BEST USE OF KNOWLEDGE IN A SPACE PROGRAM
Managing the Correlated Technologies

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Abstract: This paper presents an ongoing work being developed at the Institute of Aeronautics and Space (IAE) to provide a process and a system to support the knowledge management of new technologies applied in the conception and development of the Brazilian Satellite Launcher Program. This management is not only necessary to organize the actual research efforts but also to identify communalities and necessities for strategic planning of future research projects and development activities. The results of the research projects are usually new technologies that ought to be employed in the development of the Launcher Program. The proposed knowledge management system will not only allow the assessment of these new technologies but will also help in the definition and planning of the research topics in each important area of this multidisciplinary program, according to the Institute strategic goals and space mission.

1 INTRODUCTION

In general space programs deal with complex systems, which involve not only the employment of high technology, but also the investigation of solutions for new and singular problems that arise in the space realm. Complex space systems require some very serious systems engineering with careful planning and attention to the process (Sage, 1992). The management of the knowledge and technology of these programs is becoming even more important as the complexity increases.

This paper presents an ongoing work being developed at IAE to provide a process and a knowledge management system to deal with new technologies applied in the conception and development of the Brazilian Satellite Launcher Program. This paper is organized in five sections. Section 2 presents some aspects of the complexity of space systems engineering. Section 3 presents the proposed process for managing technologies, and Section 4 briefly comments some aspects of the knowledge management system implementation. Section 5 draws some conclusions of the work.

2 THE COMPLEXITY OF SPACE SYSTEMS ENGINEERING

Space systems engineering involves the challenges of a severe launching environment, where the structural elements of both launcher and satellite must be designed to resist the remarkable forces. Sensitive electronics and sensor elements must also resist the shock conveyed by pyrotechnic devices used for the launcher's stages separation and the deployment of a satellite. There are also tight constraints on both mass and volume that impact in costs (Wertz and Larsen, 1996).

Technological projects, unlike most others, have the potential to fail to meet their goals. If it is a new technology, the implied risks are higher. Innovation means ideas applied successfully, differing for invention that is an idea made visible (Mckeown, 2008). Innovation generates technology and it results from research and experimentation, which implies that the organization has to clearly define its goals for conducting the necessary research.

In order to prioritize specific areas of knowledge for investment, a plan has to be elaborated based on strategic goals and directives for the space program. This plan is crucial for kicking off a knowledge management process.

The establishment of an efficient system to deal with innovation at IAE is based on concrete

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information about the relationship between the main research areas and Launcher Program strategic goals. The research groups (RGs) are composed by research topics (RTs), which have related research projects (RPs). The research projects are the main way to generate technology applied to the Launcher development.

The core idea behind the advanced research projects at IAE is to pour over the necessary investments when conducting a space engineering project. Therefore, a collection of new technologies in their early development stages is produced as a result of these projects. However, the incorporation of emerging technologies in a real mission needs adequate system engineering techniques to enable the transition and insertion of these technologies into current and future space systems. This process does not start when the research project is brought to an end, but back to the initial research project proposal.

3 THE PROCESS OF KNOWLEDGE EXPLORATION

3.1 Planning for Effectiveness and Efficiency

There are some fundamental factors that are considered during the process of knowledge management and exploration in order to reach the desirable effectiveness and efficiency. They are:

- **Knowledge Transfer Factor**, which effectiveness will be achieved only when there is an efficient process, incentive, or reward for delivering a particular required technology.

- **Research Project Relevance Factor,** which is achieved by a multidisciplinary approach to asses and approve new projects proposals, avoiding to approve projects that bring up solutions for problems that were not even defined.

- **Human Resource Factor,** which is very strategic in this context (Armstrong, 2006), whereas. knowledge and experiences acquired by the teams and lessons learned are taken into account when deciding which research projects proposal to approve.

- **Cost and Time Factor,** which is important to assess the costs related to the research conduction, considering the time the new technology will take to become mature enough to be employed in a space project, and the necessary investment in new infrastructure.

- **Risk Factor**, which is intrinsically connected with costs and performance, considering the technology readiness level as well (DOD, 2001).

One of the crucial points of knowledge management in a space program is to recognize the differences between the real space system and research projects and, consequently, implement scale-appropriate strategies to technology transfer. (NASA, 2008).

3.2 Setting up New Research Projects

The selection of new research projects must make full use the existent knowledge by correlating separate sources and showing how they can be exploited in an effective way (Bitten, Bearden, and Emmons 2005) and (Mankins, 1995).

A knowledge management system containing all the possible information about RGs, RTs and RGs was essential, not only to make right decisions about the research strategic investment, but also to evaluate the research projects proposals. With a decision support system based on knowledge management, much of the information available in the research proposal can be checked for consistency and reasonableness.

A Committee constituted of two investigators of each main research area of the Launcher Program, is responsible for the assessment of the projects proposals that are submitted. The project evaluation final grade is based on the fulfillment of nineteen evaluation criteria, according to five fulfillment levels: 5 (Complete); 4 (Good); 3 (Regular); 2 (Minimum) and 1 (None).

The Brazilian Space Agency (AEB) provides the research grants for the selected projects based on a list of selected projects in which a priority is established for each selected project based on their final grade.

3.3 Assessment of New Generated Technology

Once the research projects are approved, the Research & Development Coordinator (R&DC) is responsible for keeping track of each project's status. There is a very simple computer system, called Project Tracking System, used for communication between the R&DC and the projects' manager, providing up-to-date projects information to the knowledge management system as shown in Figure 1.

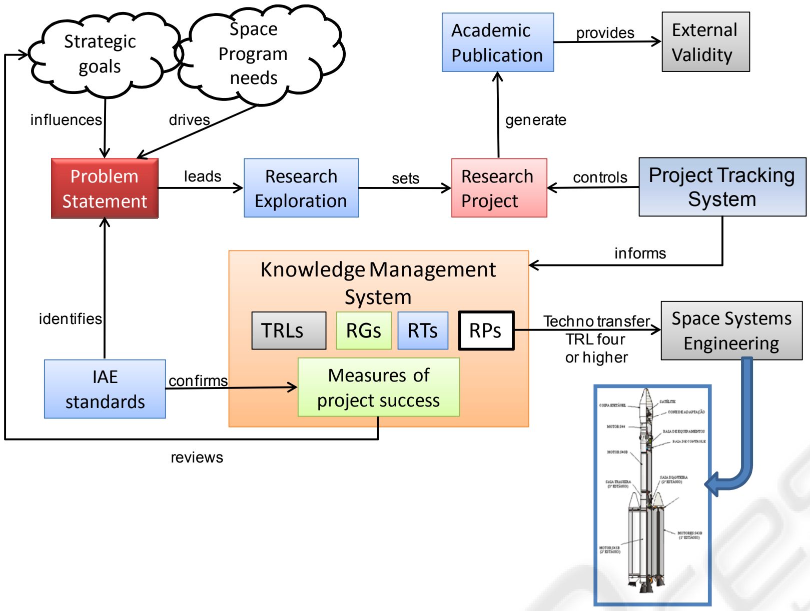

Figure 1: The proposed process for managing technologies.

Measures of the project success consist of a set of quantitative and qualitative information including the following data:

- Technology delivered;
- Projects' outcomes that resulted in successful technology transfer for the space program;
- Appropriate combination of basic and applied research, if it is the case;
- Descriptions of lessons learned;
- Research accuracy in meeting the original selection criteria to include potential for technology transfer;
- Interaction with other RGs;
- Uncertainty of the results and conclusions.
- Waiver of the results compared to the initial projects goals and theories;
- Experiments with inconclusive or negative results;
- Procedures that can guarantee the data exposition and tests reproduction;
- Generalization of the results to more general cases.

The evaluation of the resulting technology of a research project considers the technology readiness level (TRL) as well (DOD, 2001). The resulting technology has to be at least level four in order to be employed by the Space Systems Engineering. One of NASA successful technology transfer measurement is called Penetration Factor (McGill at all, 2006).

Figure 1 presents a pictorial view of the proposed process for managing technologies that is being implemented at the Institute. This process is strongly based on the knowledge management system as a sustention pillar to manage the correlated technologies within the Space Program.

4 THE KNOWLEDEGE MANAGEMENT SYSTEM

The main idea behind the conception and development of a knowledge management system is to organize and to store information about the RGs, RTs, and RPs, capturing the experiences of investigators and research groups, the resulting technologies and their association with the Space Program. Besides, the design, review, and implementation of both social and technological processes help to improve the application of knowledge in the Institute.

Figure 2 illustrates the schematic idea adopted in the conception of the knowledge management system, showing the important role of the research projects as generators of new technologies. The adequacy of the research project to the Space Program goals is given by its measures of success. Figure 2 also illustrates the hierarchy between RGs, RTs, and RPs, reinforcing the power of projects in this context.

A database to implement the knowledge management system is now under development. It stores all the data related to the RGs, RTs, RPs, HRs and their relationship. The sets of criteria used to evaluate project proposals and research groups are also incorporated in the system, as well the TRLs.

The database was designed to keep up with the dynamic aspect of a knowledge management environment. A friendly user interface was designed, providing an extensive set of possible queries by all the Institute staff. The insertion of new information and its updating is easily done by authorized personal and certified by the R&DC.

5 FINAL CONSIDERATIONS

This paper presented an ongoing work at IAE to promote the best use of the available knowledge to manage the correlated technologies and employ them efficiently in the Brazilian Satellite Launcher Program. A process was defined to carry on these activities and a knowledge management system is under construction to support it.

One of the expected benefits with the implementation of the proposed process and the core knowledge management system is the assurance that the intellectual capabilities of Institute are shared, preserved, and institutionalized.

Justification of the investments in research is another side of the coin. The Brazilian Space Agency will carefully look at past research projects and the effective utility of their results for the Launch Program in order to concede grants for future research projects. This fact increases the responsibility of the Institute in promoting strategic research that adequately fits its space mission.

Suggestions from researchers to make improvements in the space program and involvement of practitioners and developers in research design needs are also important as it leads to better research evaluation, grants greater recognition, and promotes the integration of scientific research to system engineering activities.

Improvements will certainly be necessary in the process and the original system conception to incorporate new requirements as the process gets more mature. The final aspiration of this work is that the overall benefits of a knowledge management will be found in tomorrow's new space programs.

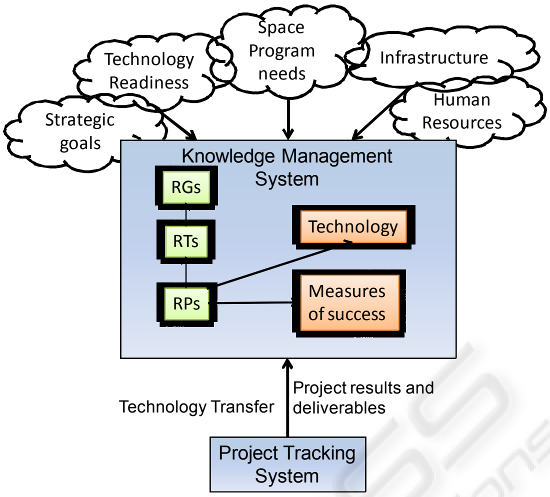

Figure 2: A schematic idea of the knowledge management system.

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