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**A COMPARATIVE STUDY BETWEEN PMBoK/DoD AND
ECSS/MANAGEMENT PROCESS FOR
SOFTWARE ACQUISITION**

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Abstract

This article presents a comparative study between the ECSS standards, more specifically in terms of the requirements of the ECSS software management process and the defense-intensive processes of PMBOK DoD. Since there is a sense that a complete comparison study is a lengthy process, the scope of comparison is restricted to space software acquisition. Most of the software systems are developed under contracts in which the government is the customer and the contractor is generally a space industry company. Both government and industry use project management processes in order to build the required system successfully within cost, time, quality, and risk requirements. On the contracting side (government) there are two well known approaches for project management for software acquisition: PMBOK and ECSS. The motivation is to facilitate the relationship between customer and software provider when the customer is a space agency who is familiar with ECSS processes and the software provider is familiar with the practices of the PMBOK guide. The results of this comparison demonstrate that there is a great deal of similarity in terms of what is expected in ECSS and what the PMBOK DoD can provide. We believe that the study can diminish the gap between the two approaches and provide a better understanding of the ECSS for the aerospace industry, which is used to the practices of PMBOK.

1. Introduction

Software systems are required on operations of artificial satellites, stratospheric balloons, launchers and aircrafts. The systems usually have specific requirements concerning security, secrecy, safety, reliability and performance.

Space projects are generally expensive and take a long time to complete. The insertion of the industry into the space programs environment, as subsystem suppliers, has demanded improvements into the space agency's project management processes in order to successfully accomplish the projects.

In different areas of application, one can see initiatives of industry and government toward the standardization and best practices of project management. Excellent results of such efforts are provided by the Project Management Institute – PMI with a Guide to the Project Management Body of Knowledge – PMBOK [1], applicable

for projects in general. The PMBOK is a term that describes the sum of knowledge within the activity of project management and the PMBOK Guide is used to identify and describe that subset of PMBOK that are applicable to most projects most of the time. There is a widespread consensus about its value and usefulness.

Efforts towards project management into space domain are provided by the European Cooperation for Space Standardization – ECSS [2]. The ECSS standards are resultant of a cooperative effort of the European Space Agency (ESA), National Space Agencies and European industry associations.

The U.S. Department of Defense (DoD) prepared an extension to the PMBOK Guide in order to identify and describe defense applications of the core project management knowledge areas contained in the PMBOK Guide, as well as those defense-intensive knowledge areas that are not contained in the Guide [3]. The DoD motivation was that PMBOK Guide is a valuable document adopted by DoD Program Managers. Therefore, tailoring PMBOK processes to the defense acquisition life cycle allows aggregating defense-intensive practices to the PMBOK.

The National Institute for Space Research (INPE) is the Brazilian governmental organization responsible for the development of various satellite missions. INPE has adopted the ECSS standards in the satellite project management for scientific satellite missions.

In space mission programs, as well in defense projects, software is a critical component due to fact that it supports the safety or the dependability of critical functions that, if incorrect or inadvertently executed, can result in catastrophic or critical consequences. The constant evolution of microprocessors and VLSI (Very Large Scale Integration) devices technology has speeded up the use and increased the complexity of computational systems. Space agencies have dedicated special attention to the software project management. Such concern is reflected, for instance in the ECSS-M-30A [4], ECSS-Q-80 [5] and ECSS-E-40 Part 1B [6], volumes dedicated respectively to project management, software quality assurance and software project engineering.

Focusing on software project management, this article presents a study that compares the ECSS software management process described in terms of requirements with the PMBOK DoD software acquisition process. The goal is to simplify the relationship between the government (space agency) customer and the companies, when the customer is familiar with the ECSS processes, and the provider is familiar with the practices of the PMBOK guide. The comparison between ECSS and PMBOK DoD, instead of the original PMBOK, is due to the fact that management aspects in defense projects are also common to space projects, particularly in the software acquisition domain.

2. PMBOK DoD aspects for space software acquisition management

The nine knowledge areas identified in the PMBOK Guide are applicable to the DoD for the development, production and fielding of defense systems. They are: Project Integration Management, Project Scope Management, Project Time Management, Project Cost Management, Project Quality Management, Project

Human Resource Management, Project Communication Management, Project Risk Management, and Project Procurement Management. Additionally five other defense-intensive knowledge areas are key to the defense acquisition. They are: 1- Project Systems Engineering Management, 2- Project Software Acquisition Management (SAM), 3- Project Logistics Management, 4- Project Test and Evaluation Management, and 5- Project Manufacturing Management.

While the nine original knowledge areas and the five defense-intensive areas have distinctive characteristics, they are related in that the defense-intensive areas each rely on several of the PMBOK Guide areas to be successful. The figure 1 (a), from reference [3], shows the primary linkages between those areas. Each area describes project management knowledge and practice in terms of their component processes. For instance, the Project **Integration** Management describes the processes required to ensure that the various elements of the project are properly coordinated. It consists of three processes: project plan development, project plan execution, and integrated change control.

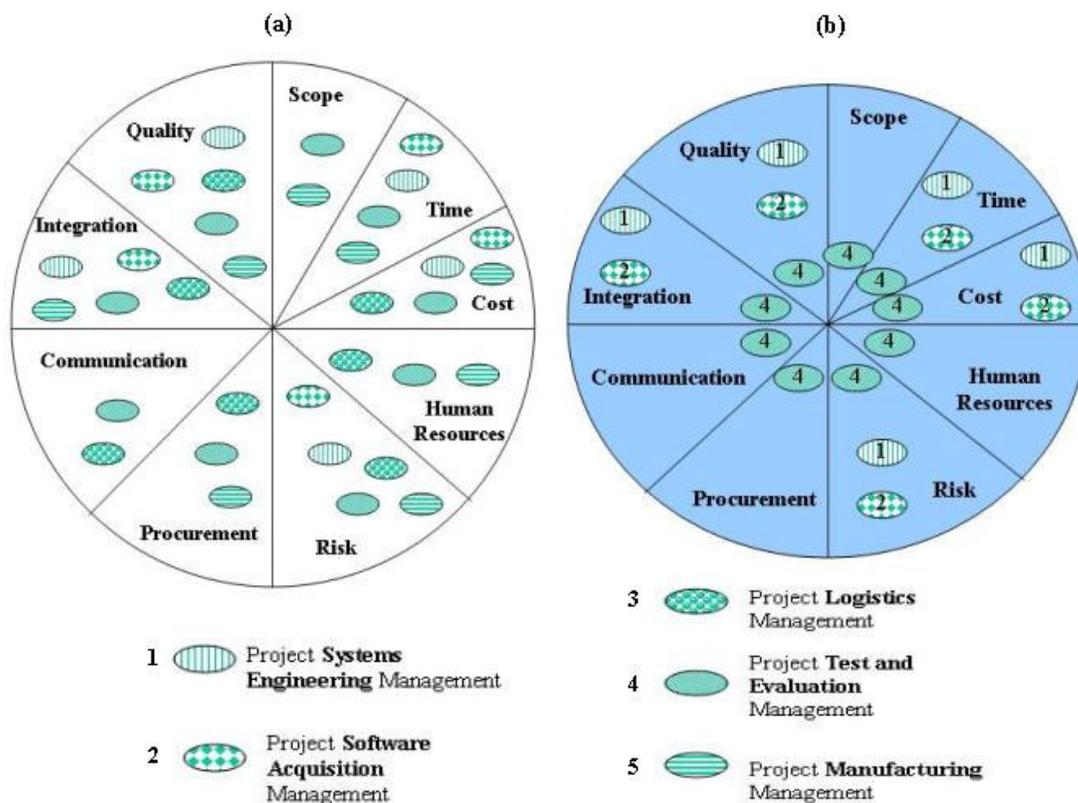


Figure 1 – PMBOK core knowledge areas and defense-unique knowledge areas relationship

The processes associated to the five defense-intensive knowledge areas are described below. Project Systems Engineering Management includes the processes by which the technical aspects of a program are evaluated, managed, and controlled. SAM includes the process required to manage the acquisition and development of software-intensive DoD systems from the acquirer's viewpoint. DoD software intensive systems are understood as those for which software is the

largest segment of the system development cost, risk, functionality, or development time. Such systems are generally complex and have a wide spectrum of requirements to be met. Project Logistics Management includes the processes to address the concerns associated with the material support of a DoD system throughout its entire life cycle. Project Test and Evaluation Management includes the processes required for planning and execution of both test and evaluation. It is part of the systems engineering. It identifies levels of system performance, provides data to support trade-off analysis, reduces risks, and assists the Project Manager on correcting deficiencies. Project Manufacturing Management includes the processes required to plan, organize, direct, control, and integrate the use of people, money, materials, equipment, and facilities to accomplish the manufacturing effort economically. Refer to [3] for more details.

In PMBOK framework, every process is described in terms of the elements: Inputs, Tools and Techniques (T&T) and Outputs. The “pie” (b) in figure 1 highlights the three most relevant knowledge areas for software project management, object of this study.

3. ECSS aspects for space software project management

In ECSS standards, project management provides the framework for the definition and implementation of the space project through planning, organization, performance, monitoring and assessment of the results. Project management follows a structured approach to manage scope, quality, time, cost, organization and logistics of the space project, throughout all stages of its life cycle and at all levels of its hierarchy, breaking down the project into manageable elements. The major elements of project management to serve these principles are: Management of Risk, Project Breakdown Structures, Project Organization, Project Phasing and Planning, Configuration Management, Information/Configuration Management, Cost and Schedule Management, Integrated Logistic Support, Product Assurance Management and Engineering Management [2]. They constitute the branch M within the ECSS standards and are complemented by two other groups: engineering and quality assurance standards, branches E and Q, respectively, in which software projects take relevance. Requirements on software product assurance are defined in ECSS-Q-80 [5], which is the entry level document of ECSS-Q series for software projects. In particular, ECSS-E-40 [6] contains a tailored set of requirements from ECSS-M standards applicable to the management of software projects and additional requirements, which define the engineering and control of software development in a space systems project. It bridges the gap between the other ECSS-M and ECSS-Q standards and the software engineering activities, describing the software management process where the management and the control tasks are divided into four groups: Software life cycle management; Joint technical review process; Interface management; and Technical budget and margin management. Each group includes a set of requirements and expected outputs. For instance, the interface management has two requirements: interface definition and interface management procedures. The requirement interface definition has an expected output, the

interface requirements document, whereas the requirement interface management procedure has as expected outputs: the interface management procedures and part of the configuration management requirements.

Figure 2 presents the ECSS basic mission life cycle activities distributed along the typical space mission phases: O – Mission Analysis/ Needs Identification, A – Feasibility, B – Preliminary Definition (Project and Product), C – Detailed Definition (Product), D – Production/ Ground Qualification Testing, E – Utilization, F- Disposal [4]. It also presents the activities related to the software engineering process described in the standard ECSS-E-40 Part 1B, taking into account the existing ISO 9000 family of document and the ISO/IEC 12207 standards [7]. The right side of the figure, more precisely, the last two columns present respectively the software development processes (primary) and the software management process recommended in ECSS standards. The scratched bars represent the period that each space mission activity is carried out under system point of view. The fulfilled bars correspond to the software activities related to the software life-cycle development under subsystem view.

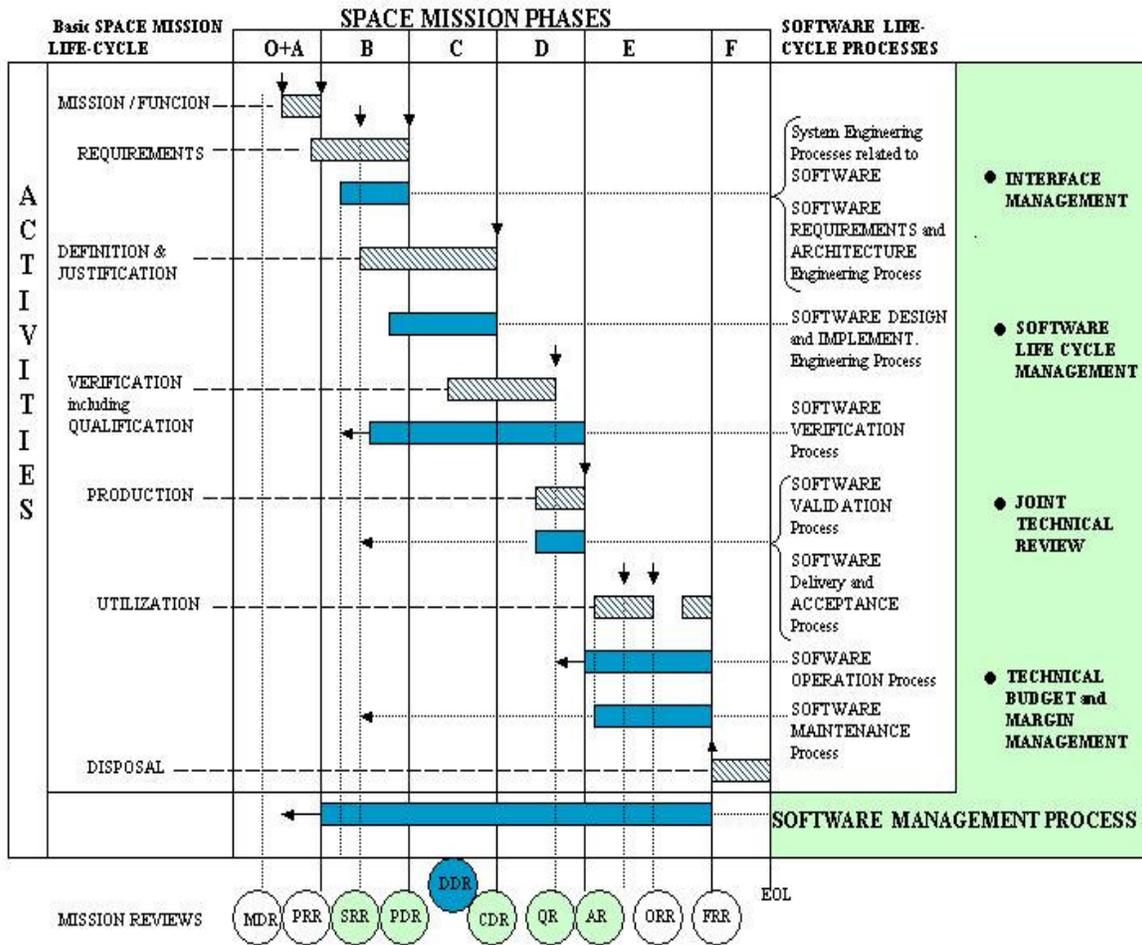


Figure 2 – ECSS typical project life cycle

On the bottom of figure 2 one may observe the typical sequence of reviews followed in the space mission project, at system engineering level. They are: MDR - Mission Definition Review, PRR - Preliminary Requirements Review, SRR - System Requirement Review, PDR - Preliminary Design Review, CDR - Critical Design Review, QR - Qualification Review, AR - Acceptance Review, ORR - Operation Requirements Review, FRR - Flight Readiness Review. Since software project is usually considered to be a subsystem in the hierarchy of space system development, it shall be synchronized with those milestones. Moreover, depending on the complexity of the software, the reviews in green may be replicated at the subsystem development level. DDR - Detailed Design Review is particularly recommended for software projects.

4. Comparing PMBOK/ defense-intensive processes and ECSS/software management process

Although the typical project life cycles for defense and space missions are different from each other, the concern for software project management is evident in both approaches. PMBOK/DoD adds the Project Software Acquisition Management (SAM), a particular defense-intensive knowledge process for software acquisition management. On the other hand, specific requirements for management and control tasks of software management process were defined in ECSS-E-40 Part 1B under the four groups introduced in section 3.

In a similar way, ECSS and PMBOK/DoD engage software as subsystem in the whole program. Both approaches establish their system policies and procedures for software acquisition or development on the client and supplier relationship.

The aspects mentioned above based to compare the two approaches for software acquisition management taking into account both the elements (input, tools and techniques, output) of defense-intensive processes, from the three PMBOK/DoD knowledge areas presented in figure 1 (b), and the software-intensive requirements described in the four groups of the ECSS software management process.

Figures 3 and 4 synthesize the way that the analysis of each requirements group was carried out. The following procedure was adopted: every software-intensive requirement **R_i** and the correspondent expected output **O_i** of each group of the software management process, described in ECSS-E-40 Part 1B, are listed, respectively in the two columns under ECSS subtitle, in order to identify at least one occurrence of that requirement **R_i** on the elements of the defense-intensive processes listed in the columns under the PMBOK/DoD subtitle.

In figure 3 one may follow the comparative analysis for the fifteen requirements associated with the Software Life Cycle management. The numbers used in the Defense-intensive processes, listed in the first column, follow the notation adopted in reference [3] in order to simplify the link with the elements description (Input, T&T, Output) of each process, which are not transcript here in totality. Therefore, the processes 13.1, 13.2 and 13.3 are related to the defense-intensive knowledge area named 1 - Project Systems Engineering Management, highlighted in figure 1 (b). The 14.1 is the unique process of 2- Project Software Acquisition Management

area. And 16.1 and 16.2 are processes of 4- Project Test and Evaluation Management area.

SOFTWARE LIFE CYCLE MANAGEMENT					
PMBOK/ DoD				ECSS	
Defense-intensive Processes	Input	T&T	Output	Software-Intensive requirements	Output
13.1 System Engineering Planning			•Technical, functional and integrated master Plans (R1, R2, R3, R5)	R1. Definition of Software life cycle phases	O1. Software Dev. Plan
13.2 System Engineering Activities			•Functional & Physical Architecture •Documentation (R4)	R2. Software life cycle identification R3. Identification of Inputs and Outputs associated to each phase	O2. Software Dev. Plan O3. Software Dev. Plan
13.3 Analysis and Control			•Specifications (R7) •Baselines (R6)	R4. Identification of Documentation relevant to each milestone R5. Identification of Interface between the development and maintenance processes	O4. Software Dev. Plan O5. Software Dev. Plan
14.1 SAM Activities	<ul style="list-style-type: none"> •System/ Subsystem Specification (R7) •Systems engineering plans •Software Development and management Plans (R1, R2, R3, R5) •Software Requirements (R1, R2, R3, R4, R5) •Test and evaluation master plan – TEMP (R11, R12, R13, R14) •Contracting approaches (R15) •System acquisition strategy (R15) 	<ul style="list-style-type: none"> •Life-cycle tailoring (R1) •Spiral development models (R2) •Support contractor resources (R15) •Independent expert program reviews •Risk assessment 	<ul style="list-style-type: none"> •Various management, support, and fielding plans •Software Items 	<ul style="list-style-type: none"> R6. Requirement Baseline at the SRR R7. Software technical specification phase R8. Preliminary design review R9. Detailed design review R10. Critical design review R11. Software verification and validation R12. Qualification Review R13. Acceptance review R14. Validation activities phasing with regard to the acceptance review R15. Software procurement process implementation 	<ul style="list-style-type: none"> O6.Customer Approval O7.Document O8.Customer Approval O9.Customer Approval O10.Customer Approval O11.Document O12...Customer Approval O13. Customer Approval O14...Customer Approval O15...Customer Approval
16.1 Test and Evaluation Planning	•System performance specification (R7)	•T&E integrated product team	•Test and Evaluation master plan (R11, R12, R13, R14)		
16.2 T&E Execution & Reporting	•T&E resources		•T&E reports (R8, R9, R10, R12, R13, R14)		

Figure 3 – Relationship between PMBOK DoD processes and ECSS requirements

Only a set of elements considered relevant for the purpose of this study are referred in figures 3 and 4.

An important result in this comparison is that all the requirements related to Software Life Cycle management group were recognized as part of output elements of the PMBOK DoD processes. As an example, the ECSS requirement **R3**, which expected outputs are specified in Software Development Plan **O3**, is contemplated by one of the technical master plan produced in the System Engineering Planning Process (13.1), as output element of PMBOK DoD.

JTR / IM / TBMM					
PMBOK/ DoD				ECSS	
Defense-intensive Processes	Input	T&T	Output	Software-Intensive requirements	Output
13.1 System Engineering Planning				R16. Support to software reviews	O16. Milestones Review report
13.2 System Engineering Activities			•Documentation (R16, R17, R18, R19, R21)	R17. Technical reviews	O17. Technical review report
13.3 Analysis and Control			•Baselines (R16, R19, R20)		
14.1 SAM Activities	• Test and Evaluation Master plan – TEMP (R17)	•Independent expert program reviews (R16)	•Software Items	R18. Interface definition	O18. Interface Requirement Document
16.1 Test and Evaluation Planning				R19. Interface management procedures	O19. Requirement Baseline
16.2 T&E Execution & Reporting	•T&E resources (R17)		•T&E reports (R17)		
				R20. Software technical budget and margin philosophy definition	O20. Requirement Baseline
				R21. Software technical budget management	O21. Requirement Baseline

Figure 4 – Relationship between PMBOK DoD processes and ECSS requirements

Still concerning **R3** analysis on PMBOK DoD side, one can observe that the information related to “the inputs and outputs associated to each phase of the software life cycle” is essential to SAM activities. Therefore, it is also recognized as input element for the SAM activities process (14.1).

Figure 4 shows some results of the analysis for the other six requirements, respectively, **R16** and **R17** related to the Joint Technical Review – JTR; **R18** and **R19** related to the Interface Management - IM; **R20** and **R21** related to the Technical Budget and Margin Management – TBMM.

The 21 requirements and their expected outputs related to software management process, defined in ECSS-E-40 Part 1B, were analyzed. The purpose of the study was reached since the objective was to correlate every requirement of that process with at least one element of the defense-intensive processes. The analysis was not exhaustive in terms of all possible occurrences of the requirements in PMBOK DoD processes elements. Such correlations should require many assumptions and tailoring of the PMBOK DoD elements to particularities of the space domain what was not effective considering the high abstraction level of this study.

Another important result of the present analysis is that, however PMBOK DoD extension emphasizes software subject in defense-intensive processes creating SAM, the requirements specifically defined in ECSS for software management were not restricted to the elements of SAM activities process. This was expected since defense acquisition life cycle follows the PMBOK approach in which the knowledge areas complement each other and the processes are arranged in five groups: initiating, planning, executing, controlling and closing [1], in order to accomplish the project management.

4. Conclusion

This paper has presented a comparative study between the ECSS software management process, described in terms of requirements, and the elements of PMBOK DoD software acquisition processes. The study aims to facilitate the relationship between customer and industrial contractor when the customer is a space agency who is familiar with ECSS processes and the software provider is familiar with the practices of the PMBOK guide. The goal was reached since the results of comparison demonstrated that all requirement of the ECSS software management process were identified in at least one element of the defense-intensive processes. Therefore, concerning software acquisition project management there is a great deal of similarity in terms of what is required in ECSS and what the PMBOK DoD can provide. It suggests that a method can be proposed to evaluate the processes implemented by a software supplier used to PMBOK approach, taking defense-intensive processes as reference. Once the elements of the processes have been identified, the ECSS software management process requirements and their expected outputs might be associated.

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