Requirements for Process Management Support: Experience from the Japanese Aerospace Industry

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ABSTRACT
In recent years, software process management has been a major topic in research and industry. But only few of the proposed research approaches have been transferred into industrial practice and significant challenges remain in practice. Today organizations have to deal with complex process model hierarchies, which are often used in a distributed collaboration context. This experience report outlines current practitioners' requirements regarding software process management and their use to evaluate and select a suitable technology to support the Japan Aerospace Exploration Agency's software process management activities.

Categories and Subject Descriptors
D.2.9 [**Management**]: Software process models (e.g., CMM, ISO, PSP)

General Terms
Management, Documentation, Standardization

Keywords
Software process management, practitioner's requirements

1. INTRODUCTION
Many different aspects of process supporting technologies have been developed in academia and by commercial providers over the last two decades. Still, in practice, significant problems remain regarding processes and process management. Particularly in large organizations from safety-critical domains, processes are becoming increasingly large and complex. Today these organizations no longer deal with one process model, but rather with process model hierarchies, which are often used in a distributed collaboration context. These challenges make process management activities [3] [9] increasingly important for maintaining and supporting software processes adequately throughout their entire lifecycle. This paper sheds some light on the requirements regarding software process management from the viewpoint of the Japan Aerospace Exploration Agency (JAXA).

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The aerospace domain is known for its high safety and reliability requirements with respect to both hardware and software. JAXA acquires most of its technology and software from external suppliers, only a fraction is developed internally by JAXA. Projects are mainly conducted in a distributed collaboration setting. All suppliers that collaborate with JAXA are obliged to obey specific quality criteria and to provide appropriate proof. Hence, for software, comprehensive tests and analytical quality assurance measures are used. Additionally, means of constructive quality assurance are promoted by mandating the use of specific processes during software development. For this purpose, JAXA provides a standard software development process for all units (ground segment, launch vehicle, and spacecraft) that must be tailored to the respective unit's and project's specific needs. This leads to a three-layer process architecture, specifying the organization-wide, unit-tailored, and project-specific processes [4].

Process management responsibility lies with the Software Engineering Team of JAXA's Engineering Digital Innovation Center (JEDI). The Software Engineering Team is thus responsible for the creation, establishment, maintenance, and improvement of all software development processes. In a previous project with Fraunhofer IESE, JAXA's process engineers already developed a sound process standard for the organization-wide process level. However, tailoring it to every unit and every project proved to be a rather effort-intensive activity, in particular with the current Microsoft Word-based documentation. Hence, in order to better support process management activities such as tailoring, JAXA decided to move towards more sophisticated technological support. In this context, the current collaboration between JAXA and IESE focused on eliciting appropriate process management requirements and on initially validating those requirements by applying them for the evaluation of different software process management technologies.

This paper is organized as follows: Section two briefly discusses related work. Section three describes the approach employed for developing the requirements and gives an overview of the results. Section four presents initial evaluation results. A summary and a discussion of experience conclude this paper.

2. RELATED WORK
The idea to use systematic process management to support software processes throughout their entire lifecycle is strongly influenced by Osterweil's work in the field of software processes in which he states that "software processes are software, too" [11]. In analogy to software products, this means that software processes also need to be managed systematically. Consequently, support is needed that allows performing effective software

process management in an efficient manner. During the last two decades, a multitude of different approaches and languages for process modeling have been developed [1] [11]. In addition to this, more or less encompassing process management support in the form of process-centered software engineering environments (PCSEEs) has been developed [1] [3] [9]. However, only very few of the proposed approaches were transferred into industrial practice [8]. A multitude of home-grown solutions, varying from text-file or Wiki-based solutions to graphical representations in Visio or PowerPoint, can be encountered in different organizations.

In the process management research area, requirements for process support have been defined from different perspectives and for different process needs [1] [2] [6] [10]. But as only few of the developed approaches could be transferred into industrial practice, Fuggetta [8] states that several relevant practitioners' requirements have not been addressed sufficiently. These include, for example, describing processes with the purpose of understanding and communicating them within the practitioners' organization [1] [8]. In line with these findings, Fuggetta argues that process support must be easy to use, intuitive, and not over-formalized in order not to become a burden.

Furthermore, additional requirements became relevant in the context of process management. Among these are capabilities for managing increased flexibility, distribution, and complexity of process models [9]. Hence, the question of how to support process management remains relevant [5] [9] and any answers to it should address both functional and non-functional practitioners' requirements.

3. ELICITATION APPROACH FOR PROCESS MANAGEMENT SYSTEM REQUIREMENTS

The collaboration between this paper's authors can be characterized as a distributed project, where process experts from IESE were located in Kaiserslautern, Germany and JAXA's Software Engineering Team was located in Tokyo, Japan. Therefore, we decided to follow a two-step approach for requirements elicitation. Project work was performed iteratively within these two steps, with a total of five video-conferences held to discuss major issues and achieve a common viewpoint.

JAXA's Software Engineering Team is responsible for the management of all software development processes within JAXA. Consequently, we decided to start elicitation by deriving an organizational concept of all currently relevant process management activities. In the second step, these activities were used as a basis for defining corresponding functional requirements that a suitable process management system should provide. Additionally, we elicited non-functional requirements. The overall approach of elicitation thus consisted of the following steps:

(1) Define process management concept: Derive an organizational concept containing relevant process management activities.

(2) Refine process management concept into requirements: Define functional requirements for a process management system that shall support the relevant activities. In addition, define non-functional requirements.

In the following, the steps of the elicitation approach are discussed in more detail.

3.1 Define Process Management Concept

For the derivation of the organizational concept of process management activities, we reviewed existing literature to support the discussion. Gruhn [9], for example, presents a basic process management lifecycle that includes the activities of modeling, analysis, process support, and continuous improvement.

A more general organizational concept that can integrate process management activities and was successfully used for the institutionalization of continuous improvement was proposed by Basili and Rombach [6] in the form of the Experience Factory (EF). Additionally, the concept of the EF was successfully applied in the space domain and makes an explicit distinction between a project organization and an experience organization. We thus based our process management concept on the EF. Hence, we elicited relevant activities by creating high-level use cases and discussing them during a workshop performed via video-conference, where we also confirmed the suitability of the experience factory concept.

One of the tasks of JAXA's software engineering team is to systematically capture experience from projects and transform it into reusable processes and artifacts. The team is thus an organizational unit that supports JAXA's project organization. Hence, it can be seen as the "Experience Organization" within the Experience Factory concept. In contrast, the projects performed within JAXA's different units represent the "Project Organization". In accordance with the EF concept we defined two perspectives of process management, an organizational perspective and a project perspective. One central process management activity we derived is "Experience Management", which links the two perspectives described above. In summary, we derived seven main activities, which are shown in Figure 1 (left side).

The organizational perspective consists of the following activities:

(1) *Process Definition* deals with process modeling as such and also with the provision of an adequate process description and guidance.

(2) *Process Maintenance* deals with systematic process model analysis and maintenance.

(3) *Process Publishing* deals with providing the process documentation to the process users.

The project perspective consists of the following activities:

(4) *Process Tailoring* deals with tailoring JAXA's processes to specific units and projects.

(5) *Supplier Monitoring* consists of tasks for informally controlling the process performance of suppliers in distributed collaborative projects.

(6) *Project Management* deals with project management activities like project planning and creating a work-breakdown structure in accordance with JAXA's process model.

Organizational and project perspectives are linked by the activity for experience management:

(7) *Experience Management* deals with the systematic gathering, analysis, and packaging of experience.

This set of activities was used as a basis for deriving more detailed functional requirements for the process management system that shall support JAXA's process management activities.

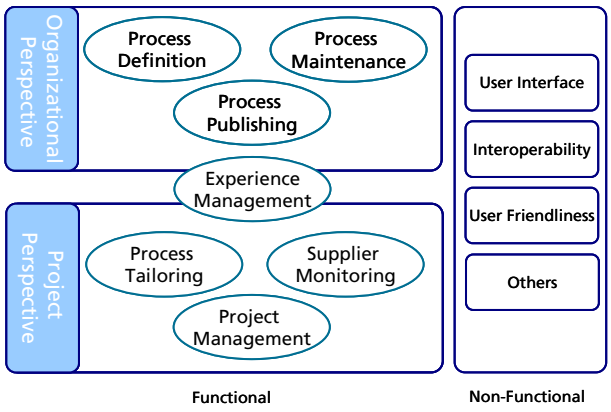

Figure 1. Requirements categories

3.2 Define Process Management System Requirements

Using the resulting set of activities from the first step, the second step focused on deriving a refined list of functional requirements of a process management system that would be suitable for JAXA. For this purpose, we held two more video-conferences and gave a live demonstration in order to gain a deeper understanding of the actual needs and thus to be able to derive more refined functional requirements. The functional requirements were categorized according to the relevant process management activities. Due to space restrictions we can only present a high-level overview of the required functionalities.

(1) Process Definition: The system shall provide functionality for process modeling and for specifying textual descriptions of the process model and the terminologies used. The system shall be model-independent and provide functionality for the provision of different process guidance artifacts.

(2) Process Maintenance: The system shall provide process model libraries, configuration management, and process model analysis capabilities. Furthermore, it shall ensure model consistency when changes are performed.

(3) Process Publishing: The system shall provide functionality for document-based publishing and web-based publishing.

(4) Process Tailoring: The system shall provide information for process tailoring. Further, it shall provide functionality for performing and documenting the tailoring.

(5) Supplier Monitoring: The system shall provide information for supplier monitoring, i.e., information and guidance on how to best perform supplier monitoring.

(6) Project Management: The system shall provide basic project management functionality, i.e., capabilities for project planning and creating work-breakdown structures in accordance with JAXA's process model.

(7) Experience Management: The system shall provide functionality for the systematic gathering, analysis, and packaging of experience.

Additionally, we elicited non-functional requirements, as these were regarded as important for the acceptance of such a process management technology. Hence, we defined non-functional requirements for:

(8) User Interface: The system shall be able to provide JAXA-specific views of the process model information. Furthermore, it shall provide process visualization capabilities, functionality for easy model editing, and adequate presentation of data to the user. Finally, controlled user access shall be provided.

(9) Interoperability: The system shall support integration with other organizational management systems, external communication systems, and external project-related systems.

(10) User Friendliness: The system shall provide easy installation and configuration. Furthermore, it shall provide ease of use.

(11) Others: This section subsumes different further non-functional requirements, like adaptability, continuous support, and costs of the system.

Figure 2 presents an excerpt of the requirements for the process definition activity, particularly the sub-section about relations that include process model hierarchies.

1.1.1.8. Relations

1.1.1.8.1. Produces, consumes, modifies relation

1.1.1.8.2. Successor, predecessor relation

1.1.1.8.3. Decomposition hierarchy: [is a structural relation among same or different elements]

1.1.1.8.3.1. Activity hierarchy

1.1.1.8.3.2. Process hierarchy

1.1.1.8.3.3. Process model hierarchy

1.1.1.8.3.4. Artifact hierarchy

1.1.1.8.4. Cross-reference: [is relation of elements between standards from different domains]

1.1.1.8.4.1. Activity cross-reference (i.e. linkages of standards from different domains)

1.1.1.8.4.2. Process cross-reference (i.e. linkages of standards from different domains)

Figure 2. Excerpt from requirements

4. PROCESS MANAGEMENT SYSTEM EVALUATION AND VALIDATION

Based on the elicited set of requirements, two evaluation steps were performed:

(1) Evaluation of process management system technology alternatives: This step included prioritization of the requirements as well as an evaluation of different technologies and the selection of one technology based on the evaluation results.

(2) Initial validation of the technology selection and of the requirements: This step included training sessions with the chosen technology and self-responsible usage of the

technology on a specified example case. Additionally, follow-up validation of the technologies and the requirements suitability was performed.

The following sub-sections present details and selected results from these two steps.

4.1 Evaluation of Process Management System Technology Alternatives

The first step in the application of the elicited set of requirements consisted of their prioritization, which was performed by JAXA's process engineers. Hence, we were able to obtain a more refined picture of the current needs and the importance of the respective requirements. The prioritization was aggregated to the level of the eleven requirements categories. The top five categories resulting from the prioritization were in order of ranking: 1.) User Interface, 2.) Process Definition, 3.) Supplier Monitoring, 4.) Experience Management, and 5.) Process Publishing.

On the basis of the prioritized requirements, we evaluated a set of process management system technology alternatives. This set of technologies consisted of four different groups. For each group, we chose one representative process management system. Thus, our evaluation contained one representative of commercial desktop solutions, one commercial web-based solution, one open-source desktop solution, and one open-source web-based solution.

The technology evaluation was performed by evaluating every requirement for every process management system on a three-level scale (Fulfilled, Partially fulfilled, Not fulfilled). Additionally, we used a comment field to provide the rationales for the respective rating. In a first step, these individual ratings were aggregated to a level that represents specific functionalities/ capabilities within the eleven requirements categories. Then these ratings were further aggregated to the level of the eleven categories.

Based on the prioritized requirements and the consolidated ratings, the best-suited process management system was selected by JAXA's Software Engineering Team. None of the systems covered all of the requirements. The best suited systems achieved the following results in the top five requirements categories (sum of full and partial requirements fulfillment): User Interface (85%), Process Definition (91%), Supplier Monitoring (100%), Experience Management (83%) and Process Publishing (64%).

4.2 Initial Validation of the Technology Selection and of the Requirements

The purpose of the second step was to validate the selection of the process management system and, additionally, to at least qualitatively validate the elicited set of requirements.

During a two-day face-to-face workshop with engineers from JAXA's Software Engineering Team, we performed a training session on the selected process management system in order to introduce the functionalities of the system and to make it as easy as possible to start using the system. The training included a theoretical introduction to the basic usage concepts as well as guided usage of the system. Furthermore, JAXA's engineers were required to use the system on their own to solve several exemplary tasks taken from JAXA's process standard context. These tasks mainly included process modeling, tailoring, and publishing.

After this workshop, we performed the validation by using a questionnaire based on the Unified Theory of Acceptance and Use of Technology (UTAUT) [13]. This questionnaire consisted of three major parts. The first section of the questionnaire dealt with "ease of use" and "usefulness" of the selected process management system. The second section of the questionnaire focused on the requirements categories and the "usefulness" of the functionalities that the system provided in these categories. Additionally, we qualitatively evaluated specific difficulties or issues, including missing functionalities for the requirements categories, by using telephone interviews and text fields in the questionnaire.

Figure 3 presents the evaluation results, with "1" representing a low rating of the respective question, and "5" representing a high rating. At the current state of the evaluation, only two of JAXA's engineers have participated, but we would still like to briefly discuss these initial evaluation results. In particular, further evaluations are planned when the system is rolled out in the organization.

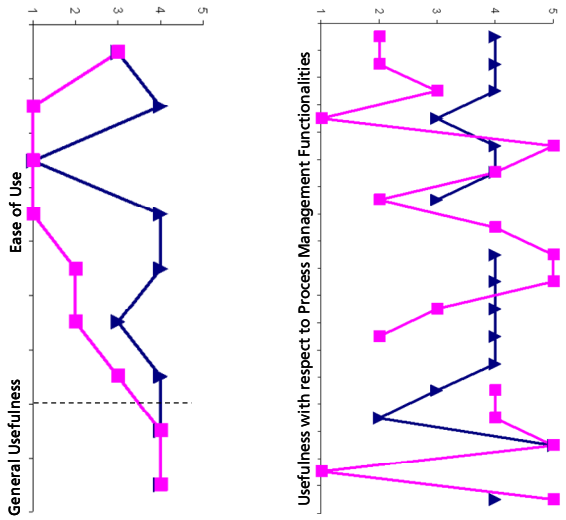

Figure 3. Overview of evaluation results

One of the participants (triangle) gained more practical experience with the system as he continued to use the system after our workshop. The other participant (rectangle) was only involved in the workshop.

In the section that deals with "ease of use" and "usefulness" (see Figure 3 left side), we find that the more experienced engineer gives equal or higher ratings for the individual items, compared to the less experienced engineer. The discrepancy is higher for ease of use and lower for usefulness. One reason for the higher discrepancy regarding ease of use might be the different levels of experience. The ratings for usefulness show that the system was perceived as useful by both engineers.

With respect to the "usefulness" of specific functionalities (see Figure 3 right side), we find that the experienced engineer rates most functionalities as useful. His ratings have low variance. In contrast, the less experienced engineer has higher variance in his ratings, considering some functionalities as very useful and others as less useful.

In the qualitative evaluation of the requirements and specific issues we found that several comments dealt with practical usage issues with respect to the selected process management system. Other items that were discussed included how to realize the functionalities that were listed in our requirements but not provided by the system. However, there were no comments or remarks with respect to missing functionalities that were not covered by the requirements. Although we cannot make general statements about the completeness or general adequacy of the elicited set of requirements, this fact can be seen as an indicator for the suitability of this set of requirements.

5. CONCLUSIONS

The purpose of this experience report was to shed some light on current requirements for software process management from the viewpoint of the Japanese aerospace domain.

The set of requirements we elicited contains eleven categories of requirements. Seven categories cover functional requirements and four categories cover non-functional requirements. Based on these categories and their prioritization, we can see that process definition or modeling is still among the most relevant topics. Consequently, process management technologies have to support process models that are used in industrial practice.

We find that disseminating processes and associated experience are regarded as further important topic. Experience management, process publishing, and partly user interface requirements deal with the systematic capturing of software development experience on the one hand, whereas on the other hand, there is a strong focus on transforming experience into reusable process artifacts that can be shared easily within the organization. Process management technology support is mainly seen as a facilitator in this respect.

Additionally, we find that distribution is a further relevant aspect. The focus of required support lies on gaining and exchanging experience on how to perform best within distributed collaboration scenarios, and not so much on a sophisticated supplier control mechanism. Process enactment support requirements mainly deal with project-specific tailoring of the process model. In particular, process performance support was regarded as less important, as the processes are performed at the suppliers' sites.

We applied the set of requirements for the evaluation of process management system alternatives and selected the alternative that best suited JAXA's purposes for further validation. Based on the selected system, we performed a validation of the selection and an initial qualitative evaluation of the set of elicited requirements. We found that the selected alternative is useful for application in JAXA's process management context, although the initial learning curve might be steeper than anticipated. Additionally, the results indicate that the set of requirements seems to cover current requirements for software process management from the perspective of the Japan Aerospace Exploration Agency.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Ambriola, V., R. Conradi, and A. Fuggetta. 1997. Assessing process-centered software engineering environments. *ACM Transactions on Software Engineering and Methodology (TOSEM)* 6, no. 3: 283–328. DOI= 10.1145/258077.258080

[2] Angkasaputra, N., Bella, F., and Riddle, W.E. 2005. Perspective-based evaluation of software process management tool suites. In *Proceedings of the 3rd World Congress for Software Quality* (Erlangen, Germany, September 26 – 30, 2005).

[3] Arbaoui, S., Derniame, J. C., Oquendo, F., and Verjus, H. 2002. A comparative review of process-centered software engineering environments. *Annals of Software Engineering* 14, no. 1: 311–340. DOI= 10.1023/A:1020513911052

[4] Armbrust, O., and Ocampo, A. 2009. Software Process Lines and Standard Traceability Analysis. In *Proceedings of the 7th Workshop of Critical Software* (Tokyo, Japan, January 14-15, 2009).

[5] Armbrust, O., Ebell, J., Hammerschall, U., Münch, J., and Thoma, D. 2008. Experiences and Results from Tailoring and Deploying a Large Process Standard in a Company. *Software Process: Improvement and Practice (SPIP)* 13, 301-309. DOI= 10.1002/spip.v13:4

[6] Basili, V., Caldiera, G. and Rombach D. 1994. Experience Factory. In *Encyclopedia of Software Engineering* 1, 469-476.

[7] Dowson, M., and Fernström, C. 1994. Towards requirements for enactment mechanisms. *Software Process Technology*, vol. 772: 90-106. DOI= 10.1007/3-540-57739-4_13

[8] Fuggetta, A. 2000. Software process: a roadmap. In *Proceedings of the Conference on the Future of Software Engineering* (Limerick, Ireland, June 4-11, 2000) ICSE '00. ACM, New York, NY, USA, 25-34. DOI= 10.1145/336512.336521

[9] Gruhn, V. 2002. Process-centered software engineering environments, a brief history and future challenges. *Annals of Software Engineering* 14, no. 1: 363–382. DOI= 10.1023/A:1020522111961

[10] Lonchamp, J. 1993. A structured conceptual and terminological framework for software process engineering. In *Continuous Software Process Improvement, Second International Conference on the Software Process*, 41-53. DOI= 10.1109/SPCON.1993.236823

[11] Rombach, H. D., and Verlage, M. 1995. Directions in Software Process Research. In *Advances in Computers*, Elsevier, vol. 41: 1-63.

[12] Osterweil, L. 1987. Software processes are software too. In *Proceedings of the 9th international conference on Software Engineering* (Monterey, USA, March 30-April 2, 1987) ICSE '87. IEEE, Los Alamitos, CA, USA, 2-13.

[13] Venkatesh, V., Morris, M., Davis, G., and Davis, F. 2003. User Acceptance of Information Technology: Toward a Unified View. *Management Information Systems Quarterly* 27, no. 3: 425-478.