2-27-2013

Rapid Development: A Content Analysis Comparison of Literature and Purposive Sampling of Rapid Reaction Projects

Andrew R. Smith
Air Force Lifecycle Management Center

John M. Colombi
Air Force Institute of Technology

Joseph R. Wirthlin

Recommended Citation

Smith, A. R., Colombi, J. M., & Wirthlin, J. R. (2013). Rapid Development: A Content Analysis Comparison of Literature and Purposive Sampling of Rapid Reaction Projects. Procedia Computer Science, 16(0), 475–482. https://doi.org/10.1016/j.procs.2013.01.050

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Computer Science 16 (2013) 475 – 482

Procedia
Computer Science

Conference on Systems Engineering Research (CSER'13)
Eds.: C.J.J. Paredis, C. Bishop, D. Bodner, Georgia Institute of Technology, Atlanta, GA, March 19-22, 2013.

Rapid development: A content analysis comparison of literature and purposive sampling of rapid reaction projects

Andrew R. Smith[a]*, John M. Colombi[b], Joseph R. Wirthlin[b]

[a]*Air Force Lifecycle Management Center, 2640 Loop Rd West, WPAFB, 45433, USA*
[b]*Air Force Institute of Technology, 2950 Hobson Way, WPAFB, 45433, USA*

Abstract

In the current environment of military operations requesting short development timelines to counter insurgent tactics, the engineering team often searches for ways to deliver the "80% solution", typically in 6-12 months. These are labeled rapid development projects. A content analysis of best practices in commercial product development literature, where time to market is often a driving factor, was accomplished showing varying emphasis of systems engineering (SE) technical and technical management processes. This analysis confirms a preconceived notion of "plan upfront and early" by emphasizing Stakeholder Requirements Definition, Architecture Design and Technical Planning. A purposive sampling of Air Force Research Laboratory rapid development project managers and engineers was conducted to identify important SE processes and then compared to the literature content analysis. The results of this sampling did not strongly emphasize one process over another, however Architecture Design and Implementation scored higher among Technical Processes. Decision Analysis, Technical Planning, Technical Assessment and Data Management scored slightly higher among Technical Management Processes. Anecdotal evidence also emphasized iterating prototype designs based on early customer feedback, focusing mostly on managing critical risks and holding frequent early reviews until trust is built in the team.

Selection and/or peer-review under responsibility of Georgia Institute of Technology

Keywords: Defense Acquisition, Systems Engineering, Rapid Development, Rapid Reaction, Air Force Research Laboratory

The accelerated pace of change in the tactics, techniques and procedures used by adversaries of the United States has heightened the need for a rapid response to new threats. Fielding systems in response to urgent operational needs over the last half decade has revealed the DoD lacks the ability to rapidly field new capabilities for the warfighter in a systematic and effective way. – Report of the Defense Science Board Task Force on Fulfilling Urgent Operational Needs, July 2009

1. Introduction

Complex weapon systems require a level of organization to communicate designs, establish milestones and determine a schedule. The field of systems engineering (SE) has developed a framework with a track record of helping projects stay on cost and on time[1]. However, SE is perceived in the science and technology (S&T) culture

* Andrew Smith. Tel.: +1-937-255-5131
E-mail address: andrew.smith3@wpafb.af.mil.

Selection and/or peer-review under responsibility of Georgia Institute of Technology
doi:10.1016/j.procs.2013.01.050

of the Air Force Research Laboratory (AFRL) as non-value added[2,3]. Previous studies have investigated 1) How Department of Defense (DoD) rapid development/rapid acquisition organizations use innovation to meet urgent needs[2] and 2) How AFRL implements a systems engineering approach across all its projects to effectively deliver products to the acquisition community[4].

This effort synthesized the two ideas to identify the systems engineering practices necessary for successful rapid development efforts. If a traditional SE approach can be tailored and validated for rapid development projects, this approach would be well suited to meet user expectations by delivering quality products under aggressive schedules. The objective is to develop such a framework through literature review and validate by correlating the model with recent rapid development efforts in AFRL.

2. Methodology

A mixture of qualitative and quantitative methods was used to assess the relative importance of various processes and artifacts defined in Chapter 4, Systems Engineering, of the Defense Acquisition Guidebook (DAG), 5 May 2010[5] with respect to rapid development projects. Terms referenced in the definitions of each process were compared with those found in literature and evaluated based on importance. A management approach is proposed based on the relative importance of each process. A comparison with key activities identified by a purposive sampling of AFRL rapid development team members provides an evaluation of the proposed strategy compared to recent projects.

2.1. Content analysis of rapid development literature

Sources for the content analysis were drawn from business management literature as well as software development sources. The former having established the incentive of "time-to-market" and the latter as a newer source of management principles. Among well known product development texts, Wheelright and Clark's *Revolutionizing Product Development*[6], Robert Cooper's *Winning at New Products: Accelerating the Process From Idea to Launch*[7], and Smith and Rienertsen's *Developing Products in Half the Time: New Rules, New Tools*[8] as well as newer texts, *Product Lifecycle Development*[9] and *The PDMA Toolbook 3 for New Product Development*[10], were chosen from management literature. Martin's *Rapid Application Development*[11] along with articles by Millington and Stapleton[12], Beynon-Davies, et al[13] and Jones and Leung[14] were selected from the software development field. While newer texts referenced older ones, particularly Wheelright and Clark, content not associated with the primary author(s) was not included.

Processes were evaluated on their importance by a content analysis of each literature source. Importance in this study was equated with frequency of keywords for each SE process referenced in the texts. Keywords, listed in Tables 1 and 2, were selected from descriptions of each process as written in the DAG. The reader is referred to chapter 4, section 4.2.3 of the DAG for complete definitions of the technical and technical management processes.

Table 1: Keywords for Technical Processes

Technical Process	**Keywords**
Stakeholders Requirements Definition (SRD)	Requirements, Concept of Operations, Constraints, Stakeholder
Requirements Analysis (RA)	Functional Analysis, Performance Requirements, Functional Architecture
Architecture Design (AD)	Design Solutions, Logical Models or Views, Physical Architecture, Specification
Implementation (Imp)	System Elements, Production, Component Testing
Integration (Int)	Assembly, Interfaces, Incorporation, Prototype
Verification (Ver)	Demonstration, Inspection, Analysis, Test
Validation (Val)	Validation, Evaluation
Transition (Trans)	Installation, Integration, Fielding

Table 2: Keywords of the Technical Management Processes

Technical Management Process	Keywords
Decision Analysis (DA)	Trade Studies, Analyses- Alternatives, Supportability, Cost, Trade Off
Technical Planning (TP)	Scope of Technical Effort, Systems Engineering Plan
Technical Assessment (TA)	Technical Review, Program Review, Technical Interchange, Interface Control Working Group
Requirements Management (Req Mgmt)	Requirements, Traceability, Change Management
Risk Management	Risk- Identification, Analysis, Mitigation, Tracking
Configuration Management (Config Mgmt)	Technical Baseline, Functional Baseline, Allocated Baseline, Product Baseline, Change Management, Audits
Data Management	Technical Data, Records, Organization, Sharing
Interface Management (Int Mgmt)	Interface Specifications, Standards, Compliance

Keywords were counted throughout each of the texts. The frequency count of the keywords was normalized and assigned an importance score ranging from "1- Not Important" to "5- Extremely Important" as shown in Table 3. Normalized scores were calculated by the equation:

$$Score(normalized) = \frac{Score_i}{MAX(Score_i)} * 5 \quad (1)$$

Where $Score_i$ is the number of keyword references from each author for a process, i, $MAX(Score_i)$ is the maximum number of references from each author in a particular process. The quotient of the two is then multiplied by 5 to match the scale in Table 3.

Table 3: Importance Scale Descriptions

Importance Scale	Description
0-1	Not Important
1-2	Somewhat Important
2-3	Important
3-4	Very Important
4-5	Extremely Important

2.2. Purposive sampling of AFRL engineers

A purposive sampling was conducted between AFRL Scientist and Engineer (S&E) employees that have participated in rapid development projects. Individual interviews sought to establish a baseline of common practices for project managers. Interviews were conducted among 7 engineers and program managers with 2-6 years of experience in AFRL rapid development with projects ranging from 6 months to 3 years in schedule and $500,000 to $12M in budget. Backgrounds ranged from prior military service to active duty to career civilian with positions in and outside of AFRL. Team sizes for their rapid development projects ranged from 3 to 12 people.

Interviews with key personnel (project managers and engineers) on rapid development projects provided an evaluation of the current emphasis placed on each process. Each process was assessed by the author on a 1-5 scale of importance based on verbal responses to a standard list of questions. The criteria were derived from SE technical process outputs as outlined in the INCOSE Systems Engineering Handbook, v3.1.

These definitions were chosen over standard DoD Acquisition terminology to encompass activities that met the intent but weren't specifically defined by DoD terminology. Some criteria, however, were augmented by DoD

Developmental and Operational Test activities where the INCOSE SE handbook provided insufficient measures to stratify the formality of a particular process (i.e. Verification and Validation). These scores were then compared with the model determined by the content analysis of product development literature.

3. Results and Analysis

3.1. Content analysis

Figures 1a and 1b display the results of the content analysis. Based on the literature, the most important Technical Processes are Stakeholder Requirements Definition, Architecture Design and Integration. Requirements Analysis, Implementation and Transition received low scores having not been emphasized in the texts. Error bars representing the standard deviation for each score are also shown. While these large deviations are based on a smaller set of literature sources, the general trend for the scores is still valid. A larger set of literature sources along with frequency counting software could reduce the statistical error without overburdening the researcher.

The most important Technical Management processes for rapid development are Technical Planning, Decision Analysis, Risk Management and Technical Assessment. There is a general concurrence that Technical Planning is a must for product development as this process has the highest score with one of the smallest deviations. All other Technical Management data show a mixed emphasis for each of the other processes. Decision Analysis, Technical Assessment, Risk Management are slightly more emphasized while Requirements Management, Configuration Management and Data Management slightly less and Interface Management almost not at all.

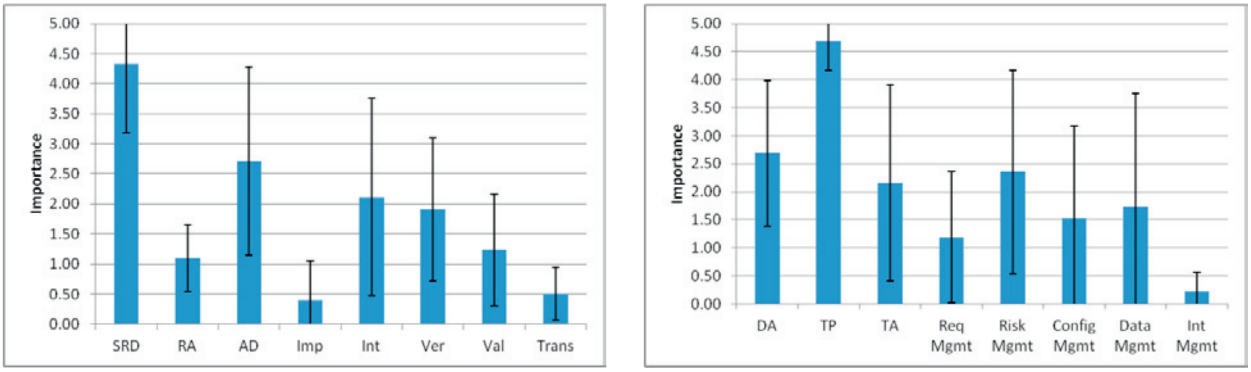

Fig. 1. (a) Technical Process Scores; (b) Technical Management Process Scores

By converting the scores to an overall percentage, as shown in Figures 2a and 2b, a project manager can weigh each process relative to the other and plan out a project. The percentages were calculated by dividing the process score by the total score in each case. Since these are process resource allocations it is more reasonable to apply these percentages to the management of a project rather than the overall budget, which could include high-cost items. It can be helpful to think of applying the percentages to the time allotted during regular meetings or hours in an overall project schedule or relative team sizes.

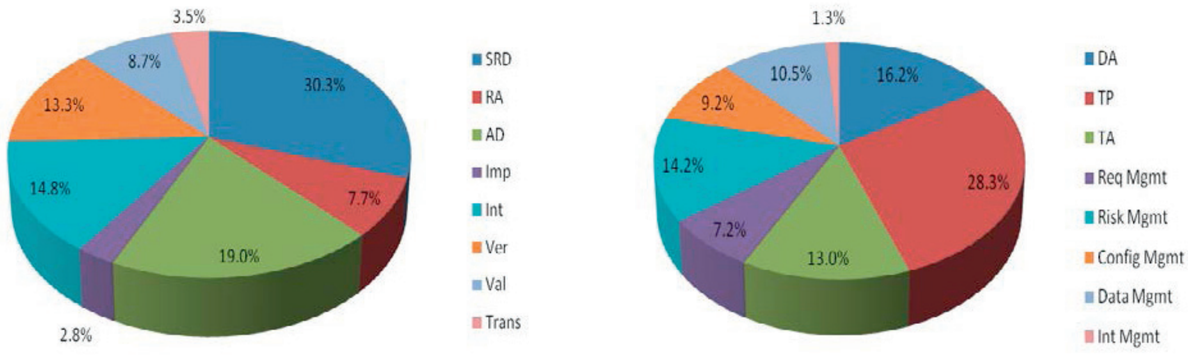

Fig. 2. (a) Technical Process Resource Allocation; (b) Technical Management Process Resource Allocation

One concept not captured in evaluating the different processes was iteration. Most product development sources named process iteration as a key strategy. Once a design is created, it is presented to the stakeholders for feedback and refinement. This could happen multiple times; the Rapid Application Development group suggests at least three iterations.

The shortcomings of this evaluation to capture the importance of design iteration could give project managers a false impression that a single pass development strategy using the above resource allocations will produce a successful product. One strategy would be to integrate the user into the development team providing constant feedback as the project moves from requirements to specifications to assembly and test. A 2010 Software Engineering Institute of Carnegie Mellon suggested incorporating Agile methods, specifically iterations within the design cycle.[15]

3.2. Comparison of literature and AFRL rapid development engineers

When combined, the content analysis and purposive sampling results offer an interesting comparison. Interviews were conducted by the author where a standardized set of 3-5 questions assessed the importance for each category. The questions were derived from technical and technical management process outputs described in the Systems Engineering Handbook, v3.1. These definitions were chosen over standard DoD Acquisition terminology to encompass activities that met the intent but
weren't specifically defined by DoD terms. The importance according to the AFRL engineers was then compared to the importance as determined by the content analysis. Figures 3a and 3b show both sets of scores for the SE processes. The solid bars are from the content analysis of rapid development literature, while the striped bars are from the purposive sampling of AFRL engineers.

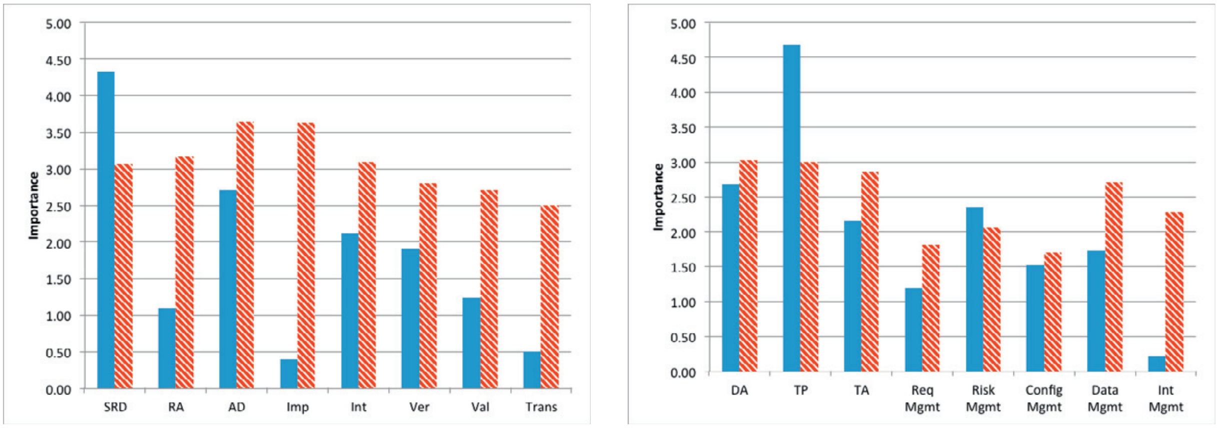

Fig. 3. (a) Combined Technical Process Scores; (b) Combined Technical Management Process Scores

While both sets of Technical Process scores agree that Architecture Design is important, the literature does not emphasize Requirements Analysis (RA) nor Implementation to the same degree that the AFRL S&E's place importance on those processes. The literature does, however, place a larger emphasis on Stakeholders' Requirements Definition.

The main discrepancies in Technical Management are in Technical Planning and Interface Management. The literature places the most emphasis in determining the scope of the technical effort and developing a systems engineering plan to cover all aspects of a project. However, many of the interviewees attested that iterating on a design with feedback from the user was more important than developing a "fire-proof" plan. Interface Management was emphasized more among AFRL S&E's than in the literature.

This could be due to the integrated nature of defense products especially with sensor technologies that are designed to push information and intelligence products across an enterprise of users. The literature is either not concerned with products integrated with external interfaces, such as designing a portable CD player, or assumes that the external interfaces exist and are well defined, like the USB ports on your personal computer, and thus assigns it relatively little importance.

To summarize the technical process scores, the literature and AFRL S&Es agree to the general principle of "up-front and early" when conducting rapid development. The literature emphasized Stakeholders Requirements Development and Architecture Design. The S&Es were more uniform in their results and agreed on the importance of Architecture Design but also emphasized Implementation. The technical management processes were also generally similar, but the literature showed Technical Planning was of stronger importance and Interface Management of lesser importance when compared to the AFRL S&E scores.

3.3. Analysis and Additional Comments

While effort was taken to include a broad set of perspectives, the literature chosen for examination is not an exhaustive listing of rapid development sources. Further, having a sample size of eight texts in the content analysis and seven AFRL S&E experts lead to the high standard deviations shown in Figures 1(a) and 1(b). However, without the aid of content analysis software or access to additional practitioners of AFRL rapid development projects, these sources were chosen given time constraints of the study.

A possible explanation for differences in both analyses is the "pundit vs. practitioner" effect. With respect to the "pundits", the content analysis of the literature has shown a strong preference for one process over another, in this case Tech Planning vs. Interface Management. The authors may be assuming a level of understanding within their intended audience that masks the relative importance of each process. They could also overemphasize processes that either were historically ignored or were executed poorly.

From the point of view of the "practitioner" there may be a stronger emphasis on the processes that are requirements due to policy or practicality. Most of the technical process scores cluster around 2.75, with a score of 3 meaning the process was "important" vice "very important" or "not important" and the activities within the process were neither fully implemented nor fully ignored. In this study, the literature deems Implementation as "not important". This contrasts with the AFRL engineers which score it as "important". In reality, a project must implement the design, otherwise there would be no product to test or deliver.

Many interviewees had comments that could not be captured by the survey on how they execute a rapid development project. The following statements were from individuals and not themes expressed by multiple people. One interviewee likened rapid development to a "jazz [band], not an orchestra." Another noted that he would conduct frequent "Interim Program Reviews" with newer teams to build up the trust in the group and cut back once the team was performing at a sufficient level. His advice on time management was to "identify the most critical risks" to the project, mitigate during weekly, hour-long conference calls and that rapid development "required strong leadership." The less critical risks were often left to individual team members, allowing senior team members to focus on the hardest problems. One suggested that you don't use Microsoft Project and that schedules don't show activities finer than one week. Another interviewee said he didn't receive enough training on risk management when applied to rapid development. One interviewee felt milestones that were schedule based vice event based were counterproductive. He felt that reviews were being held to solve problems for issues that "should be caught before test reviews". When applied to software development, he felt that rapid development didn't afford time to check bugs in code written by geographically separated programmers, and that there "wasn't time for QA [quality control].

4. Conclusions and Future Work

The objective of this study was to determine key Systems Engineering Processes emphasized by product development literature that could be implemented within AFRL rapid development projects. From the literature, Stakeholders Requirements Definition, Architecture Design and Technical Planning were strongly emphasized when compared to the other processes. This agrees with the anecdotal lesson learned "plan up front and early". While interviewees agreed that up-front technical planning was important to maintaining short schedules, progress in delivering a prototype iterating the design based on user feedback was as important. Based on these results, project managers and chief engineers participating in future AFRL and other rapid development projects should focus on these processes early on in the projects' lifecycle. Senior leaders should encourage training in developing project requirements, architectures and holding event-based reviews.

The framework developed in this study may serve as a guide for project managers of rapid development projects. Using the prescribed percentages on a pilot program would validate it as a usable model. Further refinement by additional literature and S&E sources would reduce the statistical uncertainty of the existing framework. AFRL's rapid development teams could be made aware of the findings codified by modifying the current AFRL instruction for rapid development or as an accompanying AFRL Manual. The outcome of the importance of the SE processes was highly dependent on the materials chosen. The methodology can be implemented further by including more product development literature or by focusing on a particular field (i.e. software development) and comparing to case studies within that field. This research was conducted to continue previous studies of rapid development within AFRL. The AFIT theses of Capt David Solomon and Majors Behm, Pitzer and White should also be consulted for further consideration.

References

1. E.C. Honour, Understanding the Value of Systems Engineering, *INCOSE International Symposium*, Toulouse, 2004.

2. S. Behm, J.B. Pitzer, J. White, A Tailored Systems Engineering Framework for Science and Technology Projects, Master's Thesis, Air Force Institute of Technology, Wright Patterson AFB OH, 2009

3. W. Doyle, Systems Engineering in the S&T Environment, Briefing Charts, WPAFB OH, 2008

4. C.D. Soloman, An Analysis of Methodologies & Best Practices for Rapidly Acquiring Technologies to Meet Urgent Warfighter Needs, Master's Thesis, Air Force Institute of Technology, Wright Patterson AFB, OH, 2008

5. Department of Defense, Defense Acquisition Guide, Washington, 2010

6. S.C. Wheelwright, and K.B. Clark, Revolutionizing Product Development - Quantum Leaps in Speed, Efficiency and Quality. New York, NY, The Free Press, 1992

7. R.G. Cooper, Winning at New Products, Reading, MA, Addison-Wesley Publishing, 2001

8. P. Smith and D. Reinertsen, Developing Products in Half the Time, Van Norstrand, Reinhold, New York, 1990

9. M. Grieves, *Product Lifecycle Developmen,.* New York, NY, McGraw-Hill, 2005
10. Githens, Gregory, “Using a Rolling Wave for Fast and Flexible Development,” in The PDMA ToolBook 3 for New Product Development, Eds Abbie Griffin and Steven Somermeyer, Hoboken NJ, John Wiley and Sons, Inc, 2008
11. Martin, James. Rapid Application Development, New York, NY, MacMillan, 1991
12. D. Millington, J. Stapleton, "Developing a RAD standard," Software, IEEE , vol.12, no.5, Sep 1995, 54
13. P. Beynon-Davies, H. Mackay, D. Tudhope, “‘It’s lots of bits of paper and ticks and post-it notes and things . . .’: a case study of a rapid application development project,” Information Systems Journal, Vol. 10 Issue 3, Jul 2000, 195
14. G. Jones, V. Leung, "Visual surveillance: a systems engineering approach for rapid development,", The IEEE International Symposium on Imaging for Crime Detection and Prevention, 7-8 June 2005, 161
15. M.A. Lapham, R. Williams, C. Hammons, D. Burton, and A. Schenker, Considerations for Using Agile in DoD Acquisition, Software Engineering Institute, Carnegie Mellon, April 2010