enhances the requirements elicitation process. Their studies did not, however, address the issue of scaling their method for larger projects, in particular the fact that it would take significant resources and time to operate a large project in the manner they propose. Further work on viewpoints continues, but much of it focuses on tools that can be used to represent and support multiple views [8].

The facilitator method presented here uses a modified form of viewpoint resolution to achieve requirements definition quickly for large projects. It differs from the approach introduced by Leite and Freeman in a number of ways. For one, the facilitator method does not specifically use formal rule-based models and multiple analysts. The stakeholders, rather than the analyst, become responsible for representing their viewpoints by graphical means and supporting them with annotated data. Another difference is that in the facilitator method the generation of a model happens concurrently with the elicitation process. This speeds up the development process when the scale of the project is increased and many diverse stakeholders are involved. Finally, the facilitator method is a more dynamic process of merging viewpoints and defining requirements as completely as practical at any one point in time. It deals with the fluidity of contingencies, politics, interpersonal dynamics, and the evolving nature of viewpoints.

The remainder of this paper describes a case study that served as the seed for the facilitator method and then describes the method in some detail. We conclude with a look at future work.

2 Case Study

The experience presented in this paper spanned a period of fourteen months. The product was a complex, high-technology medical system. The overriding requirement was to meet the time-to-market deadline. The product sold for over one-million dollars and the investment in capital equipment to produce it was very high. The company had bought out a small 25-person firm that made chemical research systems using the application technology that was to be applied to the medical product. The new product was substantially different from the existing one, but a prototype was built based on the chemical research system that existed in the previous company.

The company grew quickly and at the time of first

Figure 2: Application Scientist View of System.

impediment to effective communication. Eventually, an analyst (one of the authors, R. Gonzales) met with the stakeholders, the unofficial technical leaders from each group, and sketched out with them independent models of how each saw the system. They used data-flow diagrams with real-time extensions. Figures 1 and 2 show simplified example diagrams given by two representative stakeholders. In the figures, rectangles represent elements outside the system, ovals represent transformation of data, and arrows are the data flows themselves. As the modeling proceeded, a formal data-flow technique was introduced to the stakeholders, but they often strayed away from the strict definition of the notation.

After several models were created from the individual stakeholders, they were combined into a system model that represented a merged view. This merged view is illustrated in Figure 3 and reflects the views captured in figures 1 and 2 together with the views

Figure 3: Merged Stakeholder View of System.

of other stakeholders. (Merging is discussed in more detail below.) The system model was then distributed and communication between the stakeholders began to take place.

As the model was iterated, it became clear to the stakeholders which components needed to be defined first in order for progress to be made. For example, the components that formed an interface between the predominately hardware side of the system and the predominately software side needed definition. Another concern was the RF component, where the "horsepower" for the application resided and where communication between application scientists and engineers was most difficult. A common property of these critical components was the diversity of the stakeholders required to fully define them.

The same resolution process, but involving different subsets of the stakeholders, was followed for each of the critical components. In one specific instance, a meeting was held so that each of three stakeholders could present their case for how the term "digital receiver" should be interpreted. The marketing contingent wanted to advertise that they had a digital receiver. To the RF engineer, this meant using specific higher-technology design components. One of the engineering managers made the argument that the notion of a digital receiver was not strict. He was able to convince the application scientists and the marketing people that what he proposed was more feasible and could also be considered a digital receiver. Similar discussions and resolutions took place in defining the requirements for each critical component. The system model that emerged was one with which all the stakeholders were content.

Although the edict to be ready with a product in a year remained in place, there was still some latitude in what would actually be delivered in the product. Moreover, the development staff could request additional resources. Information about how long it would take to develop each of the components in the system was sought in the same manner as before, namely separately from each stakeholder. By asking for specifics on resources and time, further definition was required by the stakeholders. Of course, this had an effect on the system model. The results of this process were a new model at the system level, a model for three of the most critical areas of the system, and a time line. In the process, the marketing and management staffs were forced to make some compromises on what would be shipped, while the technical staff prioritized the various parts that needed to be built so that the minimum system could be delivered.

Several months into the development of the system it was recognized that a key component was not going to be available in time for the application scientists to perform the development needed on the actual system. At that point an existing component used in the prototype was made to fit into the new system and development continued. This was the only significant problem that was encountered. The data necessary for FDA approval was taken before the product was shipped, the beta-test system was shipped just before the show, and results from the new system were successfully demonstrated. Some of features of the product were not quite competitive, but it had other distinctive features that set it apart. The fact that the company was at the show with a real product made it a contender. This was the goal of the company.

2.2 Lessons Learned

This was a high-pressure experience and during development there was never a moment that product shipment was certain. In an ideal world, one might observe that the schedule requirements were not reasonable. It was, however, realistic within that highly competitive market, and similar market pressures do exist for other products. While the analyst in this case study was rather experienced, the standard methods that were available for her to use were too inefficient. Potts characterizes this as "slim pickings" when talking about the gap between the research and the practical application [9].

This was an extreme case, but generally the real-world still cannot afford the time most standard methods require, since they rely primarily on the analyst for the modeling and, as a result, require the analyst to become an expert in many complex areas. The analyst in this case acted as a model refiner and simply mir-

rored the combined system image that was given her. The alternative would have been to require everyone in the company to become an analyst. The scientists and medical technicians, along with many others, resisted learning a complex analysis method, especially when they were under pressure. This is not surprising, since they are highly trained and their concerns are in areas other than systems analysis. While evolving the system model, strict adherence to a modeling notation impeded communication. Most of the stakeholders naturally were able to draw a visual representation for a system, and flexibility was a necessity, since the stakeholders were actively doing the modeling. Of course, it may be possible over time for all the stakeholders in a single company to eventually adopt a single, rich notation. In fact, during this case study, some of the people did use the notation presented to them by the analyst. But the time-to-market pressures did not allow this to occur more widely.

Many existing methods do not take into account the people issues involved in developing complex products. Working with the caliber of people that existed in this project was extremely tricky. They were considered experts, but had diverse experiences. Their opinions were quite entrenched and they had to be convinced of alternate views. They were often impatient with the engineers, wanting them to "just go away and build the machine". People began to circumvent the requirements process when they did not feel adequately involved and when it appeared to be taking too long. Bridging the gap in this situation required the analyst to be a neutral party and to work hard to adequately represent the concerns of all the stakeholders.

Equal opportunity to contribute to a system model was necessary, but lengthy face-to-face communication among diverse stakeholders did not prove to be an efficient use of time. When the project first got underway, it was as if a group of people speaking different language dialects were trying to understand one another. One could occasionally pick out constructs and meaning that give an overall feel for what was being talked about, but not enough meaning for effective communication. The JAD method, because it relies so heavily on such meetings, requires careful control over meetings, something which is not easily attained in a setting of diversity. Many times during face-to-face meetings early in the project, the technical people of the group dominated the discussion. This lead to divergent conversations and the result that most of the people were left frustrated. Having a system model in which all of the stakeholders were invested anchored the communication, and meetings were held only as necessary and among subsets of stakeholders.

3 The Facilitator Method

We call the model that captures the merged view discussed in the previous section an *Integrated System Model* (ISM), while the analyst role that promotes the creation of an ISM we call a *facilitator*. A skilled facilitator is able to rapidly iterate to an ISM that is useful for determining requirements by using the prototypes that exist in the company, the market, and the knowledge of the experienced stakeholders.

There are two parts or perspectives to an ISM, a graphical system model perspective and a project-level commitment perspective. Unlike the method used by Leite and Freeman, where both parts are formulated in parallel to create each viewpoint and then combined with other viewpoints, the graphical perspective in the facilitator method is first formulated and combined with graphical perspectives held by other stakeholders. After agreement on the graphical perspective, the commitment perspective is solicited and acts to validate the first perspective. By resolving the parts of the ISM in series, the facilitator method capitalizes on the strengths of what has already been agreed to by the stakeholders.

The facilitator begins the ISM creation process by soliciting a block diagram of the system from each of the stakeholders. This block diagram does not have to use any specific notation. The block diagram is based on whatever preliminary marketing information or statement of need that is available. Some of the stakeholders may require assistance in developing this first-cut diagram, but even if assistance is rendered, it is important that the block diagram is owned by the stakeholder. Equal opportunity for unbiased input is critical at this stage. Complete system requirements from each stakeholder are not the concern, as much as representing all the elements that are important to the particular stakeholder.

The individual viewpoints on the system are then merged by the facilitator. The technique used in the case study was that of grouping and leveling based on structured analysis methods. In particular, the facilitator first examines the various viewpoints, looking for patterns. This involves trying to find the largest scope that defines what is being called "the system" by defining the boundary between what is inside the system and what is outside the system. The facilitator then forms logical groups of functions into components and subsystems based on the terms used by the stakeholders and on the communication among the elements they are trying to model.

For example, in figures 1 and 2, the two stakeholders were looking at the system from different perspec-

tives, and both stakeholders had major concerns about the user interface. The surrogate customer saw the hardware as a monolith, with the exception of the patient table, which was a piece of hardware of interest because of the customer responsibility for placing and setting up the patient. On the other hand, the application scientist was interested in the part of the hardware that generated the scans, but not in the patient table. When the merged viewpoint shown in Figure 3 was developed after input from engineering and other stakeholders, it became apparent that the patient table was a part of the system, but the patient was not. It also became apparent that the coils were outside the system, but the instrumentation that combined with the coils to make up the RF and gradients was a part of the system. There were many other such system boundary, leveling, and scoping issues like these that were resolved before the final ISM emerged.

The outcome of merging is the graphical portion of an ISM. The ISM does not have to be in any specific graphical notation, but a notation should be used that is consistent and adequate for describing the entire system at a high level. Notations such as those used with structured analysis or object-oriented design are acceptable candidates, as long as they are kept simple and not made too technical for the given stakeholders. Using a notation that is overly rich can impede communication among the stakeholders at this level. For example, in the case study, many of the specialized notations for the structured analysis real-time extensions used by Hatley and Pirbhai [4], such as control bars and dotted line notation, confused the stakeholders and had to be compromised. As a system gets more defined and the stakeholders more comfortable, more sophisticated notations can be introduced.

The ISM is then given back to the stakeholders for iterative refinement and discussion. At that point, many issues arise and a synergy of thought occurs. What one stakeholder has included sparks another stakeholder, and the diagram undergoes significant change. The key is to anchor all communication to the ISM. Issues are resolved in a series of face-to-face meetings that include subsets of the stakeholders with or without the facilitator. This allows more freedom of interaction and makes it so the stakeholders are not dependent on the facilitator in order for communication to take place. Once the issues are resolved to the satisfaction of the parties involved, a modified ISM is given to the facilitator. In the case study, about three weeks were required for the building of the original graphical ISM and two weeks for feedback to be returned to the facilitator. This time was reduced as the process matured. It is the responsibility of the facilitator to turn the next version of the ISM around to the stakeholders quickly. The iteration continues until the ISM more or less stabilizes. This happened within about four to six iterations in the case study.

The facilitator then asks for specific information on each component from each stakeholder to formulate the commitment portion of the ISM. Table 1 contains an example. The information is in the form of text and includes attributes describing resources that will be required to design, build, and test the component, and the time required for each phase of development. Estimation techniques and direct consultation with the group represented by the stakeholder may be required to get the detail necessary. The reason to ask for this project-related information at an early stage is to make explicit all assumptions and areas that are not yet well defined or understood. People pay close attention when commitments need to be made. This is a so-called "truth-generating mechanism" [3]. When the data from the stakeholders are taken in aggregate, they reveal what is not known about the system, areas of discrepancy, and risk areas.

The facilitator takes the individually crafted information and forms as complete a picture as possible from the given data. Of course, such a picture may not be possible without further leveling of the ISM. The facilitator therefore uses all the information given so far and creates a first cut at the next level of the ISM. The merged data are then presented to all the stakeholders as a basis for communication. The graphical ISM is subject to change at this point as more things become apparent to the group of stakeholders. In this way, the second perspective validates the graphical model that was achieved previously. The feedback in the form of modified graphical and commitment information are given to the facilitator for the next iteration of the ISM.

The outcome of this process is a multi-level ISM with the necessary project information achieved by collaboration and consensus. It is important to notice that the facilitator method places responsibility for the completeness and correctness of the information where it should be, namely on the stakeholders and not on the analyst.

3.1 The Facilitator's Role

Hall [3] gives the following definitions for various third party roles:

> "A facilitator helps with the logistics in the proceedings of meetings. A mediator guides or helps people come to a voluntary agreement. An arbitrator tries to understand the

Name of Component	Acquire Raw Scan Data
Function of Component	Takes data from hardware, formats and passes them to processing elements
Defining Characteristics	The interface between the RF and main computer, so speed is critical (xx bytes/sec)
Expertise Required	*Define:* App. Sci., DSP Eng., Software Eng., Production Eng., Analog Eng., RF Eng. *Design:* DSP Eng., Software Eng. *Build:* DSP Eng., Technician, Production Eng. *Test:* DSP Eng., Software Eng., Technician, Production Eng. *Integrate:* Systems Eng., DSP Eng., Software Eng., Technician, Production Eng.
Estimated Schedule	*Define:* 4 wks X 6 people X .50 days *Design:* 8 wks X 2 people X .75 days *Build:* 3 wks X 3 people X .75 days *Test:* 2 wks X 4 people X .75 days *Integrate:* 2 wks X 4 people X .75 days
Problems and Constraints	Need to use new DSP boards; new DSP boards are complex to build; need to train Production Eng.

Table 1: Example of Commitment Information for a Component.

> issues on all sides and then imposes an agreement, as a judge."

The facilitator in the method described here serves a bit of each of these. In particular, the facilitator is someone that should be well trained in system design, should cause the resulting ISM to embody the proceedings of meetings held by the stakeholders, and should help bring iterations of the ISM to closure.

The fact that there are diverse stakeholders working on a complex project with many issues needing rapid resolution makes developing requirements and high-level design definition an "integrative bargaining problem" [3]. The facilitator reduces this integrative bargaining problem to a "distributive bargaining problem" [3] at which point the facilitator is no longer necessary. It may take multiple facilitators to achieve this, because as the abstraction levels become more specific, facilitators with different specialties may be needed. To accomplish this reduction, the facilitator sets up a dynamic mechanism to resolve potentially conflicting views of the system or its subsystems. These conflicting views are a rich source of information. The dynamic mechanism starts with a sort of bidding about what the system looks like. The multiple views are then transformed into a neutral model, yet each stakeholder's concerns are not overridden or forgotten in the process of face-to-face meetings.

It is necessary that the facilitator be independent from any of the stakeholder organizations. One common error that can be made is to fill the role with a project manager belonging to one of the engineering organizations. The requirements document that results would be biased toward the engineering stakeholders, leaving marketing, users, customers, and other stakeholders left to figure out what the requirements mean in the terms they care about. In the case study, the facilitator was made a neutral party. This was very helpful, since there were times when the facilitator had to suggest a solution that was not in keeping with the biases of the engineering managers, but made sense to the rest of the stakeholders.

The marketing focus is a grounding in the reality that the product must sell. The goal is to negotiate what is physically possible and what is marketably possible. There may not be a margin of overlap, but it is up to the facilitator working with the stakeholders to quickly figure out whether or not there is. Even if there is an overlap, it may not remain so over time as requirements and the market demand both change. Therefore, market feasibility for any one product defined by a set of requirements is not constant. The sense of urgency in achieving requirements definition quickly is one of the elements that is missing in many requirements elicitation methods. The window of opportunity for any potential product shrinks as time passes and risks increase. If there is an overlap, then a solution that comes with an acceptable risk must be developed as quickly as possible. The facilitator method makes risk areas apparent because it shows discrepancies in how stakeholders view the system. It is up to the facilitator to flag the risk areas and pursue them with the appropriate management and staff. Depending on the situation and the company, this may be done by assigning a team to mitigate a specific risk area or by renegotiating requirements with the customers or marketing, whatever is necessary to get the job done.

4 Conclusions and Future Work

The facilitator method outlined in this paper is a practical, systematic approach of using experienced stakeholders to achieve requirements definition

rapidly. It is based primarily on the experience presented in Section 2. The need for speed in defining requirements for a product is paramount given most marketing environments. The use of a facilitator as ISM builder, rather than as formal analyst, speeds up the process of developing a system model that can be used for requirements specification. This can be achieved with some, but effectively little, impact on completeness, using viewpoint resolution [6] as modified for this method. The use of a commitment perspective helps validate the graphical model perspective of the ISM and it provides the measure by which a project should be evaluated. This method can be scaled to small projects, but is most effective for large projects where diverse stakeholders are the norm, such as in the case study described in this paper.

The facilitator method needs to be tested on controlled projects to determine how much training a facilitator would require in addition to a standard systems engineering background. The interaction and potential problems that can occur with an ineffective facilitator need to be investigated further. The facilitator could potentially become a bottleneck, but no more so than a project leader, a product manager, or someone in a similar systems role. Controlled studies would be useful in determining what impediments a facilitator would have to overcome to be effective. In the case study, it was determined that ownership of the ISM by all of the stakeholders is critical. The facilitator is key in fostering this ownership. Specific ways a facilitator can cultivate this ownership is an area that should be studied.

The type of graphical notation used primarily at the highest levels of abstraction needs further investigation. A notation that is natural for people from diverse disciplines would be most useful. Block diagrams of different flavors seemed to be a common method of communicating by most of the stakeholders in the case study. The marketing staff drew block diagrams, as did the scientists and production people. Some questions still remain: how much information is communicated in common block diagrams and how rich does a notation have to be to achieve the level of understanding required for the facilitator method to be effective? Another aspect of the graphical notation is the use of specialized tools. The goal would be for the stakeholders to use whatever graphical editor is most convenient for them to use. Given the diversity of the stakeholders for a large project, a tool that is too restrictive can cause a stakeholder to be less effective. The cost of investing in a tool, especially in terms of time, should not be an obstacle to using the facilitator method.

The specific information that needs to be provided in the commitment perspective is another area that needs further investigation. This information could potentially vary from company to company and between abstraction levels for a single project. This information should allow the determination of product feasibility—i.e., is there an overlap between what the market requires and what the developers can realistically produce? The information must flag risk areas and provide a means to validate the graphical model perspective of the ISM.

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