Development of the ibm.com Interactive Solution Marketplace (ISM): A Systems Engineering Case Study

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ABSTRACT

IBM's ibm.com business unit contracted with IBM Global Services (IGS), another business unit of IBM to develop their Interactive Solution Marketplace (ISM) application. ISM is a single point of entry on the ibm.com website for browsing and searching for a suite of solutions as opposed to individual software and hardware items. The first release of ISM experienced schedule and release content challenges. Development of the second release of ISM (ISM 2.0) became one of the first projects where IBM Global Services implemented their formal Systems Engineering and Architecture (SE&A) process. During the SE&A process implementation, particular emphasis was placed on requirements analysis and management, and on structured and scored reviews. This technical paper presents this implementation and the results in the form of a systems engineering case study. Implementation of the SE&A process during the development of ISM 2.0 was successful. ISM 2.0 was delivered on schedule, at 5% below projected cost, and it constituted the functionality and features expected and desired.

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by stakeholders. Consensus on core stakeholder requirements was achieved early during project development, and the technical reviews allowed the team to identify and resolve key issues before proceeding into subsequent phases. This discipline, along with the expenditure of resources to develop quality requirements, greatly reduced project rework. As such, only one-tenth of anticipated defects were actually found and reported during testing. The quality of the deployed application was further validated by the minimal number of post-launch defects reported. © 2005 Wiley Periodicals, Inc. Syst Eng 8: 000–000, 2005

Key words: PLEASE PROVIDE

1. INTRODUCTION

1.1. Scope and Methodology

This case study investigates and illustrates the formal implementation of the SE&A process and principles on a troubled medium-sized $3M Web-application development project. The case study demonstrates that significant benefits can be achieved through appropriate application of SE&A principles. These benefits include the completion of a development project on time, under the projected budget, and with fewer defects at delivery. The SE&A principles described in this case study are similar to those articulated in the US Department of Defense Acquisition Policy. As such, this case study is also a demonstration of the applicability of DoD SE&A principles in improving system acquisition and development.

Section 2 discusses some of the deficiencies of the existing development methodology, prior to its integration with the SE&A methodology, and the relevant changes realized through this integration on the ISM 2.0 project. Section 3 describes how a project team, inexperienced with the practical application of formal system engineering practices, applied these practices successfully on ISM 2.0. Significant findings are summarized in the final section of this paper, and some concluding remarks are proposed.

The research presented in this paper is based on the Friedman and Sage [2004] framework for systems engineering case study research. Specifically, all aspects proposed within this framework are addressed with the exception of “Life Cycle Support.” Since the development team on this project was getting introduced to formal systems engineering methods and practices, emphasis of this case study research is on the “Concept Domains” of “Requirements Definition and Management” and “System and Program Management.” Further, in the responsibility domain, this research replaced the concept of “Government Responsibility” with “Customer Responsibility” given the nature of the contractual agreement for this development [Friedman and Sage, 2004].

Authors of research methods have discussed the strengths and limitations of case study method of research [Graziano and Raulin, 2002; MacNealy, 1997; Friedman and Sage, 2004]. Case studies provide rich description of events, behaviors, and situations which have not been studied and researched. However, they are weak in generalizability, and are susceptible to threats of reliability and validity. Friedman and Sage [2004] discuss the threat of researcher bias and highlight the importance of “sufficient validity.” In this regard, the researchers had access to key project stakeholders and leaders, and while each stakeholder had selected biases, there was remarkable agreement among them on the significant aspects of the case study. This was also evident in the data collected from the development and customer team members. In addition, this concurrence was confirmed through the project-related technical documentation, and relevant project management information.

1.2. Background of the ISM Project

Two trends in the IT industry in late 1990s led to the initiation of the Interactive Solution Marketplace (ISM) development project. The first was the exponential growth of Internet usage and its increasing importance as a marketing and sales channel [Odlyzko, 1999; Roberts, 2000; Teresko, 1999]. Second, IT customers increasingly requested complete solutions to solve their business needs rather than discrete software, hardware and service elements that had to be subsequently integrated [MacLachian, 1998].

IBM was an early adopter of the Internet as a communication channel, but their web presence was product oriented and did not provide an integrated solutions approach. As an example, potential customers had to
navigate the ibm.com site specifically and separately for server technologies, application software, and IT services. IBM and its business partners realized the limitations and business implications of this product-centric approach.

The ibm.com business unit was chartered to initiate the ISM development program to specifically address the business limitations of a product-centric web presence. The primary mission of ISM is to provide a single point-of-entry for solutions-oriented browsing and searching, allowing potential customers to search for integrated services, technologies, and products to address their business needs. The goal was not to replace traditional face-to-face sales strategies, but to enhance them by providing initial product information in an integrated fashion to potential customers. Further, ISM would capture valuable customer and product leads and provide the sales organization with relevant information for direct engagement.

According to internal IBM documentation, ISM was to “become the vehicle to help customers identify business problems, involve decision-makers from the beginning of the purchase process, and line up the capability to ensure IBM is actively engaged throughout the solutions sales purchase process. ISM will be a stand-alone portal for demand generation activities. It will also serve as a publishing tool (common service) that supports display of solution content in the context of a brand or audience site. ISM revolves around the concept of selling ‘solutions’ to customers and as such must become a desirable and sought-out resource for Line-of-Business (LOB) decision-makers and IT buyers wanting to find, evaluate, and connect with solution providers. By providing a positive user experience, offering search and research tools and a robust repository of solution information from IBM and Business Partners, ISM can advance IBM’s objective.”[IBM Internal, 2002zaq:2]

Given the “scope” of the ISM application, and the need to present integrated solutions to potential customers, ISM impacted most business units within IBM. To make this “single point of contact” sales and marketing approach work, business processes of different business units had to be realigned and diverse needs of these business units had to be satisfied. Accordingly, it was a challenge for the ISM team to obtain scope and intent concurrence from numerous stakeholders on the often overlapping and conflicting requirements. As one member of the SE&A team put it, “Everyone wanted everything.”

This was especially evident during the development of the first release of ISM. While there was a tangible framework of processes and methods for project management and software development, formal processes for stakeholder requirements and system requirements were largely absent. Application requirements kept changing, and the deployment at the end of 2001 seemed in jeopardy. As a result significant compromises had to be made with the functionality and scope of the first release of ISM (ISM 1.0) in order to meet the deployment schedule. Much of the capability originally envisioned for ISM 1.0 had to be implemented in the second release of ISM (ISM 2.0). At the same time, the business imperative to present IBM as an integrated solutions provider over the Internet resulted in increased visibility and senior management attention for the project. Changes were also made by the ibm.com business unit to their project management team for ISM 2.0 development project.

IBM Global Services (IGS) was contracted by ibm.com to develop and deliver the technical solution for ISM. The IGS project manager saw an opportunity to deploy the recently developed and formalized Systems Engineering and Architecture (SE&A) methodology. This methodology was soon to become mandatory on all IGS projects with a development budget greater than $500,000 as part of their CMMI® [2001] initiatives. The ibm.com program manager was receptive to the SE&A approach, and ISM 2.0 became one of the first projects to embrace the complete SE&A methodology.

2. IGS’ SE&A APPROACH

IBM Global Services has a framework of processes and methods governing any internal or external customer engagement. This framework outlines necessary activities, roles, and life-cycle models for typical business engagement scenarios and domains. Further, over 280 standard work products are defined within this framework to provide a common reference for project planning and documentation. In its existing state (pre-SE&A) this framework did not address requirements, architecture development, integration, and verification as part of a coherent Systems Engineering methodology. Existing descriptions of these SE&A practices were general and open to interpretations, and often “hidden” in broader activities and work products.

Formal descriptions of SE&A activities, practices, roles, and work products were added to the IGS methods framework in mid-2001. These SE&A artifacts are consistent with the methods discussed in the SE literature [Kossiakoff, 2002; Sage, 1995; Sage and Armstrong, 2000; Verma and Fabrycky, 1997; INCOSE,
After the formal definition and integration of SE artifacts into the IGS methods framework, an SE education and training initiative was launched and conducted within IGS from mid-2001 on a continuous basis to provide practitioners with the necessary support to facilitate application of SE&A practices to IT development and integration projects. To provide a necessary context for this case study research, a brief discussion of the SE&A related additions to the IGS methods framework is included herein.

Figure 1 shows a mapping of the IGS SE&A model to the existing models in the IGS methods framework. The existing models were largely focused on program and project management and software development. The SE&A model provided a coherent, multilevel (system, subsystem, application, and subapplication) and recursive emphasis on requirements, architecture development, design, verification and validation, and integration. Selected and relevant aspects of the SE&A life-cycle model are discussed in the following subsections.

2.1. Systems Engineering Reviews and Technical Baselines

As shown in Figure 1, a gating concept was present in the existing IGS methods framework in the form of Decision Check Points (DCPs). DCPs are not technical reviews, but rather executive assessments of project status and its readiness to progress to subsequent phases of the framework. As an example, the “Plan DCP” is critical since this is the milestone where final commitment is made to project scope, budget, and schedule. Technical reviews, their scope, and rigor were left to the discretion of the project manager in the existing IGS methods framework. SE&A introduced a set of technical reviews to the IGS methods framework as shown in Figure 2. These technical reviews are keyed to project baselines. For example, the Customer Baseline is fixed at the Business Requirements Review (BRR).

These reviews had a dual purpose. They provided a more detailed assessment of a project’s technical maturation to support the executive decisions made at DCPs, while providing the formality of a systems approach to the development of key SE artifacts. The latter is important when transitioning to a systems approach since a correlating set of SE artifacts provide a pragmatic basis for the systems approach. Technical baselines provide a reference for the expected maturity of a project at different development milestones. They are also the basis for change control and management.

To promote consistency in the SE&A technical reviews, a scoring scheme was introduced. For each technical review a set of entry and exit criteria was defined. Each of these criteria was weighted on a scale of 1 to 4, and scored by the reviewers. An example is shown in Figure 3. A “red”, “yellow”, or “green” score is used to assess the quality of the work products reviewed. Issues contributing to a “red” score (below 70) must be resolved before a phase can be exited. Issues contributing to a “yellow” score (between 70 and 85) must be resolved by the next SE&A technical review.

2.2. Problem vs. Solution Domains: Impact on Requirements Quality

While the importance of “good” requirements is undisputed in the systems (SE) and software (SW) engineering communities [Sage and Armstrong, 2000; Blanchard and Fabrycky, 1998; Standish Group 1994–2001], there is a divergence on characteristics of “good” requirements. Furthermore, there is general acceptance within the SE community of the value of clearly separating the problem domain (WHAT) from the solution domain (HOW) [Sage and Armstrong, 2000; Blanchard and Fabrycky, 1998; Alexander, 2002; Alexander and Stevens, 2002; Hooks and Farry, 2001]. This is emphasized in the IGS SE&A model.

The IGS SE&A model defines three categories of requirements: stakeholder requirements (or business requirements, or business process requirements, or cus-
tomer requirements), system requirements (or design requirements), and component requirements. Component requirements can exist at multiple levels as a function of system complexity. Templates are provided in the IGS SE&A framework to support the development of “good” stakeholder, system, and component requirements.

2.3. Traceability of Requirements

The existing IGS methods framework lacked a consistent emphasis on requirements traceability. This was addressed by the SE&A methodology. Requirements traceability and verification matrices were added as work products to the existing IGS methods framework to ensure traceability from business requirements to system requirements, to component requirements, and finally to test and verification cases. This provided the development team a method to ensure consistency through the different phases of development, test, and integration.

2.4. SE&A Roles and Responsibilities in a Project Organization

While a project manager was and is ultimately responsible for project success, the SE&A enhanced IGS methods framework facilitates the allocation of roles and responsibilities between project management and systems engineering.

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<thead>
<tr>
<th>Topic</th>
<th>Weighting Factor (0-5)</th>
<th>Score (0-4)</th>
<th>Total (Weighting Factor x Score)</th>
<th>Comments</th>
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<td>Acceptance Criteria</td>
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| Total Review Score (Sum of Individual Totals) | 8.9 | | | Red - <70
Amber - >=70 & <85
Green - >=85 |

Score Legend:
- 0 = No Data Available
- >0 & <=1 = Critical Issues Identified (Prevents Signoff)
- >1 & <=2 = Major Issues Identified with Possible Workarounds
- >2 & <=3 = Major Issues with Known Workarounds
- >3 & <=4 = Minor or No Issues Identified
- - = No entry required

Figure 3. A sample scorecard for the review of system requirements at the SRR. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]
IGS SE&A methodology requires that there be a Lead Systems Engineer (LSE) on a project, optionally assisted by a Lead Systems Architect and other systems engineers depending on project size and complexity. The LSE has overall responsibility for the technical solution and serves as the project manager’s technical focal point. The LSE assumes responsibility for interdisciplinary collaboration, interfacing with the project stakeholders, the development team, and the test and verification team during project development, test, integration, and deployment.

3. SE&A Deployment on ISM 2.0

3.1. ISM 2.0 Project Context and Characteristics

ISM 2.0 was the second release of the ISM application for the ibm.com website. Given the limited scope and functionality of ISM 1.0, ISM 2.0 included the primary functionality needed for solutions-based browsing. The critical nature of the second release attracted significant executive management oversight and attention. The ISM 2.0 concept phase was launched in late January 2002 with a development budget of $3 million. The planned release date was mid-December 2002.

While the development and integration of ISM 2.0 was executed internally at IBM, a formal customer–contractor relationship existed between the two IBM organizations. ibm.com was the internal customer organization and IBM Global Services was the internal contractor. A Project Development Team Lead (PDTL) within ibm.com was assigned to ISM. He had overall responsibility for the definition and planning of features and functionality across the multiple ISM releases. The ISM PDTL was supported by two project managers. One managed the maintenance and support for ISM 1.0 while the second project manager managed the ISM 2.0 acquisition and deployment. A Requirements Manager together with a team from Business Analysis and Marketing rounded off the ISM team within ibm.com. Additional stakeholders and subject matter experts from other IBM business units were engaged on an as-needed basis.

The IBM Global Services team constituted a project manager, supported by three project teams. These three teams were the software development team, the test team, and (for the first time) the SE&A team led by a Lead Systems Engineer with overall responsibility for the technical solution of ISM 2.0.

It is worth noting that the ibm.com and IBM Global Services teams were geographically spread over four continents. This is the norm rather than the exception within IBM, and a companywide infrastructure of e-collaboration tools and virtual “Team Rooms” accommodate the necessary communication and collaboration between the project team members. Apart from a single ISM 2.0 workshop that caused the two (customer and contractor) teams to meet for live discussions, the project team members did not meet in person. The entire project, including the technical reviews, was conducted and completed using IBM’s virtual project environment. Only the software development team within IBM Global Services was physically collocated.

3.2. Controlling the ISM 2.0 Scope

A Requirements Manager joined the ibm.com team soon after the ISM 2.0 project start. Her initial task was to consolidate and document the “unrealized” requirements from ISM 1.0. In the absence of formal requirements management and traceability, this was a tedious task. In addition to formal documents such as the original Request for Information, Business and Functional Requirements document, she had to glean requirements from informal and ad-hoc sources such as e-mails and meeting minutes. Once consolidated, these unrealized requirements numbered approximately 100.

ISM 2.0 was approaching the end of concept phase by the time the development team (IBM Global Services—IGS) had the charter and resources to formally deploy the SE&A methodology. The Lead Systems Engineer (LSE) joined the project 10 days before the scheduled System Requirements Review (SRR). Consolidation efforts by the Requirements Engineer on the customer team contributed to the successful conduct of this review. A number of pre-SRR sessions were organized by the LSE to generate “review ready” stakeholder and system requirements compliant with SE&A standards and practices. These sessions involved the SE&A team along with all relevant stakeholders and subject matter experts from ibm.com and other IBM business units. The software development and test teams were also represented on a limited basis. The focus of these pre-SRR sessions was on the following aspects of the requirements:

Clear distinction between stakeholder and system requirements: The consolidated list of original requirements was reviewed and reformulated to express stakeholder needs and expectations (This represented the business or problem domain). A number of stakeholder requirements were reclassified as system or component requirements, since they represented the solution or implementation domain. This was the first time team members on the ISM 2.0 project had experienced such
rigor in separating the problem and solution domains.

System requirements were developed in the context of the ISM 2.0 architecture. System requirements were developed to a level of detail and completeness necessary to ensure that the stakeholder requirements and expectations were adequately addressed and that the architecture was feasible for the ibm.com environment.

Understandable and unambiguous requirements: Considerable time was invested during the pre-SRR sessions on the understandability and clarity of requirements. The LSE insisted that every relevant stakeholder and development team member understand and agree with the meaning and implication of each requirement (reflected through the definition of acceptance criteria). This became their pragmatic definition of a “good” requirement, avoiding the more theoretical discussions in the literature.

Acceptance criteria: Each critical system requirement was linked to a quantifiable set of acceptance criteria. This was agreed to at the SRR. This practice enhanced the understanding and clarity of system requirements while also facilitating the definition of test cases during the ISM 2.0 development. Further, this practice increased the level of commitment and trust between the customer and contractor teams, thereby reducing the probability and risk of dispute during system delivery.

Stakeholder ownership: Every stakeholder requirement was “owned” by a specific stakeholder. This “owner” stakeholder was involved in any decisions or trade studies that impacted this requirement during the project.

Requirements-database with discrete and uniquely identified requirements: The ISM 2.0 project used the IBM “Team Room” infrastructure. This served as a project data repository while also providing a suite of online collaboration tools. This environment was enhanced with basic requirements management capabilities such as attribution, sorting, filtering, and reporting to overcome the limitations of document based requirements management and to facilitate easy access for team members.

Figure 4 shows an example ISM 2.0 stakeholder requirement with corresponding system requirements.

The ISM 2.0 SRR was conducted as a three-day online collaboration session. This event passed with a
“green” score per the scoring scheme discussed earlier. Leading up to the SRR, the approximately 100 stakeholder requirements from the original list were reduced to 46. Eighty-nine corresponding system requirements were formulated. Rather than signifying scope reduction, the reduction in stakeholder requirements reflected the team effort to reduce redundancy, overlap, while providing the necessary development focus and consistency on the ISM 2.0 project.

Team discussions to finalize stakeholder and system requirements were often difficult to resolve. Converging on the functional scope of ISM 2.0 was a challenging task. After SRR the SE&A team felt they had a set of “good” requirements. They were not, however, confident that they had the “right” requirements for the scope of this release. The concept of project or mission objectives has been discussed in the systems engineering literature [Hooks and Farr, 2001; Sage and Armstrong, 2000; Sage, 1995]. This practice was used to facilitate convergence on functional scope. The team defined five nonnegotiable project objectives. These objectives were called Critical Mission Requirements and reflected the core functionality and features of ISM 2.0 desired by the stakeholders. One of these five Critical Mission Requirements was the release date. This reflected the criticality of getting the core functionality released on time.

3.3. High Level Design and Detailed Development

As shown in Figure 1, a completed SRR marked the end of the ISM 2.0 Concept Phase. The project then entered and exited the Plan Phase with definitive commitments to scope, cost, and schedule. The project focus was now on finalizing the ISM 2.0 architecture, its high-level design and component requirements, and preparing for the Preliminary Design Review (PDR). Schedule and cost estimates were refined and final commitments were made with acceptable risk.

As the ISM 2.0 high-level design evolved and the detailed development schedule and budget was developed, it became obvious that all stakeholder requirements agreed to during SRR could not be implemented in the designated timeframe. The project team had to go back to the stakeholders and prioritize each stakeholder requirement. Additionally, they developed an estimate of the implementation effort necessary for each stakeholder requirement. To assess priority, each stakeholder requirement was examined in terms of its contribution to the Critical Mission Requirements. This proved critical to defining and scoping the capabilities of the ISM 2.0 release. A member from the customer team recalled: “It killed discussions about this whistle or that bell and focused us on the core functionality to be implemented.” An enhanced level of customer involvement assured that customer expectations were aligned with the technical solution being developed.

The charter of the SE&A team made them responsible for the system and component architectures. Traditionally this responsibility was allocated to the software development team. The ISM 2.0 approach constituted a significant change from their perspective. Further, resource constraints prevented the desired level of involvement from members of the software development team to support the SE&A activities during the plan phase. This impacted quality during the formulation of the high-level design and became critical to the overall project success.

The software development team was critical to the success of the ISM 2.0 Preliminary Design Review (PDR) conducted in mid-July 2002. Several issues and deficiencies with the high level design were identified during the PDR. These had to be resolved before the project could enter the component development phase. The SE&A team and the software development team, along with representatives from a third party vendor, were involved in a week-long workshop to resolve
critical technical issues. Given the traceability between the stakeholder, system, and component requirements in the context of the ISM 2.0 architecture, the workshop was structured into focused breakout sessions to address and resolve specific technical issues and deficiencies.

The resulting high-level design had the necessary quality to enable the development team to complete the detailed design and conduct the Critical Design Review (CDR) in 3 weeks. Thereafter, the coding and component level testing was completed in 5 weeks to keep the project on schedule. Well-defined components and component interfaces made it possible to add resources to the development team without significant coordination challenges.

The CDR resulted in some contention between the SE&A and software development teams. While the software development team was used to internal peer reviews, they were skeptical of the value of using precious development time for conducting a high level review with the stakeholders. The program manager and the LSE insisted on this review since the CDR was a formally required review by the SE&A methodology. Further, the stakeholders’ involvement on the ISM 2.0 project thus far had been very strong and constructive. They did not want to lose the final opportunity to identify any remaining issues before full scale coding was initialized, while also reassuring stakeholders that their expectations would be met.

3.4. Verification and Delivery

Preparations for system level integration, and functional, usability, and performance testing started long before the Test Readiness Review. The test organization was involved at the SRR when the acceptance criteria were defined and agreed to with the stakeholders. The SE&A team also involved the test organization during the Plan Phase (Figure 1) to define the test architecture. The test team collaborated with the SE&A team to define the test data requirements, and the requirements for monitoring performance and volume during the performance tests. After PDR, once the architecture and high-level design stabilized, the SE&A team engaged the test team to define and review test cases. Misunderstandings were identified and resolved and the test team gained a deeper understanding of the ISM 2.0 architecture and functionality. The result, the test lead commented, was “flawless test cases.” In his experience, misunderstood requirements and poorly defined test cases could cause up to 10–20% of reported defects during system testing.

The test team had expected and planned for a defect rate of approximately 20%. This was based on experience with other development projects of similar size and complexity. The functional verification test, with approximately 1350 test cases, actually reported only one tenth of the estimated number of defects. This is shown in Figure 5. System level testing began after 5 weeks, 2 weeks ahead of the planned schedule. The usability test team from ibm.com had a similar experience. Their lead would comment that usability testing was a matter of hours rather than the usual practice of days or weeks.

Performance testing in the target environment encountered some issues. This caused unplanned troubleshooting before a configuration discrepancy in the test and target environments was identified and resolved. This activity was not on the project critical path and did not cause any schedule delays.

ISM 2.0 went live in December 2002 per the schedule. At completion, the ISM 2.0 project had spent $2.85

![Graph](http://example.com/graph.png)  
Figure 5. Anticipated vs. actual defects found during the functional verification test.)
million out of the $3 million development and integration budget.

In the first 3 months, following the deployment of ISM 2.0, the operations unit at ibm.com reported an average of 12 defects per month. Only two of these were of a severity that required an immediate fix. According to ibm.com, this was a remarkably low defect rate for a Web application of this complexity.

### 3.5. Project Management Aspects

It is interesting to highlight the reflections of the customer and contractor project managers with regard to using the SE&A methodology. The contractor project manager (PM) from IBM Global Services highlighted the following aspects:

*Ability to focus on project management and customer relationship at the business level:* Used to working in a constant “firefighting mode,” engaged in technical scope discussions, and as mediator between software development and customer, the PM could instead focus on prioritizing conflicting tasks, managing resources and engaging with the customer team on business and management issues. On the ISM 2.0 project, the PM delegated “technical mediation” to the LSE and his team.

*Ability to assess technical status and compliance throughout the project:* The quality of the technical solution and its compliance with stakeholder expectations is often not revealed until verification or deployment. Any critical deviations discovered late often lead to project delays and expensive rework. With the concept of scored reviews and stakeholder involvement, the SE&A team could quantify the quality and maturity of work products early in the project, along with ensuring compliance between the technical solution and stakeholder expectations. The PM especially identified the PDR as a valuable milestone in that the project would not have recovered in time if they had not been able to understand and isolate the gap between the ISM 2.0 requirements and the ISM 2.0 architecture. Good traceability between requirements and the architecture enabled risk and impact assessments with fidelity and confidence, and provided a desired level of confidence in the PM’s communications with the customer.

*Management of third party subcontractor:* Well-documented requirements and a clean component structure were invaluable in the development of subcontract work packages. This significantly lowered the potential for conflict with the third party supplier. Project rework was also significantly minimized because of this and the project required four man-weeks less work than originally planned.

![Defect Detection ISM 2.0 vs. Non-SE Projects](image)

*Figure 6.* ISM 2.0 defects detected by phase vs. average of 19 similar IT projects.
The PM on the customer team (ibm.com) also made similar comments. He highlighted the project documentation and the structured interaction between stakeholders and developers as key contributors to the success of ISM 2.0. He also confirmed the credibility of the ISM 2.0 status reports, and the associated risk and impact assessments.

The Project Development Team Lead at ibm.com was convinced early of the utility of the SE&A methodology. In specific, enhanced risk assessment and management was cited as a key advantage of the SE&A methodology. In his opinion, SE&A reduced overall risk, while also enabling better understanding of risks and their mitigation. “For once,” he said, “I felt in control of what was being delivered.”

3.6. Deployment of the SE&A Methodology within IBM Global Services

IBM Global Systems is currently sponsoring research to quantify the impact of formal SE&A methodology on the effectiveness and efficiency of IT development and integration projects [Barker and Verma, 2003]. One aspect of this study involves investigating the distribution of identified requirements and design defects over project phases. Figure 6 reflects preliminary results from this research where the ISM 2.0 project is compared with an average across 19 similar IT projects not using the formal SE&A methodology. A more detailed publication on this subject is forthcoming. Profile of the curves suggests a “cause and effect” relationship between early attention to requirements and architecture, and defect prevention in earlier versus later project phases when the correction cost is significantly higher [Boehm, 1981; Clark and Fujimoto, 1991; Fricke et al., 2000].

4. SUMMARY AND LESSONS LEARNED

Application of the SE&A methodology on ISM 2.0 was successful both from the customer and contractor perspectives. They acknowledged certain core features of this methodology that contributed to its successful implementation. These are listed below:

Definition of critical mission requirements: Defining the critical mission requirements was instrumental in providing focus along with facilitating the priorities and trade studies during the project. It also helped in clarifying the project scope.

Making schedule a critical mission requirement: Both ibm.com and IGS point to this as being critical to limit scope creep. Supportive of this approach, Boehm et al. [2004] report on a number of successful IT development projects that are on schedule, on budget, and meeting customer expectations using Schedule as an Independent Variable (SAIV).

Intimate stakeholder involvement throughout: Close involvement of the stakeholders helped develop trust between customer and contractor teams. The problem and solution domains were aligned with each other throughout the project, and the inevitable trade studies and change management were conducted relatively smoothly.

Traceability: Rigorous management of traceability provided the contractor project manager with an “architectural understanding” of risk and impact of proposed changes. Both the customer and contractor acknowledged the increased credibility of the communication as a result of good traceability management. The test organization was a key beneficiary of this practice, and consequently the quality of test cases was significantly enhanced.

Structured baseline change control: After an agreed to baseline, every change request was evaluated for its impact and its relevance to critical mission requirements. This promoted structured change control and discipline. ibm.com was cognizant that every change had consequences on project schedule and budget, and IGS recognized that every technical change with system level impacts had to be resolved with the owning stakeholder.

Scored reviews: Numerical and graded scoring of reviews brought consistency to the review process along with quantifying the maturity and quality of work products. This enabled better risk assessment and mitigation.

Important lessons were learned during the ISM 2.0 project. These are listed below:

Involve key software development personnel in the early SE&A activities: This is a critical lesson learned. While the SE&A team included experienced software architects, they did not have the necessary time or resources to develop a high level software design of sufficient quality. The consequences of not prioritizing the necessary resources from software development to support the SE&A team in the architecting and high-level design activities were underestimated. By the time the software team got involved (at PDR) they had to get familiar with the evolving ISM 2.0 architecture and requirements along with adapting to the SE&A methodology.
Scheduling of technical reviews relative to project decision check points: Based upon the ISM 2.0 experience, particularly the PDR, additional time was introduced in the framework between the reviews and the decision check points. This provided time for critical issue identification, assessment, and resolution before a DCP.

Allow sufficient time for requirements analysis before SRR: This can go a long way in reducing “flux” and the possibility of a scope creep over the life of the project.

5. CONCLUSION

The implementation of SE&A methodology on the ISM 2.0 project demonstrated that a motivated customer and contractor team could very rapidly adopt and apply systems engineering practices on a time critical and complex project. The advantages of the SE&A approach from the perspectives of the involved parties could briefly be summarized as follows:

The stakeholder perspective: The stakeholders felt they had an unprecedented transparency in how their requirements would be implemented. The SE&A approach also helped them to focus and to prioritize the scope according to the overall objective for this particular release. The project management on the customer side expressed their confidence with regard to having good control over all project risks. The high quality of project documentation augmented their confidence in the IGS team. The final product had fewer defects during initial operation than expected for a new application of this size and complexity.

The development team perspective: SE&A provided a structured way to interact with the customer regarding the technical scope and project progress. For the project manager this meant that more attention could be devoted to managing the project team and interacting with the customer at a business level. The SE&A team especially highlighted the value of a disciplined change control and technical reviews. The focus provided by a rigorous requirements baseline and traceability between requirements and high-level software design facilitated scope control on the project. The requirements driven high-level design provided the software developers with a better contextual understanding. Good requirements and early involvement allowed the test team to define test cases based on a good understanding of the requirements and the application architecture.

It would, however, be incorrect to conclude that the application of the SE&A methodology was the sole reason for the success of the ISM 2.0 project. Everyone interviewed explicitly acknowledged leadership and management support, and the highly motivated customer and contractor teams as being critical to project success. The authors believe that systems and project management, and leadership are mutually supportive. It is difficult to introduce a new way of project execution without leadership, motivation and management support. On the other hand, good project leadership and management depend upon a measurable reference framework and structured baseline control. The SE&A methodology provided this framework and the associated baselines. As appropriately pointed out by a team member, “the requirements and the architecture might have been the glue of the project, but it was the team that made it stick.”

ACRONYMS

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>BRR</td>
<td>Business Requirements Review</td>
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<tr>
<td>CDR</td>
<td>Critical Design Review</td>
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<td>CMMI®</td>
<td>Capability Maturity Model® Integration</td>
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<td>DCP</td>
<td>Decision Check Point</td>
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<td>IGS</td>
<td>IBM Global Services</td>
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<td>ISM</td>
<td>Interactive Solution Marketplace</td>
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<td>LSE</td>
<td>Lead Systems Engineer</td>
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<td>PDR</td>
<td>Preliminary Design Review</td>
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<td>PDTL</td>
<td>Project Development Team Lead</td>
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<td>PRR</td>
<td>Production Readiness Review</td>
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<td>RSD</td>
<td>Requirement Specification Document</td>
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<td>SAI IV</td>
<td>Schedule As an Independent Variable</td>
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<td>SE</td>
<td>Systems Engineering / Systems Engineer</td>
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<td>Test Readiness Review</td>
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