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# GUIDELINES FOR SMALL EMBEDDED SYSTEM COMPANIES AIMING TO ENTER THE SPACE INDUSTRY

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**Abstract**

This guide summarizes useful information about the European Space Agency (ESA), the European space industry, the ECSS standards and product assurance for small and medium enterprises that are aiming to enter the industry. Additionally, the applicability of agile development in space projects is discussed.

**Keywords**

European Space Agency, European space industry, small and medium enterprises, embedded system development, ECSS standards, agile development

# Contents

# 1 Introduction

This guide has been made to give a brief introduction about the European space industry and to help small and medium enterprises that are aiming to enter the industry. The guide is targeted especially for small companies having expertise on a specific domain of technology which could be exploited in space applications but do not have previous experience on participating in space projects.

Since European Space Agency (ESA) plays a major role in European space industry, it is introduced along with its procurement and tendering practices. The ECSS standards, which are widely utilized in European space projects, are gone through covering their background, structure and utilization. It is also shown how they affect a typical mission project and product assurance. The importance of product assurance is emphasized in space projects compared to other projects. For companies already utilizing agile and lean methods, the applicability of these methods in space projects is discussed. For others interested in agile and lean methods a short introduction to agile methods is presented.

# 2 European Space Agency (ESA) and Small and Medium Enterprises

The European Space Agency (ESA) is an organization established in 1975 for cooperation in space research and technology between European countries. It currently has 22 member countries in Europe in addition to a cooperating member, Canada. [1]

As ESA plays the main role in space industry related projects around Europe, a company must be familiar with its practices, such as the tendering process, and its rules and regulations. ESA provides valuable information related to these aspects on their website.

ESA actively promotes the importance of small and medium-sized enterprises (SMEs) through its own SME policy. While a few large organizations employ the majority of the people working in the space industry, SMEs play a major part in many parts of the supply chain of the projects. [2] ESA maintains the ESA SME Database[1] where SMEs in the member countries can reach more European-wide visibility [3]. Also much of the other information on the ESA website is written keeping SMEs in mind.

ESA has certain rules and criteria in their definition of an SME. Most of them originate from the definition made by the European Union in 2003, such as the company size which cannot exceed 250 employees. An SME must also have an annual turnover that does not exceed 50 million euros or an annual balance sheet total that does not exceed 43 million euros. [4, 5]

## 2.1 Procurements

ESA runs several programmes on different fields of space industry. To provide invitations to tender (ITT) for organizations to participate in, it has its specific procurement flow. [6]

An important aspect concerning ESA, SMEs and the procurement process is the "fair return" policy of ESA. The policy affects the funding in the procurements in a way that it is distributed to companies in each ESA membership state accordingly to each country's financial contribution to ESA. This increases the competitiveness of the SMEs especially in countries where the space sector is smaller. [7, 2]

[1] http://smed.esa.int/ (Accessed: July 2015)

The ESA procurement flow has multiple steps of which some more or less affect the tenderers. These are discussed in the "Tendering" section. An overview of the procurement flow can be read on the introductory presentation[2] from 2014 and the details from the "How to Do Business With ESA" section on the ESA website[3].

## 2.2 Tendering

An invitation to tender (ITT) (also known as call for tender, request for proposal, call for bidding and request for quotation) is an official request for potential supplier companies to submit a tender for the implementation of a project. [2]

In the ESA procurements, the tender process occurs in the EMITS system managed by ESA. It is used to publish and manage ITTs. All companies, institutes and universities that want to take part in the bidding in ESA projects must enter the system and register as "potential bidders" and get an ESA Bidder Code [6].

The EMITS system consists of two types of ITTs: open ITTs that are open to all potential bidders to participate in and intended ITTs that are forthcoming ITTs. Details are provided about each ITT such as what it is about, what is the estimated price range and countries that are allowed to present an offer. [8, 9]

A company can post an expression of interest to an ITT which is essentially a reply to that particular ITT. When an expression of interest has been made, the company is then subscribed to any changes or development that occurs with the ITT in question. This way also other companies can see which companies are interested in the ITT. An in-depth description on how to use the functionalities in EMITS are provided in the help section of the site. [8, 6].

To get an ESA contract, the tender needs to be high quality and full attention and understanding to all of the requirements of the ITT is required as the practices differ vastly from project to project. There should also be knowledge about the strategy and resources of the competitors and about ESA space programmes and activities. National delegations (such as Tekes in Finland) also have a role in the procurement process. In some procurements, formal support is required from national delegations. From their national viewpoint, they can also provide additional help and contacts for companies entering the space industry. [6, 10]

[2] https://tk.parp.gov.pl/files/74/575/590/755/19458.pdf (Accessed: July 2015)

[3] http://www.esa.int/About_Us/Industry/Industry_how_to_do_business/How_to_do_business_with_ESA2 (Accessed: July 2015)

# 3 European Space Industry Projects

## 3.1 Roles in Projects

The companies and other organisations participating projects in space industry have several different roles. These mainly include roles of customer, tenderer, prime contractor and subcontractor.

**Customer** in European space projects is typically ESA or some large company initialising the procurement. The procurements are typically carried out through open or limited invitations to tender or direct negotiations with certain companies or organisations.

**Tenderer** is a company or organisation providing itself to execute the work ordered by the customer. Typically, when a tender has been accepted and the contracts negotiated the tenderer becomes a prime contractor.

**Prime contractor** (often referred to only as **Prime**) is the organisation in charge towards the customer to execute the ordered and appointed work. The work may be carried out by several companies from which one is acting as a prime, the others being subcontractors.

**Subcontractors** (often referred to as **suppliers**) collaborate with the prime contractor and the other subcontractors carrying out their own share of the work. The prime typically coordinates the work and acts as a contact interface between the customer and the subcontractors. It is also typical to have several levels of subcontractors.

The relationships between these roles can require extra attention if the company is new to the European-wide practices. For instance, the prime contractor can be exempted from VAT while subcontractors can be anything from individual companies to universities, all with different taxation rules that can also depend on the country they are located.

## 3.2 Mission Project Phases and Reviews

The space sector has several types of projects, such as mission projects and research projects. The standards are utilized in almost all of these, but they focus mostly on mission projects.

A common structure for a mission project is presented in ECSS standard M-10 Project planning and implementation (ECSS-M-ST-10C). The projects are scheduled in a way that several milestones throughout the project divide the project into sec-

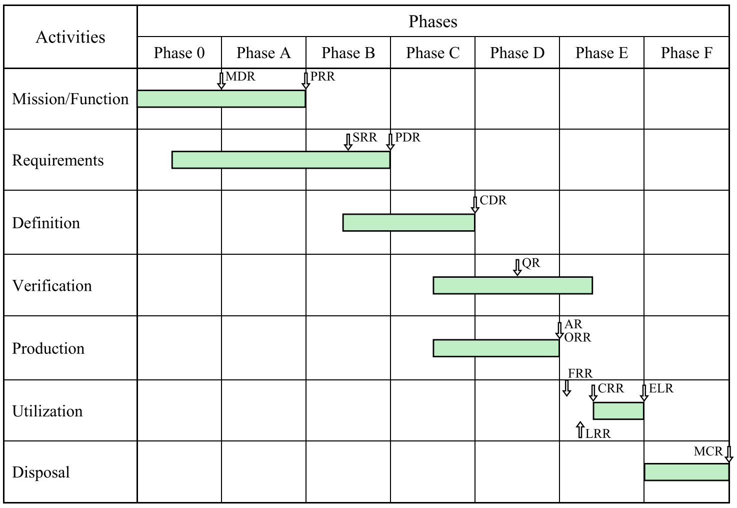


Figure 1: A typical space project with its phases (adapted from [11]).

tions. These milestones are review ceremonies where the suppliers present the results of the work done so far to the customer. A typical project with its phases are presented in Figure 1. The phase 0 (Mission analysis/needs identification) is typically run by the project initiator (customer), whereas the phase A (Feasibility) involves only top level customer and some first level suppliers. The product is designed in phases B (Preliminary definition) and C (Detailed Definition). The rest of the phases – phase D (Qualification and production), phase E (Operations/Utilization) and Phase F (Disposal) – concentrate on production, utilization and disposal.

The customer and contractors agree the followed set of reviews and their schedule: especially preliminary design review (PDR) and critical design review (CDR) are major milestones for the design. Since typically the subcontractors have their subcontractors, the review lifecycle has several levels as presented in Figure 2. [11]

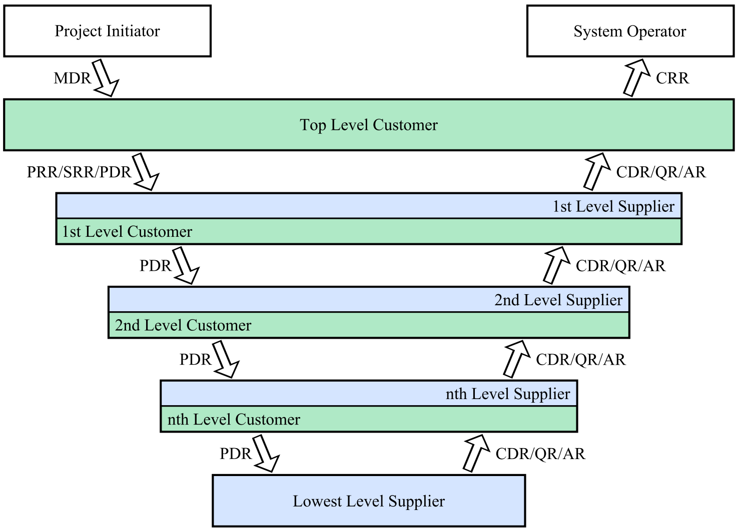


Figure 2: The review life cycle (adapted from [11]).

# 4 ECSS Standards

## 4.1 Background

European Cooperation for Space Standardization (ECSS) originates back to the year 1993 when the European Space Agency (ESA) decided with national space agencies to replace the old practice-based PSS-05 standard. The goal was to create a new, coherent and recognized space project standardization system which would be continuously updated to adapt to the changing needs of the space industry. [12]

First ECSS documents were introduced in 1996 and a necessary set of branches and disciplines was set up by 2006. In recent years, the development of ECSS has primarily been maintenance work with already existent standards. [12]

The ECSS system has been accepted as a sole requirements source for space standards by the European Commission in the mandate M496. There has been some mutual recognition of standards between ESA and other space agencies, such as JAXA (Japan Aerospace Exploration Agency). There have also been requests by some space nations such as Russia to translate and use sections of the ECSS standards. [13]

Generally, the ECSS standards have been designed so that they are generic for a given discipline and they cover many possible mission and product types. Some conflicts may still arise or tailoring needed when the standards are desired to be adopted. For instance, a small or medium-sized enterprise might operate differently than larger organizations which have been the main contributors in the development of ECSS.

The ECSS standards aim not to be teaching books or encyclopedia. Also, they generally are not meant to be used independently from other standards in most domains or interfere with internal organization of the suppliers or their quality system. [14]

## 4.2 Structure

The up-to-date set of ECSS standards can be downloaded from the ECSS website [14]. This document covers the ECSS standards package issued in the February of 2015. The package contains all active ECSS standards in addition to superseded standards, Documents Requirements Description (DRD) documents and some supporting material, wrapped inside of a CD-ROM image file. Handbooks and technical memoranda are not included in the package, but the handbook URLs are gathered in an Excel file where also all active and discontinued ECSS standards are listed with some statistics about the standards.

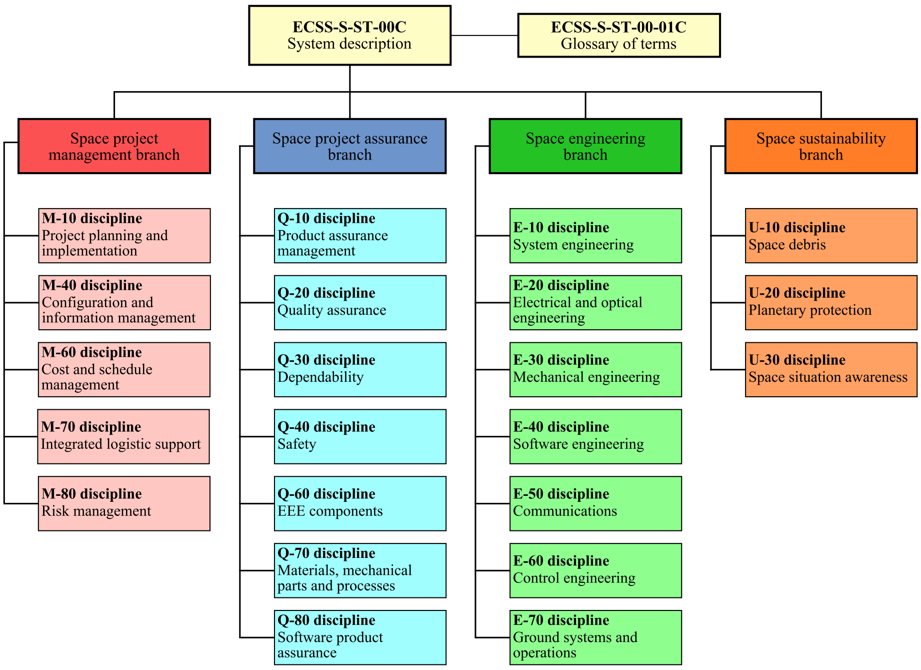


Figure 3: The ECSS branches and disciplines (adapted from [15]).

The ECSS standards are organized in four branches: 1) Space project management branch, 2) Space product assurance branch, 3) Space engineering branch, and 4) Space sustainability branch. Each of these branches contain multiple disciplines that can hold one or more of the actual standards. An overview for the structure is provided in the "ECSS-DOC-001: ECSS Document Tree and Status" file in the root of the standards. In Figure 3, the topmost level is presented from the document.

The documents are labeled with letters. The "M" (management), "Q" (product assurance), "E" (engineering) and "U" (sustainability) documents fall into corresponding branches presented earlier and present the actual standards. Most of the ECSS standards are in the "M", "Q", or "E" branches. There are also two "S" (system) documents that describe the ECSS system itself and give instructions on how to use it. The document names can also be combined with labels "HB" or "TM" for handbooks or technical memoranda, respectively.

In addition to the standards, handbooks and technical memoranda, there are two additional disciplines: "ECSS Policy" (one document labeled with "P") and "Configuration and Information Management" (a few documents labeled with "D"). The ECSS policy document is included among the standard documents. The documents for the configuration and information management are available only on the ECSS website separately as they mainly cover principles and practices related to the standardization process itself.

Based on [16], the difference between standards, handbooks and technical memoranda can be summarized roughly as follows:

- A **standard**:
  - Describes what to do, not how to do.

  - Consists of requirements, recommendations or permissions for contractual relationships.

- A **handbook**:
  - Describes how to properly do something important.
  - Is non-normative.
  - Contains useful background information, orientation, advice or recommendations about a specific subject.

- A **technical memorandum**:
  - Provides useful information to the space community on a specific subject.
  - Contains irrelevant or not mature enough data to be published as a handbook or as a standard.

## 4.3 Standards

The structure of each standard document follows the same pattern, although some parts can be included or excluded depending on the standard in question.

In the beginning of a standard document, possibly after a short introduction (usually less than one page), the scope of the document is declared. The scope chapter is usually less than one pages long, and describes what the standard is about and what parts of the space project it is applicable in.

Most standards are linked to other standards. Hence, after the introductory chapters, the list of normative references is presented. Some of the normative standards can also be from outside of the ECSS system, such as from the ISO standards. After this chapter, there is usually a chapter where terms, definitions and abbreviations are listed.

Next in the document, the actual content of the standard is described. This is where most of the variation comes into play with the structure of the chapters between different standards. Quite a common structure consists of two chapters, where first the fundamentals or principles behind the subject is presented and then a "Requirements" chapter is followed where many of the same topics are described in a form of requirements. This structure can be extended quite a lot for some standards, for instance the "ECSS-Q-ST-40C: Safety" standard is described in "Safety principles", "Safety programme", "Safety engineering", "Safety analysis requirements and techniques", and "Safety verification" chapters.

Finally, in the end of most standard documents, there are several annexes, followed by a bibliography.

### 4.3.1 Standard Utilization

The "ECSS-S-ST-00C: Description, implementation and general requirements" document is very important to get familiar with as it contains the top-level definition of the ECSS structure and instructions about how to utilize them. Before the utilization of the standards, project characteristics must be identified and analyzed along with risks. Not all of the standards have to be utilized in every project and relevant standards must be evaluated beforehand while keeping in mind that most standards link to other standards.

The standards applicable in the project form a set of requirements to be followed. However, these requirements are assessed and classified in three different categories – Y (applicable without change), M (applicable with modification) and N (not applicable) – based on the cost, schedule and technical factors of the project. When a standard is either partly or fully categorized as M or N, the decision needs to be recorded and justified.

The impact on daily work varies from standard to standard. The lower lever the Technology Readiness Level (TRL) is, the more room is given for the organization of work and vice versa. Depending on the tasks, the standards can either help with details (e.g. present specifications for the system) or create constraints that need to be addressed (e.g. limit the component choices).

### 4.3.2 Space Project Management

The space project management ("ECSS-M") branch aims to implement a process where successful completion of the project can be achieved in terms of cost, schedule, and technical performance. The branch attempts to cover all stages of project life cycle and all levels of the customer-supply chain.

In this branch, there are five disciplines and a total of six published standards.

### 4.3.3 Space Engineering

The space engineering ("ECSS-E") branch covers the engineering aspects of space systems and products. These include the engineering process as applied to space systems and to the elements or functions of space systems, in addition to the technical aspects of products that are used to accomplish or are associated with space missions.

In this branch, there are seven disciplines and a total of 54 published standards. Quite a large portion of the standards (a total of 18) belong to the "Mechanical engineering" discipline.

### 4.3.4 Space Product Assurance

The space product assurance branch ("ECSS-Q") aims to assure that the space products accomplish the defined mission objectives and that they are 1) safe, 2) available, and 3) reliable. "ECSS-Q" supports project risk management by ensuring adequate identification, appraisal, prevention and control of technical risks.

In this branch, there are seven disciplines and a total of 57 published standards. A major part of the the standards (a total of 35) belong to the "Materials, mechanical parts and processes" discipline.

### 4.3.5 Space Sustainability

The space sustainability branch ("ECSS-U") covers aspects related to space debris mitigation and planetary protection. It contains the smallest set of standards among all the branches: while there is only one standard published, three disciplines are already in place in the ECSS tree.

## 4.4 Handbooks and Technical Memoranda

Handbooks and technical memoranda published by ECSS are a collection of non-normative documents providing additional information for space industry. Each handbook or technical memorandum is also categorized to one of the ECSS branches. The currently published handbooks and technical memoranda all belong either to the space engineering branch or the space product assurance branch. All documents can be downloaded from the ECSS website, under the "HBs & TMs" section. The document structure of handbooks and technical memoranda is very similar to that of the standards. [16, 14]

Currently there are 22 handbooks published. 15 of them belong to the space engineering branch and seven to the product assurance branch. In the engineering branch, most of the handbooks cover aspects related to materials and other practicalities in space engineering. There are guidelines for verification, communication and radiation analysis, among other topics. In the space product assurance branch, examples among the handbooks are guidelines for worst case analysis process and software quality assurance practices.

There are 15 published technical memoranda of which 10 belong to the space engineering branch and five to the product assurance branch (very similar ratio to that of the handbooks). In the space engineering technical memoranda, the topics vary from logistics engineering to simulation modelling. The space product assurance technical memoranda cover topics such as end-of-life parameter drifts of EEE components and identification of sneak circuits.

# 5 Product Assurance in Space Projects

Product assurance (PA) ensures that a system works reliably as specified. Without following product assurance and customer requirements the system can fail and cause a lot of harm to a human being or environment. Product assurance also includes risk management and analysis. In a project utilizing the ECSS standards, the recognition of failures are important already from the beginning of the project. [14]

Product assurance is in a major role in space technology because product development processes and requirements differ from mass production. The main difference comes from the difficulties on fixing space products after the deployment and from the the fact that the lifecycles of space products are longer than the lifecycles of many other products. This also means that the quality of used components and materials needs to be high. The product assurance process of space product is standardized and takes more resources, such as time, making it more expensive than traditional product development processes. [17]

In the space domain, the standardization is managed by ECSS. The main goal of the product assurance standards is to take care that the space products fulfil the specific requirements and missions. Only then it is certain that the products are safe and reliable. Product assurance also supports risk management of the project and makes it easier to identify and evaluate risks. [18]

The space product assurance standards in ECSS standards are divided into seven disciplines: Quality assurance; Dependability; Safety; EEE components; Materials, mechanical parts and processes; and Software product assurance. These seven disciplines address a wide spectrum of areas to be considered in a space project to ensure quality and reliability. For instance, the component and material standards give instructions to quality and cost efficiency related aspects, and the software standards guarantee that the software works correctly with components under the required conditions. [14]

Standards also define the role of a product assurance manager who ensures that the product assurance guidelines are followed and tools are used correctly. [14] If the company is small, it might be hard to find this person inside the company and the product assurance activities may be outsourced. The role of a product assurance manager might also have been taken care of in another part of the consortium, in which case a subcontractor does not need to deal with this role and only need is to ensure that the standards are followed in the engineering work.

In the space domain, the specifications of product assurance are tight already in the beginning of the project. Documentation and milestone requirements are good to adopt as soon as possible. Also tools and working methods should be taken into use in the beginning of the project, because then it is possible to ensure that all team members understand the methods and know how to use the tools.

Space product assurance standards can be difficult to understand and the amount of information is large. That is why the fledgling company can benefit from previous usage of some other product assurance standardization system, such as for example ISO9000 standards. This can make it easier to understand the product assurance process and easier to start the product development in the highly standardized space technology domain.

# 6 Agile and Lean Development in Space Industry

Agile and lean software development methods originate from software engineering and mostly from the environment, where the requirements change rapidly when the understanding of the product evolves. This section presents a short history and introduction to agile methods following consideration of the applicability and ways to tailor agile methods to fit to ECSS standardized environment. This information is relevant, when a company already agile is entering space industry, or a company which is already in space industry wishes to take agile methods into use.

## 6.1 Agile and Lean Development in General

### 6.1.1 History and Background

Agile and lean methods originate from software engineering, where they are proven to be successful in making the team work efficiently towards a common goal. According to a survey made in 2012 [19], the usage of agile and lean methods in Finnish software development is over 50 %.

For a long time, software engineering was mainly based on a so-called waterfall approach, where the phases follow each other: design, analysis, coding and testing. In the 1990s, many other approaches arose to challenge this quite heavy approach and in 2001 opponents of these methods formalized an agile manifesto. This manifesto formed the values and principles of already existing agile methods to gather the essence of these methods. Many agile methods, also other than lean software development, share common ideas with lean methods, which originate from the Toyota manufacturing and have been applied in other domains as well.

Common to lean and agile software development methods are iterative and incremental development: the product is developed in iterations making sure that the product is always functional, and incrementally adding new features in the iterations on top of the working product. This is achieved by the teams, which have control over their own ways of working and which work in close collaboration with the customer to be able to prioritize the features of the product. The aim is to produce efficiently a product, which fills the customer needs.

### 6.1.2 Agile Values, Principles and Methods

The agile manifesto from 2001 [20], defines four values and twelve principles for software development. The values are presented in Table 1.

*Individuals and interactions*, i.e. the team, is the core of agile methods. It utilizes its competence in the best possible way to achieve the goals defined together with the customer. The progress of the project is based on the *working software*. The product is regularly tested and it is always working, even though in the early phases of development lacking many features. The *customer* is actively involved throughout the project, giving feedback of the product under work and also steering the work through defining priorities of new features. This way, the learnings during the project are immediately taken into use. It is assumed, that in the beginning of the project every detail is not known and when the understanding over what is wanted and what can be achieved grows, the plans will change. Agile methods are focused on handling *changing requirements* even in the end of the development.

*We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:*

| | | | |
|---|---|---|---|
| 1. | Individuals and interactions | over | processes and tools. |
| 2. | Working software | over | comprehensive documentation. |
| 3. | Customer collaboration | over | contract negotiation. |
| 4. | Responding to change | over | following a plan. |

*That is, while there is value in the items on the right, we value the items on the left more.*

Table 1: Values in "Manifesto for Agile Software Development" [20].

In embedded system design, some of the values and principles are challenged. Embedded system development, composing of both hardware and software development, naturally have slower cycles than pure software development: this makes it difficult or even impossible to have a new version of working product in short intervals. Thus the focus must be shifted from the working software, not only to the working product, but to representations of the product such as simulations of demonstrations. In embedded system design, even small changes may cause huge effects on the timing or other behaviour of the product. This combined with the impossibility to produce the working product frequently hinders the possibility to change requirements in the end. Upfront design is required more than in pure software environment to overcome these issues as well as to plan the work.The product team and its knowledge flow becomes even more important than in pure software development: when it is impossible to everyone to be able to complete every work, the understanding of interdependencies and interactions between different parts of the system or work of different people will make the team more productive and focusing on what is essential at any given point of time. [21]

There are several agile methods, and here the main ideas of the three well known methods are presented: Scrum, Extreme Programming and Kanban.

**Scrum** is based on an iterative process, where the iteration, called a sprint, is two to four weeks, starts with iteration planning and ends with iteration review and retrospecting the current ways of working. Every day short stand-up meetings are held in order to understand how work is proceeding currently and if there are any challenges. The work in the project is organised to a backlog, which the product owner is responsible of keeping up to date and prioritized. From the backlog the team selects how much work it will be able to complete in each iteration. Besides the team and product owner, the third role in Scrum is the scrum master, who takes care of the Scrum process. [22]

**Extreme programming (XP)** is based on values and practices. The software is kept in good shape, allowing changes also in the late phase of the development. This is achieved with practices, like test driven development, continuous integration, refactoring and pair programming, to name a few. The values - communication, simplicity, feedback, courage and respect - go well hand in hand with agile values. [23]

**Kanban** is often related to lean methods, since it aims to visualize the workflow and find the bottlenecks in the value chain. This is basically done by moving tasks in a table from columns such as "to do", "in progress", "ready", "in operations" and restricting the number of tasks which can be in one column at the same time. [24]

## 6.2 Standards Posing Challenges to Agile Methods

Agile methods are often seen as an alternative to plan-driven methods. Thus, the standards and their strict definitions pose challenges to utilization of agile methods. In ECSS standards, it is often defined that the specifications must be defined before the implementation, even to quite deep in detail. This is opposite to agile thinking, where the specification is done only to the minimum extent possible at any given time.

Another challenge is the strict scheduling the standards propose. Every step follows each other, and often verification and validation is left in the end. On the contrary, agile methods propose short iterations, which include all the phases from specification through implementation to testing. For example, agile practice called test-driven development even propose starting the implementation from test definitions and running the test to make sure that they fail, if not implemented.

The ECSS standards define the phases of the project and reviews for the phases. If there is a need to change the design after the review, it is done through a non-conformance procedure, which is quite heavy and time consuming. This will also lead to freezing the design early in the development, whereas agile methods advice to freeze the design as late as possible.

One of the focuses of ECSS standards is the documentation required in each phase. These templates are aimed to ease the work. From the agile point of view, this might highlight too much the importance of the documentation and create work that is document driven instead of focusing on the product.

Besides project management and documentation, ECSS standards also guide the component selection and assembly. Even though this is not directly coupled with the development methods, it has one effect on the implementation of the development: the guidelines make the components a scarce resource and there is not much room for selection. This has in turn lead to long delivery times of components, which also forces to freeze the design quite early.

## 6.3 Overcoming the Challenges of Utilization of Agile Methods with ECSS Standards

To be able to create a fully agile method for European Space Industry, some processes defined in ECSS Standards would be required to be altered, such as making specification, implementation and testing more simultaneous. Still, agile methods may be utilized as long as they are tailored accordingly.

To be able to utilize agile methods in ECSS standards environment, the iterations must be fitted between the milestones of the project. This way each phase can be considered as a separate project from the agile view point. Inside the phases, the work will be completed in priority order. Also experimenting is then encouraged inside the phases.

The amount of documentation can be seen as a part of product instead of extra documentation and divided as work into iterations as well. This goes well hand-in-hand for example definition-of-done criteria utilized in agile methods: the task is seen ready only when it is documented according to the specifications of the customer.

Often the requirements are well defined already in the invitation to tender, and the tender includes specifications to some extent. These specifications are good to be gone through and even challenged when implementing the product. There is often room for discussion with the customer about the requirements in order to create the best possible product.

Even though testing and validation of product is scheduled in the end of the product development, practices such as test driven development can be applied already in the implementation phase, or in ECSS terms the defined definition phase.

There is growing interest in applying agile and lean thoughts to new domains, and space industry is one of them. ESA has already been utilizing concurrent engineering [25] in the early phases of ESA project. Concurrent engineering shares some ideas with agile and lean thinking: the design flow is iterative, the design activities are done in parallel, co-located teams are preferred and specialists of different areas collaborate in order to influence the system instead of implementing only own portion. Agile methods promote even more self-organizing teams and provide practices for fluent communication. Combining concurrent engineering and agile methods, and implementing them throughout the project can make also space engineering more efficient and reactive to changes.

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