International Astronautical Federation

International Programme / Project Management Committee

IAF-IPMC
Young Professionals
Workshop 2016

Workshop Results Report

Workshop Organizing Committee
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Group Photo of the 2016 International Project Management Committee Young Professionals Workshop delegates on 25 September 2016 at Expo Guadalajara, Mexico

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1. Executive Summary

On September 25th, 2015 a group of 25 international young professionals – working in space agencies, companies and professional organizations– met to participate in an annual workshop organized by the International Programme/Project Management Committee (IPMC) of the International Astronautical Federation (IAF). The workshop was planned and organized by a team of international young professionals working in collaboration with the IPMC. It was held at the Expo Guadalajara in Mexico in connection with the 67th International Astronautical Congress (IAC).

The YP Workshop – the fifth in a series of annual workshops organized by the IPMC – sought to gather ideas and suggestions from early career employees in the international space community and provide the IPMC and IAF member organizations with greater knowledge, insights, and perspectives that can help them better develop and empower the next generation of space program employees. The IPMC was supported in this effort by a group of young professionals who participated in previous workshops and served as the Workshop Organizing Committee (WOC) to manage the overall process and finalize preparation of a workshop report.

The workshop itself represented the culmination of an initiative that began in the second quarter of 2016 with the nomination and selection of workshop participants who were assigned to working groups focusing on three discussion topics. Over the ensuing period these groups discussed – mostly through virtual on-line discussion sessions – and investigated the topics and reached preliminary conclusions. The groups then met face-to-face at the workshop, finalized their recommendations, and presented the outcome to the IPMC members, workshop delegates and guests.

Following the workshop, the WOC prepared a final report with summary of the results and recommendations.

Topic 1: How to improve Project Management processes, methodology and tools for innovative, agile, low cost and high performance space project.

In order to fully cover the scope of the topic four subtopics have been researched in more detail;

- Agile Scrum has had a successful implementation in software projects, resulting in other businesses following its principles. Space agencies have started implementing agile methodologies such as concurrent engineering, a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively resulting in timesaving and cost saving. Agile approaches are well suited for earth observation, navigation, telecommunications and launcher projects.
- Industry 4.0, the fourth industrial revolution utilizing digitalization and digital networks for the intelligent networking of products and processes along the value chain. Companies are more likely to accept higher initial investment levels in industries with high production volumes, making Industry 4.0 for Space most applicable to the navigation and telecommunications domains.
- Standardization - and standardized interfaces - can make it easier to integrate subsystems from different manufacturers. The CubeSat standards are an attempt at defining standardized interfaces for Nanosatellites.
- Cost Controlling Policies for space projects to enable low-cost missions.

Topic 2: Knowledge Management in the Aerospace Sector

Knowledge transfer within aerospace organizations are based on the following variables and considerations:

- Culture, people and processes;
- The need for planning the gaps between current knowledge and required knowledge for future projects;
- The - long - duration of space projects (from early conception to the end of a mission);
- Lessons learned from within project teams and organizations as a whole.

Existing KM practices are categorized into three main groups:

1) the lessons learned approach;

2) the organizational administration approach;

3) the product feasibility approach.

Since there is very limited information on KM practices in the private sector, the summary in topic 2 reflects mostly KM practices provided by public or government organizations.

By implementing recommendation from this topic, an organization can begin to build a long term strategy for knowledge management and transfer, not just for current employees but for future members of the organization, thus ensuring sustainable knowledge transfer for generations to come.

Topic 3: 5 Years IPMC YP Workshop

The group's work fell into two categories: analysis of past workshop recommendations and recommendations for the workshop in the future. The analysis included the identification of concrete examples of realisations and reflect on the their respective succes. Additionally the group addressed concrete steps to update recommendations for implementation.

The past workshop topics were divided into six themes to structure the workshop research and recommendations;

1. Mentoring; focuses on benefits and methods of mentoring that can help young professionals with career development.
2. Accelerated Learning; focuses on measures to support a rapid and effective engagement and learning of young professionals newly joining an organisation.
3. Exchanges; exchanges have been identified as important and mutually beneficial for young professionals and their organizations.
4. Motivational Aspects; contains recommendations dealing with the factors that motivate young professionals to pursue aerospace careers and thrive in them once they are there.
5. Promoting Innovation; topics targeted specifically at maximizing the innovation ideas generated by Young Professionals in their organizations.
6. Management Approaches; covers all workshop topics targeted at tools, methods and skills required from Young Professionals within the aerospace sector.

Throughout the following report, the various topics will discuss in details their methodology and findings which ultimately resulted in recommendations to be implemented.

2. Introduction

The IPMC Young Professional (YP) Workshop is an annual initiative of the International Project Management Committee (IPMC) of the International Astronautical Federation (IAF). The IPMC – which brings together representatives from more than twenty IAF member space agencies, companies and professional organizations – meets semi-annually to exchange experiences, best practices and to collaborate on projects that nurture the global space workforce.

The YP Workshop is held just prior to the IAF's International Astronautical Congress (IAC). The IPMC selects a small group of young professionals who previously participated in a YP Workshop to serve as the Workshop Organizing Committee and help the IPMC organize and manage the event. For the 2016, the Workshop Organizing Committee (WOC) members were:

- Maarten Adriaensen (ESA): WOC Project Manager
- Birgit Hartman (ESA): WOC Technical Manager
- Lisa Antoniadis (EPFL): WOC Logistics Manager
- Anne Meier (NASA): WOC Communications Manager

The Workshop Organizing Committee members were also asked to closely follow the development of the discussion topics, guide the discussion group deliberations, and prepare this final report. The 2016 IPMC Young Professionals Workshop attracted twenty five early career employees from government, industry, research and professional organizations throughout the world. Each of the participants was nominated by an IAF member organization to attend the workshop in response to a call for nominations.

The workshop participants selected one of three discussion topics to continue in smaller discussion groups that met virtually during the period prior to the actual workshop session. (Please see Section 3: Virtual Session Collaboration and Pre-Workshop Activities, below.) The results of these investigations and deliberations and associated observations and recommendations are presented in this report. The ideas and views expressed herein are those of the participants as individuals and do not necessarily reflect the views or positions of the IPMC, the IAF or its member organizations.

3. Virtual Session Collaboration and Pre-Workshop Activities

Since the Young Professionals Workshop is a one-day event, the Workshop Organizing Committee (WOC) felt it was necessary to establish relationships among the delegates who would attend through virtual tools in advance of the event. With a globally distributed and diverse group, the WOC elected to encourage use of online social and collaborative tools, such as Skype, Facebook and Google Docs and the scheduling tool Doodle, to facilitate "breaking the ice" and initiate group conversations around the chosen discussion topics.

After the delegates were selected, the Organizing Committee administered a questionnaire to obtain information including individual delegate profiles for the workshops handbook, along with their preferred social networking tools and professional capabilities and personnel hobbies. This information helped establish a basis for assigning the delegates into the various topic groups. The participating Young Professionals each expressed particular interest in one of the proposed topics. In addition to their topic interest the participants could express their desire to function as either a team leader or a rapporteur.

The WOC then organized a first meeting via Skype for each group to introduce the Statement of Work (SOW) and explain in detail the expectations, goals, timelines and deliverables. This was also a good time for the delegates to ask any questions, and to share their initial thoughts and ideas.

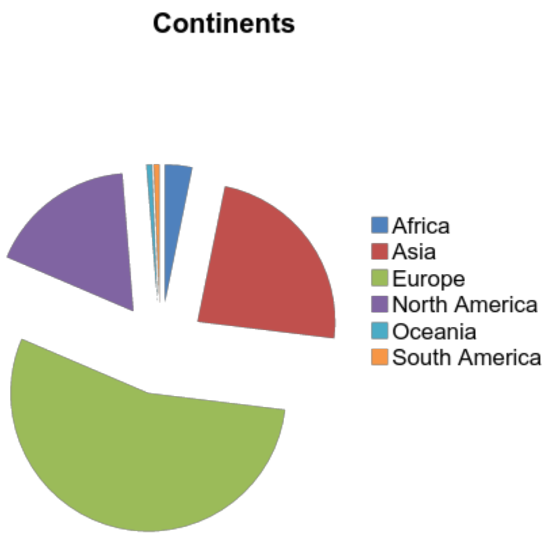
Each group selected a topic leader and a rapporteur. The topic leaders were responsible for producing requested deliverables and for managing other related discussion group tasks. The topic leaders were also the main point of contact for the WOC. The rapporteurs were asked to document the discussions and the progress made. These documents were helpful to ensure all of team members understood the status of the deliberations.

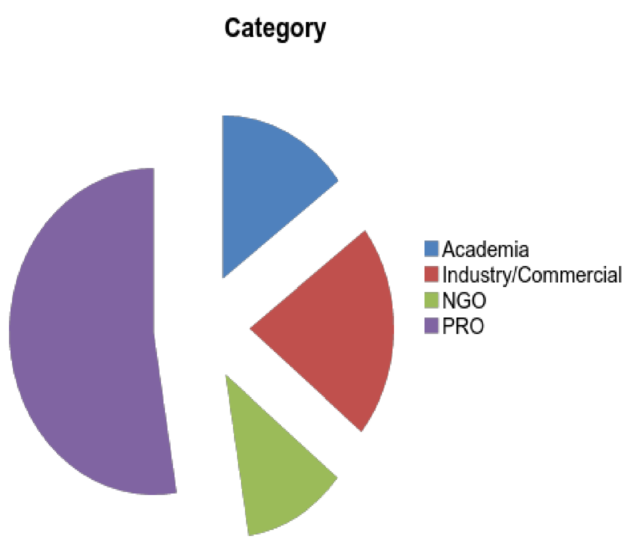
The virtual session process began in July 2016. Until the September Workshop, the delegates were asked to work on their individual topics. Discussion group meetings were facilitated via Skype and scheduled mostly through Doodle, which allowed delegates to self-organize times in line with their availability. Documents, such as mid-term reports and project execution plans were submitted as deliverables and shared under folders in Google Docs. This proved to be a very helpful and reliable tool and was easily accessible by delegates around the world. The teams then conducted in depth investigations, held various interviews, and shared their own day-to-day experiences working in the space industry as young professionals. As a tool for collaboration among thirty participants from diverse locations globally, the virtual sessions worked well as a means to bring the delegates together prior and facilitate the research prior to the Workshop.

4. IPMC YP Workshop reaching YP's worldwide

In the 5 editions of the workshop since 2012 we have had over 150 participants. Below you will find for information a breakdown of the background of the participants to the workshop. Ms B. Hartman has presented a paper on the IPMC YP workshop at the 2016 IAC.

The link to full paper and presentation can be found in chapter 9 of this report.





5. Group topic results

During the 2016 IPMC Young Professionals Workshop the three discussion groups met face-to -face for the first time, finalized the results of their discussions and presented their findings to the other groups along with several IPMC representatives. The topic reports prepared by the three groups, along with each group's concluding observations and recommendations, are presented below.

Due to the amount of information gathered, this report consists of a detailed but selected compilation of the results. The full length report and/or research annexes of each discussion group are available via the links provided in Chapter 10 of this report.

5.1. Topic 1 - How to improve Project Management processes, methodology and tools for innovative, agile, low cost and high performance projects.

5.1.1. Introduction

With tightening public expenditure and increasing global competition, the mantra for the space sector is turning towards low cost and agile space missions, with a focus on timely execution within cost perspectives and flexibility of space mission objectives and operations. The key subject addressed by the Topic 1 team delegates is ***how to improve Project Management processes, methodology and tools for innovative, agile, low cost and high performance space projects.***

5.1.1.1. General Approach & Methodology

In order to refine the broad range of concepts covered by this subject into a concise list of subtopics to be addressed a "visualization matrix" was introduced. This took the form of a two-dimensional array, with one axis dedicated to the classical space domains and the other axis representing the classical project stages. As work progressed some of these ideas were refined, some of them dropped due to lack of time, insufficient research material or the difficulty to define them in the context of the topic scope, and some of them combined, with the end result being the four sub-topics that are explored in this report. The final version of the matrix contains the areas covered by the four sub-topics (see Figure 1).

In the four sections below a brief introduction of each subtopic and its mapping onto the matrix is explained in more detail.

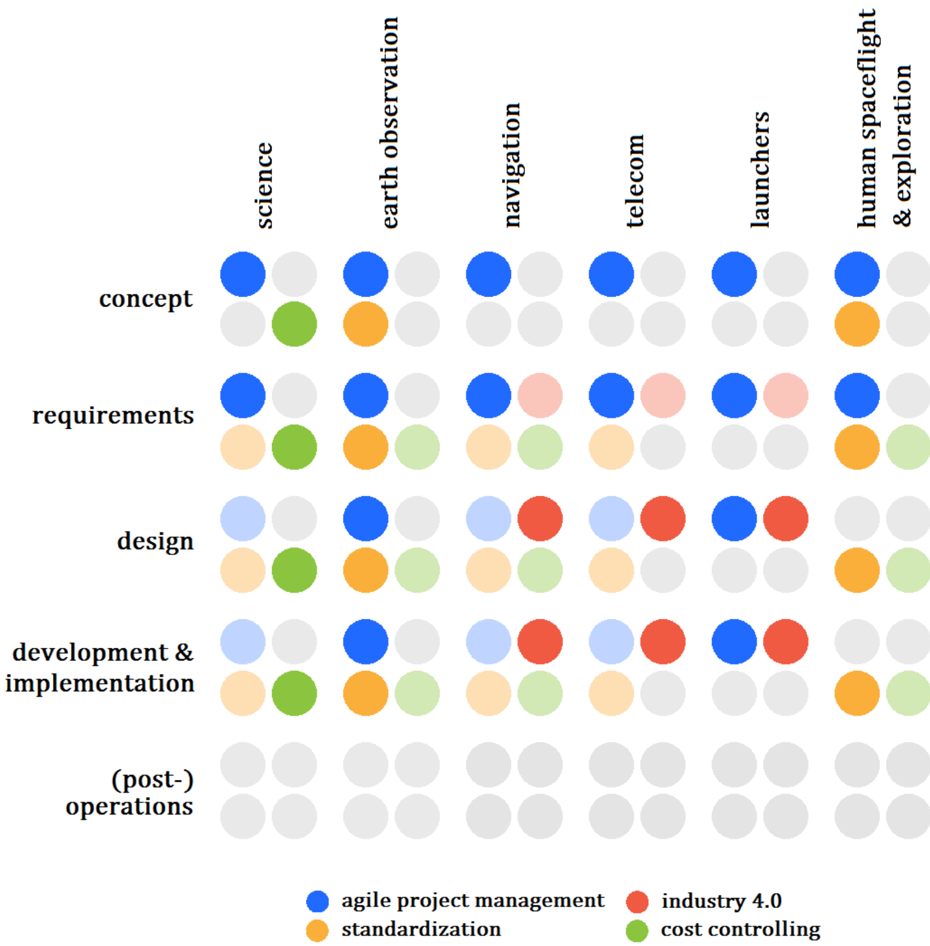


Figure 1 Final visualization matrix with four subtopics contained in report; dark shades indicate where it is already (most) applicable, light shades indicate possibilities for extended application or improvement

5.1.1.2. Agile Project Management for Space Projects

Agile, and more specifically its Scrum framework, is becoming a popular Project Management (PM) approach. Agile Scrum has had successful implementation in software projects, resulting in other businesses following its principles, such as hardware development [Backblaze Inc., 2015; Denning, 2012; Johnson, 2011; Van Schooenderwoert, 2015]. Space agencies and companies have started implementing Agile methodologies or similar practices, such as concurrent engineering. For instance, Planet Labs and Space Exploration Technologies (SpaceX) are following Agile principles to develop their products [Chaikin, 2012; Morrison, 2013; Planet Labs Inc., 2016; Vanderbilt, 2015]. ESA and NASA are both using concurrent engineering [ESA/ESTEC, 2015].The primary question addressed in this report is under which conditions Agile methodologies can be implemented for space projects.

The Agile PM methodology is particularly useful for feasibility studies since it has been developed for software projects where the solution is not known from the start. Concurrent engineering, a methodology that has a lot in common with Agile PM, is already widely being used for feasibility studies and requirements definition for space projects. However, Agile PM promotes going through all project phases in iterations, from requirements definition to implementation, essentially merging them in one iterative process; this is (partially) already done for Earth observation and for launchers.

The findings and recommendations of this study are therefore applicable to the design and implementation phase as well. Agile PM methodology could in principle be applied in other project phases.

Agile frameworks are easier to use for commercial projects where the development team is the design authority and where the process can be lightened. In the space sector, Agile PM approaches thus apply better to earth observation, navigation, telecommunication and launcher projects. Applying Agile PM principles to science and exploration projects could be more challenging and even more difficult for human spaceflight.

5.1.1.3. Industry 4.0

Industry 4.0 is the term used for the fourth industrial revolution that utilizes digitalization and digital networks for the intelligent networking of products and processes along the value chain This report explores the idea of space projects planning the involvement of manufacturing plants using Industry 4.0 developments and technologies from the early design phase in order to maximize the benefits. Changes in approach to consider methods to select the right options from a huge data pool are analyzed, to allow better understanding of the business and improved decision making.

The initial idea offered by Industry 4.0 is the enhancement of physical manufacturing processes, using interconnected machines and data analytics. This can be extended to the design and requirements phase, exploiting data exchange between software and applying methods such as rapid prototyping early on.

The introduction of Industry 4.0 in space is expected to be more beneficial to areas with higher production rates such as navigation satellites, telecom satellites and launchers.

5.1.1.4. Standardization

The standardization of interfaces has been incredibly successful in industries such as personal computing in reducing project scope, costs and shortening development timelines [Anderson, 2016]. The CubeSat standards are an attempt at defining standardized interfaces for Nanosatellites. The advantages and disadvantages of the current CubeSat standards are considered, in addition to the future applicability of similar standards to larger satellite projects.

The lower-cost Nanosatellites have typically been deployed to Low-Earth Orbit, limiting their usage mostly to technology demonstration and earth observation purposes. Earth observation and remote sensing are expected to further dominate the market of Nano satellites in the future [SpaceWorks Enterprises, 2016]. Because of the very high costs involved in human spaceflight and exploration, international collaboration is likely required, prompting the necessity of standardized interfaces as was done for the International Space Station (ISS). The modular approach taken by the examples described above defines the entire project cycle (from conception to operations) but in order to fit in the standard project conception cycle in other domains, the main focus is to utilize standardization also for projects not completely designed to follow a standardized approach i.e. after the concept phase.

5.1.1.5. Cost Controlling Policies for Space

Space agencies around the globe that execute unique and cutting-edge space science missions have been confronted by a substantial project cost growth. [Committee on Cost Growth in NASA Earth and Space Science Missions, 2010; Jonathan Amos, 2009] Cost growth can force agencies to rethink their scientific agenda and in the worst case jeopardize their scientific program. To enable low-cost missions, agencies have to make substantial effort to improve the issue of cost growth.

Cost growth is particularly relevant for space projects with no or limited commercial drivers. For the purpose of this report, space science is singled out as the theme of the discussion, but similar observations are valid in other domains such as some earth observation programs (e.g. Europe’s Copernicus program), navigation programs and human spaceflight and exploration.

The main points addressed in this section are risk management in the early phases where competitive trade-offs are required, the application of heritage technology in the design phase and improved transparency during development and implementation.

5.1.2. Subtopic 1: Agile PM for Space Projects

5.1.2.1. Introduction & Methodology

Agile programming and Space Systems Engineering perspectives were applied to this subtopic, with a literature analysis focused on the following:

- Agile methodology and the Agile Scrum framework;
- Experiences in Agile PM for hardware projects and system development;
- Experiences in Agile PM for space projects.

5.1.2.2. Discussion on Agile (Scrum) Methodology

The four values and twelve principles of the Agile Manifesto were initially created to help software development teams focus on the creation of a working product in line with customer needs whilst also respecting deadlines and budget [Layton, 2015]. The values and principles designate the team members as the authority for decision and design. They favor a working software over processes, documentation, and requirements.

At first sight, this goes against common practices in space projects where processes, standards and detailed documentation are used to increase product quality and prevent failure of mission critical space systems. Over time, these quality standards and processes have grown and they are now applied to almost all space missions. Yet, they do not prevent every failure, and the failures can often be led back to communication issues, rather than violation of processes and standards [Carpenter, 2014].

For certain projects, like CubeSats and some standard ISS experiments, quality standards and processes are questionable as they result in long lead time and high costs. The Agile PM methodology was created to fix similar issues in software development and can offer solutions to these problems in the frame of space missions. Close team cooperation, with direct and regular communication, “as face to face as possible”, improves the common understanding of team members. This, in addition to an increased level of responsibilities, enhances the willingness to work hard together to come to the right solution. Tactics in Agile Scrum such as sprint iterations and task prioritization allows earlier identification of issues and better control of the progress. Altogether, Agile Scrum can be used to improve project control on time and budget. Specific recommendations on how to apply Scrum for space projects are provided in the conclusions.

5.1.2.3. Discussion on Application of Agile Project Management for Space Projects

Successes achieved by software projects following Agile principles lead some people to recently start applying it to other fields of engineering. One of the best examples is the Wikispeed team founded by Joe Justice . They managed to do in 3 months what usually takes years: design a vehicle prototype with good driving characteristics and low fuel consumption. Agile PM has also been used in multiple space projects. SpaceX is applying Agile PM approaches and Planet Labs is using Agile Scrum to its full extent to design and built their satellites.

The following project characteristics that strongly help the use of Agile methodology for project management were identified:

- The developer is the design authority; he or she decides on the best architecture to provide for the product or the service;
- Demonstration of safety and reliability is, when possible, in the hands of the developer in close cooperation with the customer and not necessarily per standard procedures, process or document review;
- A company can design according to their own ways and methods instead of external applied processes and has the freedom to determine when to:
  - Use of commercial-off-the-shelf (COTS) components;
  - Use custom components made in-house;

  Subcontracting is not preferred;
- Implementation of standardization and interchangeability to allow modular design, and to limit re-addressing interfaces when further iterating the design of subsystems or parts;
- Use of inexpensive materials and manufacturing processes for parts or components where a high quality is not strictly required.

To what extent these characteristics can be applicable to space projects depends on the type of space system. For example, the mass reduction is a higher driver for deep space missions than for small satellites in Low Earth Orbit (LEO). The extent of using COTS products will also depend on the novelty of the space system. For cutting-edge technologies, the required parts will not be available. As another example, inexpensive materials might not be suited for certain parts of launchers or for parts exposed to the harsh space environment, or too high loads, while for experiments within the space station this is less of an issue. The safety standards also vary depending on the project type. For a big satellite constellation, the loss of a few satellites could be tolerable to still achieve mission success. This is not the case for a launcher or a deep space exploration mission.

The philosophy of putting a team together and let it work on the product in an iterative process is not new to the space business. This has already been done for several years using a methodology called Concurrent Engineering (CE). It has proven to be a successful and much faster method for performing feasibility studies than conventional approaches. This is not surprising since iterative methodologies are particularly efficient for creative processes where the product or the road to it is not clear at the start of the project. This is definitely the case for initial phases of space projects.

So far CE has primarily been used for feasibility studies [ESA/ESTEC, 2015]. The approach of iterative design in sprints could also be extended up to the actual production, instead of only the traditional preliminary and detailed design phases. To achieve this, the authors recommend to use CE and Agile Scrum together in an hybrid approach.

5.1.2.4. Conclusions & Recommendations

Based on the literature study outcome the authors conclude that Agile PM methodology can be successfully applied for certain types of space projects. The authors recommend the following guidelines for space projects:

- Implement the Agile Scrum framework with sprint iterations:
  - **Regular contact and reviews**: daily stand-up meetings, retrospective meetings at the end of sprint, regular contact with customers and demonstration of the product at the end of sprints, no external interruption of the team during the sprint;
  - **Task backlogging:**
    - Split work packages into tasks that can be completed within a few days or at least within the sprint;
    - **Prioritize the backlog** according to what can be done first, is a new technical challenge, has a low Technical Readiness Level (TRL), is mission critical or is required by the customer;
  - **Testing and demonstration**: Use simulations, breadboards, Field-Programmable Gate Arrays (FPGAs), representative hardware or even real hardware to test the product during each sprint;
- **Limit documentation** whenever possible; it can be replaced with direct communication, demonstration, 3D models and Model Based Systems Engineering (MBSE) or by other means;
- **Stimulate more involvement** of all stakeholders where possible

To account for the space projects reality, adaptations can be done to the Scrum framework. One of the biggest challenge when applying Scrum to hardware development is to allow testing at each sprint because of time and cost involved in production. This is why the authors are recommending to use simulations, breadboards, FPGAs or representative hardware when it is not possible to perform tests and demonstration on the real target hardware. It is also not always possible to reduce documentation because of certification processes and quality control. The standard one to four week sprint length for software development might need to be increased to account for this documentation and because of the longer hardware production time. The authors suggest a sprint length, with the associated delivery, every one to four months. Longer sprints lengths are not recommended because the advantages of this Agile methodology will be lost due to the late feedback. The content of the delivery is defined at the start of the sprint. It can consist of 3D models, simulated or produced hardware and software, depending on the moment in the overall project. Mandatory documentation and presentations might also be part of the delivery if needed.

Nevertheless, this should not prevent from applying Agile methodologies to space projects. Hybrid approaches can even be used, where an Agile methodology is used in combination with a more standard approach [Carpenter, 2014]. The key is to well define the role of each methodology ahead of time. It is recommended to use Agile for parts of the projects where there are a lot of unknowns, both in the scope of the project and specific novelties like new technologies.

The research has shown that Agile Scrum has already been applied successfully for the development of systems (Wikispeed) and space projects (Planet Labs & SpaceX). In particular the latter shows also mission-critical systems can be developed while following Agile principles.

Concurrent Engineering is a methodology similar to Agile. However, so far this has primarily only been used for feasibility studies. The authors recommend to use CE and Agile Scrum together in an hybrid approach. Here is a list of recommendations to achieve this:

- Involve the contractor right from the beginning or facilitate the transition;
- The first sprint corresponds to the CE feasibility study;
- Both the customer and the contractor are present at the design facility (either physically in the same facility or by having more than one facility linked together via computer tools for efficient data exchange and communications) (more on this in chapter 3: Industry 4.0);
- Subsequent sprints are managed in a Scrum iterative approach including all phases of development (with Industry 4.0 this could even be extended to production) with the customer playing the Product Owner (PO) role (see Appendix part 2.2.3) and all stakeholders returning to the design facility when needed.

The goal of this hybrid methodology would be to reduce the time frame and cost of space projects, not only during the initial design, but throughout the whole project lifetime. Mission success could potentially also be increased due to constant task re-prioritizing and reduced probability for communication errors.

A visualization of the recommendations is provided in Figure 2. The top part of the figure depicts the current project phases of a space project with the requirement and design review milestones where sets of documents are delivered, reviewed and returned with change requests (CRs) and review item dispositions (RIDs). The authors recommendation is to move to a continuous iterative design process as depicted in the bottom part of the figure. This process can be initiated by an agency and transferred to industry or executed completely in the industry. Instead of reviews of documentation sets, formal review are done by including the customer in the process and conclude with a 'snapshot' of the project. During these reviews the overall status of the project is performed, not just requirements or design. Intermediate reviews with the customer can be performed at the end of each sprint.

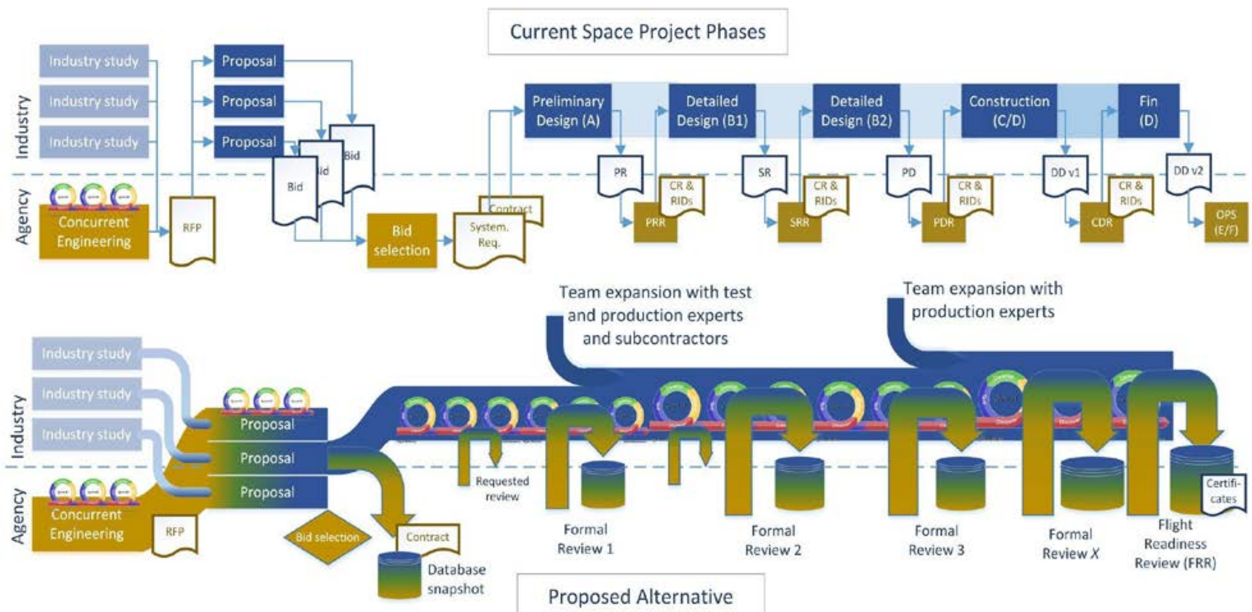


Figure 2 Comparison of the current projects phases and reviews with the proposed Agile PM approach for a space project (the abbreviations are provided in Appendix 1.1.4)

5.1.3. Subtopic 2: Industry 4.0

5.1.3.1. Introduction & Methodology

The term Industry 4.0 refers to the fourth industrial revolution that is currently taking place.

- The first, and most commonly known, industrial revolution was at the beginning of the 18th Century with the introduction of water and steam power to facilitate and improve production processes;
- The second revolution was the assembly line and the introduction of electricity as the energy source to support mass production;
- The development of computers and electronics triggered the third revolution in which further automation of production reduced labor costs;
- With the arrival of the internet and the increased possibilities for multi-device connectivity (termed the "Internet of Things"), a fourth industrial revolution is now underway.

The Industry 4.0 revolution is expected to bring about a major shift in the domain of knowledge based automation. The space industry is composed of many different entities both public and private, all of which have come into being in the relatively short period of time over the last fifty to sixty years. It is believed that the arrival of Industry 4.0 (as Space 4.0) has the potential to have far-reaching impacts for the space industry, across all project phases [Pultarova, 2016].

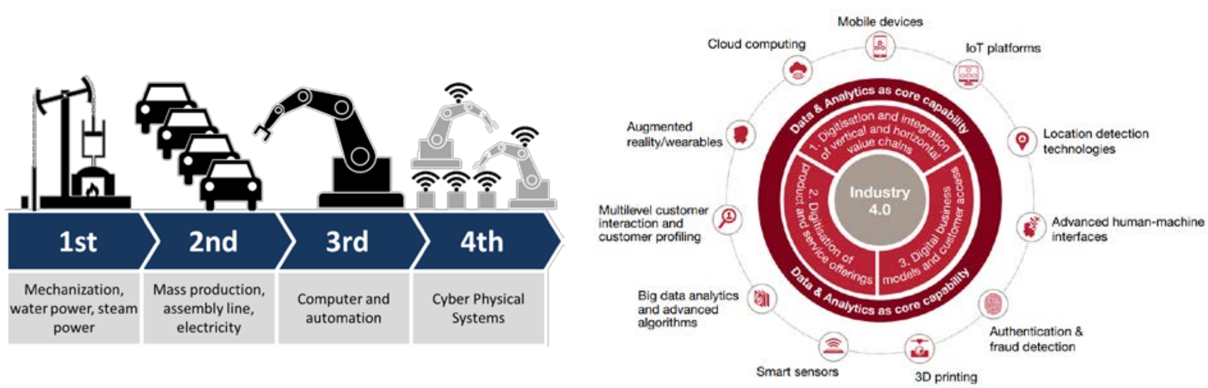


Figure 3 Left: The 4th industrial Revolution [Roser, 2015] & Right: Industry 4.0 framework and contributing digital technologies [PWC, 2016]

Industry 4.0 focuses on communication and cooperation within companies and organizations by means of four main "digitalization transformation" developments. These have been given the terms the Internet of Things or "IoT" (many devices), Data ("big data" sets covering many areas), Services (connection of devices to add value such as cloud computing and collaboration) and People (changing the ways humans access and interact with data and services). These developments aim to allow humans and machines to communicate, automate, and exchange data in both the physical and digital world.As an example in everyday terms, consider how streaming of data from the internet or home servers is now coupled to WiFi/bluetooth TVs and speakers to provide people with a simple way to create a multi-room networked media system in their own home with a few simple clicks, providing them the ability to control and monitor at any moment. Although the term Industry 4.0 has been linked to "smart manufacturing", it is also applicable to many other sectors including services and operations.

Digital transformation helps to create new business and cooperation models across countries, and the recent ability to bring high-performance, low cost and small size technology to the mass-market has already created a boom of new devices and applications being produced all over the world by many different companies.

For industries the Industry 4.0 developments allow:

- Reliability and continuous productivity: through standardization and improved quality control;
- IT security: improved control;
- Product lifecycles: traceability of components;
- Industry value chain: end-to-end networked manufacturing systems; integration of engineering across the value chain; reduction of lead times; easier transition from engineering design to AIT production;
- Data Management: sharing knowledge and lessons learned. paper-less management. software tools to assist management of: document repositories, review systems, non-conformance tracking, anomaly report tracking.

The report focuses on a number of examples to demonstrate their applicability of Industry 4.0 to space, and make conclusions and recommendations to enable the industry to take full advantage of this revolution as early as possible.

5.1.3.2. Literature Study Results

Literature study shows that the following strategies [Deloitte, 2015] can be used to increase competitiveness utilizing the Industry 4.0 digitalization technology developments:

- Optimization of opportunities and reduction of risks through data-sharing and data-mining using digital transformation (converting the "real world" into "digital world", allowing data analysis and processing). Digital transformation could however further increase the already heightened cyber risk to the manufacturing industry. Leading manufacturing companies are taking a proactive approach to both opportunities and risks;
- Adjust in-house talent and IT resources to work with IoT tools and technologies. It is necessary that companies invest in appropriate skills and an appropriate IT infrastructure. Implementing Industry 4.0 technologies will have an impact on the personnel and culture and the way they work;
- An increase in knowledge based work, continuous improvement principles, multi-skilled and diverse teams which are open, creative, networked and interactive;
- Change from the “push into the market” philosophy to “pull from the customer”, i.e. understanding the needs and materializing them into production means. Working on individualized solutions has a strong capacity to take manufacturing into a whole new era of customization;
- Utilize the momentum of the exponentially growing Industry 4.0 related technologies, such as additive manufacturing, nano-printing Nano Electro Mechanical Systems (NEMS), tele-presence, robotics, neuronal networks, virtual intelligence, drones, crowdfunding platforms, and global connectivity. Currently only a few companies make full use of these technologies and are already developing the next generation of applications. Companies and organizations that do not start utilizing these technologies now run the risk of becoming uncompetitive in the future.

Industry 4.0 will provide an advantage to organizations that fully understand its implications and how this impacts the way they function. The following step-by-step approach is recommended to move forward and transcend with Industry 4.0:

- Map out the Industry 4.0 strategy;
- Create initial pilot projects;
- Define capabilities and needs;
- Master data analytics;
- Transform into a digital enterprise;
- Actively plan an ecosystem approach.

Due to the Industry 4.0 developments, the business models of the companies applying them are evolving towards more interconnected systems [The Government Office for Science, 2013]. Companies in the Aerospace and Defense sector expect an increase from 39% to 82% within the next 5 years in the data and analytics for decision making [PWC, 2016] . For space projects this would require the capacity to negotiate with complex global markets and international supply chains.

Managing information in a digital cloud provides transparency of the processes to decision makers in order to:

- Align activities and resources with strategy up and down the organizational hierarchy;
- Coordinate the involved units along the entire supply chain and the stakeholders;
- Adapt to changing circumstances and market shifts.

Implementing digital transformation in space projects towards Industry 4.0 implies the growing need for managers with a hybrid set of science, technology, engineering and mathematics (STEM) and managerial skills. It further requires strong IT workforces capable of being re-skilled in advanced technologies, possessing soft skills for managing operations effectively, in particular for understanding the customer. Projects using Industry 4.0 will initially involve a higher financial outlay, due to a value-added activity being brought forward to an earlier stage in the process in order to reduce costs later on. Companies are likelier to accept higher initial investment levels in industries with high production volumes [BMWI, 2013], making Industry 4.0 for Space most applicable to the navigation and telecommunications domains (and, considering the expected increase in the market in the coming years, also the launcher domain).

5.1.3.3. Conclusions & Recommendations

Industry 4.0 is a new development, and like any major industrial revolution will necessitate significant change in the working practices across many domains. The authors recommend a number of key challenges and considerations that should be addressed in order to maximize the potential benefits on Industry 4.0 for the Space industry. In particular:

- Investment of effort to ensure that the communication methods and protocols are streamlined to improve inter-system (both human and machine) communication;
- Response of machines: a strong cross-link between different databases, production subsystems and customer information systems is needed to be able to add a real value to the production chain (e.g. this exists somewhat already with the concept of “part alerts” across the industry to report a problem detected in one project to other projects, but these types of links should be expanded and strengthened);
- To what extent digitalization of production is possible considering the limited amount of robotic and automated production in space products, in particular for integrators;

- How to improve upon existing data analysis capabilities, and how data is fed back to designers considering the products are in space and operated by others;
- Maximizing the advantages of existing modern production technologies coming from traditional mass sectors such as automotive, and applying them to spacecraft manufacturing practices;
- Minimizing IT system maintenance and refurbishment costs, which are currently very high in the space industry due to the existence of a significant number of project specific tools;
- In the first instance, the introduction of Industry 4.0 may lend itself better to Small Medium Enterprises (SMEs) and subsystem or component producers. Due to lower capital costs in factory design and infrastructure, and often increased (semi-)serial production, the benefits of Industry 4.0 for these companies may be more immediately realized;
- Analyze the lessons learned of Industry 4.0 developments in the automotive and aerospace industries, particularly in the areas of data collection (e.g. auto repairs utilizing computer readouts) and analysis to improve real time measurements (e.g. turbine engine performance) and service planning;
- Implementing Industry 4.0 technologies will not only require the right tools but also a change in culture, organisation, leadership and skills across the entire industry. In short, this will require a long-term shift in approach.

Companies like SpaceX (planned production of 4000 satellites over the next years) and Oneweb (planned 700+ satellites) are already taking benefit from Industry 4.0. Other programs that are suggested candidates to make better make use of Industry 4.0 are next generation navigation satellite systems, telecommunication programs and (to a lesser extent) Earth observation constellations. SpaceX and Planet Labs can be considered as early adopters of Industry 4.0, for instance in applying improved 3D design software for design, review and production. With the developments in Industry 4.0 increasing at an ever more rapid pace, it is believed now is the right time to consider implementing some of the prime principles of this methodology also at the spacecraft manufacturing stage, rather than waiting to see how these developments unfold and risk becoming uncompetitive in the global market.

5.1.4. Subtopic 3: Standardization

5.1.4.1. Introduction & Methodology

Currently, most satellite projects demand custom-designed systems to meet the needs of their specific mission. The result is that projects can become very expensive and lengthy: satellite engineering firms require experts from all the relevant fields; resources are spread among the many subsystems; each subsystem must be designed, reviewed, manufactured and tested [Kalman, 2006]. In addition to the cost and time considerations for the client, the high costs associated with such projects can often make them inaccessible to emerging satellite engineering companies, thus potentially reducing overall competition in the market.

The standardization of interfaces has been very successful in reducing project scope, costs and timelines for industries such as personal computing. The CubeSat standards are an attempt at defining standardized interfaces for Nanosatellites. Reference is made to more than one standard because, in addition to the CubeSat Specification defined by CalPoly [California Polytechnic State University, 2014], other optional standards have been defined for CubeSats to cover aspects not covered by the CubeSat Specification. The advantages and disadvantages of the current CubeSat standards are considered and as well as the applicability of similar standards to larger satellites..

5.1.4.2 Standardization of CubeSat interfaces

Standard interfaces generally allow parts from various manufacturers to be integrated with one another with reduced effort. This allows the scope of projects to be reduced to the development of single subsystems instead of the development of complete systems [GomSpace, 2016]. Scope reduction allows resources to be focused and timelines to be simplified, which can be very advantageous for the management of projects. The smaller teams associated with reduced scope also benefit from improved communication and easier management when compared with larger teams [Botma, 2016; Jordaan, 2016].

Additionally, standard interfaces provide access to mature COTS subsystems accompanied by technical support and documentation, adding to the resource pool [Kalman, 2006]. Through access to COTS subsystems, standardized interfaces allow system builders to react to customer demands more quickly [Jordaan, 2016]. A project could potentially be simplified to buying and integrating a number of COTS subsystems.

CubeSats currently apply various standards to ease the several levels of satellite integration. The only compulsory CubeSat standard, namely the CubeSat Design Specification (CDS) [California Polytechnic State University, 2014], is only a standard for the external interfaces of Nano satellites. Other standards which cover various internal subsystem interfaces are optional.

One of the more problematic standards is the CubeSat Kit [Botma, 2016; Jordaan, 2016]. This has become the community standard for printed circuit board sizes and electrical interfaces on CubeSats, but the flexibility of the electrical standard is its weakness. Flexible pinouts on the specified electrical header lead to subsystem incompatibilities.

The success of the CubeSat program is indicative of a functioning base standard, the CDS, but the lack of detail in some of the optional standards is the program's greatest weakness. For standardized interfaces to work well on satellites more detailed standards covering all technical levels are required.

5.1.4.3. Standardization Beyond CubeSats

It is believed by the authors that similar standards to those that are being implemented for CubeSat subsystems could be applied to larger spacecraft.

The International Space Station (ISS) is the most prominent example of international collaboration and standardization in space. All modules and spacecraft that physically interact or simply communicate with the ISS from a distance have to comply to certain standards for subsystems such as berthing mechanisms, communication systems, electrical power systems (EPS) and environmental control and life support systems (ECLSS). These standards facilitate international collaboration, making a project realizable which would be unaffordable for a single nation. Clearly future space stations would benefit greatly from adopting a set of international standards.

Human exploration missions could also rely on specific standards to lower cost and complexity. The creation of a multi-purpose refueling station in cis-lunar space would aid in the exploration of the Moon and beyond [Landgraf et. al., 2007; Merrill et. al., 2012; Conte et. al., 2015; Renk et. al., 2015]. Functioning standards for the interfaces between the refueling station and other spacecraft are essential for the success of such missions [Grulich et. al., 2016]. Additionally, multiple mission architectures for human exploration of Mars and its moons rely on the implementation of the same subsystem standards across all space agencies involved in such missions [Conte et. al., 2016; David, 2016]. In particular, innovative technologies such as torpor rely on the standardization of the ECLSS subsystems of spacecraft [Bradford, 2016].

Standards used for both international human and robotic missions are not necessarily hardware-related. ESA and NASA have been trying to find a nominal cis-lunar orbit that would help both European and US space agencies in the robotic exploration of the Moon and, more generally, cis-lunar space [Renk et. al., 2015].

In summary, more ambitious collaborative missions will need create the necessity of having standard interfaces for the majority of the onboard space systems, such as communications, ECLSS, TCS, EPS and docking ports.

5.1.4.4. Conclusions & Recommendations

Standardized interfaces can make it easier to integrate subsystems from different manufacturers. In the CubeSat industry the presence of a well-defined functioning base standard that allows many low-cost and flexible CubeSat programs to be successful is strong evidence that standardized interfaces could also be beneficial for larger satellite programs. However, currently many problems are introduced into CubeSat integration due to a lack of detailed standards across all technical domains. For standardized interfaces to work in general for satellite programs of all sizes, more detailed standards are required covering all such domains.

The development of a standard starts with the identification of a need for a standard. A standard should be formally defined and agreed upon by the various players in the industry via an organisation like the International Organization for Standardization (ISO) or the International Space Exploration Coordination Group (SECG), and a funding mechanism to define these standards should be agreed upon, in the first instance by the involved space agencies. The success of many future missions depends on the development of successful satellite interface standards.

5.1.5. Subtopic 4: Cost Controlling Policies for Space

5.1.5.1. Introduction & Methodology

Space agencies around the globe that execute unique and cutting edge space science missions have been confronted by a substantial project cost growth [National Research Council, 2010; Amos, 2009] Large inherent technological risks and a diffuse industrial and academic set-up of the project teams are often cited as drivers behind cost growth. Cost growth can force agencies to rethink their scientific agenda and in the worst case jeopardize their scientific program. Partly due to the absence of profitability as a driver behind cost controlling and the introduction of fixed profitability margins for industry, space agencies are lagging behind other industries in enforcing strict control.

5.1.5.2. Requirement & Technology Assessment

During the early phases of a project, the main focus of the project proposals is on science. Cost and schedule of the complete project lifecycle are subordinated to scientific return, resulting in proposals tailored to a financial envelope and turning the cost estimate into a cost target set by industry. It is in these initial phases that the agencies should strive to further intertwine scientific and financial interests for all parties involved.

The focus of the risk assessment should be shifted more towards the assessment of key technologies in the development of the spacecraft and instruments, including a realistic evaluation of the respective Technology Readiness Levels (TRLs) and link the risk to a bottom-up contingency allocation based on these assessments. Too often, contingency is allocated following rules of thumb [National Research Council, 2010] that are not sufficiently technically associated with the underlying risks within the project's control, or that are associated with risks outside the project's control, e.g. launchers. [ESA, 2010] Decisions between the proposals should be made based on the combined assessment of scientific return, cost and schedule, and the exposure to cost and schedule growth.

Part of the difficulty of technological developments is the continuous refinement of requirements reflecting the available knowledge and the interests of the stakeholders, which might be variable themselves, e.g. ExoMars. In analogy with big international defense projects, this can mean initial requirements are vaguely defined or excessive [Reuters, 2010]. The risk assessment and contingency allocation should also reflect this expectation.

Not only the costs, schedule and risks associated with the starting point should be assessed; anticipation of their evolution is of equal importance in cases of deviation from the initial requirements. The cost and schedule sensitivity of the requirements can be a useful aid in setting priorities during the development.

5.1.5.3. Complexity versus Stability

The escalation of development costs is not a new phenomenon. However, the consistency with which cost overruns occur has substantially increased despite a steady consolidation of the defense and space industry [Hobe et al., 2011]. This manifestation is exacerbated by a *juste return* principle under any form e.g. the European geo-return principle or American programs such as EPSCoR (Experimental Program to Stimulate Competitive Research). This can be partly explained by ever further-reaching objectives and requirements. A consideration is to be made whether these pioneering technology developments scientifically outweigh a stable space program with regular opportunities and involvement from the scientific community.

One possible solution would be to look for a better balance between new scientific developments and the use of adapted heritage technology. This consideration can be made on a case-by-case basis, after setting individual mission priorities for technology development. However, studies have indicated that the adaptation of heritage technology can be overestimated as a way to limit and control project cost [Barley et al, 2010] Therefore, it is of vital importance to capture the design drivers, their sensitivity and their mutual inter-dependencies during the initial development. In case of re-usage, these parameters can then be revisited in the very early stages of the project, limiting its implications on cost. The underlying idea is to design platforms for re-usage from the outset of the development, without imposing an excessive burden on industry. These platforms could be used as a baseline in requests for proposals and provided to industry for tenders.

Re-using proven technology also brings the opportunity of refining the design in consecutive iterations, using feedback from its operation. Since the operational lifetime of many satellites far exceeds the initial requirements, one can question whether these initial requirements are too demanding. Part of the reasoning behind these stringent requirements is the uncertainty surrounding the degradation of components over the longer term and their resilience to adverse environments. Large-scale monitoring of the degradation of operational components and instruments can be enabled by Industry 4.0 and can provide valuable information towards directed cost savings when applying heritage technology in new projects.

5.1.5.4. Supply Chain in the Space Industry

Unlike in private industries, where supply chains are formed organically keeping the most value-added activities in-house, supply chains in space industry are commonly set-up and driven by political interests of contributing partners and different forms of the *juste retour* principle. The outsourcing of critical parts to companies separate from the prime contractor will inevitably lead to longer reaction times, interface complications and communication hurdles in the consecutive design iterations.

Looking at the supply chain, again parallels can be drawn with international co-operations in the defense and armaments industries, where there is a higher public scrutiny towards cost overruns, e.g. Airbus A400M and Joint Strike Fighter. Due to the political nature of both industries, the dispersed development and manufacturing are inherent to the projects and their ramifications are difficult to address. It is the lack of transparency throughout the industrial consortium that hinders a holistic overview of the risks, as all evolutions will be reviewed and decisions will be taken at each level before escalation. It is up to the space agencies to install incentives to improve this transparency throughout all layers of the industrial set-up and enable adequate and quick allocation of effort and money accordingly. If this responsibility would reside with prime contractors, valuable time and oversight would be lost as the ultimate judgment lies with the governing bodies of the agencies.

One possible example would be a shared risk register - as a predictive parameter for cost and schedule overruns - that can be used to assess and approve these cost overruns based on the quality of the register. If required, these initiatives could be contractually enforced.

5.1.5.5. Conclusions & Recommendations

Though numerous sector-specific reasons make cost controlling for space projects especially difficult, space agencies have not responded adequately to tackle this challenge. In particular in non-commercially driven activities such as space science and to some extent earth observation and navigation, closer scrutiny is required to ensure stable programs. For the purpose of this text space science is singled out and policy improvements in three specific areas are proposed.

First, in the early phases of projects, agencies have to strive to put cost and schedule on the same pedestal as scientific return. Only when all three aspects are inextricably linked, competitive tradeoffs can be made in and between projects to achieve a sustainable program.

Second, space agencies have to apprehend the benefits and drawbacks of using heritage technology as a way to contain control cost. Scientific priorities have to be set and the possibility of using heritage technology has to be ingrained in all stages of the projects in accordance to these priorities. Finally, because the dispersed political setup of the supply chain in the space sector is inherent to the projects managed, more incentives have to be put in place to improve the transparency all throughout the supply chain for the agencies to retain good oversight of the risks.

5.1.6. Concluding Remarks & Overall Recommendations

The question posed for this research topic was *how to improve Project Management processes, methodology and tools for innovative, agile, low cost and high performance space projects.* From the many ideas suggested initially for investigation, four were selected based on the relevance the research would have for the space industry in particular, and the broadness of the different areas within the industry the research would cover. None of the subtopics are particularly space-industry specific, and several recommendations are made in each area based on experience from other industries and adapting their relevance for space.

The Agile Scrum methodology has already been used successfully in the space domain, and it is believed that by being combined with the Concurrent Engineering practices already employed in the industry, this could provide significant benefit across all phases of space projects. To what extent it can be implemented depends on the type of space projects and the customer/contractual relation. By providing a better anticipation of issues, task prioritization and higher involvement of all stakeholders Agile will result in a better control on the scope and cost of space projects while providing high performance products that can evolve rapidly.

Industry 4.0 is the digital industrial revolution that is taking place and will emerge fully over the next years across many domains. It is believed that for the space industry to take full advantage, research should begin now in order to exploit the potential and benefits as early as possible. This is particularly interesting for businesses associated with mass manufacturing such as communication satellite projects like OneWeb or for components producers that have (semi) serial production lines, therefore the benefits for relatively new space companies and projects such as SpaceX and Oneweb are believed to be the strongest.

It is also believed that, while there are many reasons why cost controlling for space projects can be more difficult than in other industries, more can be done in this domain. The recommendations, several of which are strongly linked to the Agile Scrum methodology, include a process to question overly strong requirements and place cost and schedule on the same level as scientific return, improving transparency throughout the supply chain to retain oversight of the involved risks, and considering the benefits (and risks) of heritage technology as a way to control costs. Given the expected increase in the private space sector over the coming years, this subject is of particular importance for those newly emerging companies and also existing space agencies, who will face challenges of a different nature as the space industry evolves.

Standardization is one area that has been heavily exploited by other industries, and although it is used to some extent in the space domain it is believed more could be done. The CubeSat industry is one area that has shown particularly good use of standardization to both reduce project costs and improve agility, and even though there are still shortcomings it is believed this can be used as an example from which the rest of the industry should take inspiration. The need of formal bodies who have the ability to define and implement standards across the industry is also recognized as fundamental if the benefits of this are to be extracted to the maximum.

5.2. Topic 2 - Knowledge Management in the Aerospace Sector

5.2.1. Introduction

The aerospace industry is a valuable source of complex knowledge, products, technologies, and manufacturing. Knowledge Management (KM) in aerospace industries can be found in communities and groups where diverse functions in design and development are performed (Holm, 2005). The productive use of employees who have a combination of education, skills, and experience make KM the center of corporate strategies in aerospace organizations (Jafari et al., 2009).

One specific problem in regards to KM is that there is a limited amount of company knowledge transferred between the newer employees and the more senior professionals within the industry. The technical barriers, language barriers, export controls, legal restrictions, and organization policies all create obstacles in knowledge management between the aerospace community. Correct implementation of KM practices can bring valuable benefits to the aerospace industry, such as the ability to train each new generation entering a project which is critical to the success of missions, particularly those of longer duration. Further, good KM practices can address the capture, exchange, and transfer of knowledge within the entire workforce, both newcomers and those who are retiring (Holm et al., 2006).

The research objective for this working group is to identify and assess the existing KM practices in the aerospace industry and propose recommendations for the future. Our research question is the following:

What are the prevailing management (firm/organizational-level) knowledge management and transfer practices? What are the constraining elements in practices and existing methodologies in knowledge transfer?

This study identifies and assesses the existing knowledge management practices in the aerospace industry and proposes recommendations for the future development by linking personal experience and providing valuable recommendations. The research provided in this study was divided in three steps. First, an extensive literature and secondary data review by using various journals, professional research databases, and documents received from employees from different in-sector active organizations. Second, we collected interviews from representatives of different organizations and firms to create a qualitative study of KM trends. Third, the existing practices as identified in the literature review are compared with the patterns observed from the interviews. Finally, we built recommendations where current KM practices should be developed or placed in use with a special focus on the young and senior generation knowledge transfer.

5.2.2. Methodology

This study applied a traditional qualitative method very common in management or knowledge transfer science. Our research setting is primarily the space industry, specialty organizations, institutes, firms, and corporations active in the aerospace industry, using cross-sectional literature review on KM and practice studies.

Public organizations such as the European Space Agency (ESA), National Aeronautics and Space Administration (NASA), Centre National d'Etudes Spatiales (CNES) or the Canadian Space Agency (CSA) appeared more willing to share information on their KM practices than private organizations. Private organizations may see KM as an internal resource for competitive advantage and are more cautious about information and knowledge sharing with potential competitors. The first observation is that there are not many studies that target KM in the aerospace sector, in particular private organizations. For the qualitative research, an interview guide of 19 questions was established and executed amongst industry professionals. In total, 36 interviews were conducted.

After the interviews were conducted, one group performed literature review, another group performed interview review, before creating recommendations. As a methodological approach to data collection, we conducted inductive qualitative data analysis (Gioia et al., Gioia, 1991). Our recommendations reflect the existing practices and the theories of KM transfer practices.

5.2.3. Research and literature review on knowledge transfer practices

Several studies previously conducted by the International Program Management Committee (IPMC) regarding engagement and interaction between senior and young professionals. These studies partially recommended that knowledge management practices be followed by organizations in the aerospace sector. For example, aerospace organizations should have established early career programs for networking or collaboration between different career-stage colleagues. Moreover, young professionals (YPs) should be supported by mid-level management in applying their creativity and drive in order to support these practices.

5.2.3.1. Reflection on previous IPMC Reports

The KT issues have already been partially discussed or linked to different issues in some previous IPMC YP Reports. The significant opportunities for KT within the aerospace industry are key antecedents for success. The 2013 report recommends focusing on the development of software tools, process improvement techniques, project management and system engineering certification, and the company organization structure. In the space sector and large-scale missions, organizations like NASA or ESA tend to require a lot of formal, detailed documentation to capture project or mission requirements. Project management documentation is the key for success for keeping information on new methods and providing a unified comprehensive approach across the sector. The process improvement technique targets the ability of the organization to develop the project requirement implementations and deliver a functional product. More spin-in approaches can enrich the culture of the project implementation and change the market needs and customer requirements in domains such as components standardization, visualization of a product, service application, and design process. Another observation in this report was that education and training should be available for all employees.

The 2014 IPMC Report showed that space projects require a well-developed level of experts networking and system thinking engineering skills, as well as the interdisciplinary breadth of knowledge required or the use of IT tools for enhancing innovation. Networking via social and professional networks are used as mediums for sharing news and faster communications to maintain work momentums. Face-to-face networking with senior professionals has been particularly highlighted, since it increases the ability for accurate and mature verbal demonstration of multidisciplinary skills. KT in the space sector includes a wasteful amount of information caused by the creative and innovative approach to project implementation. On the contrary, there is an industry shortage of system thinking competencies. There are not enough experienced system engineers within the industry and the well space-experienced workforce is retiring or has definitely been lost over time. Knowledge from multiple disciplines is essential for success in space projects. Successful systems require an extensive range of technical and non-technical disciplines. YPs and workers in the space sectors can benefit from exposure to a wide range of disciplines beyond their core expertise.

5.2.3.2. Theory and research of knowledge management practices

According to Argote and Ingram (Argote, 2000), creation and transfer of knowledge are the basis for competitive advantages. According to them, “the knowledge management in organizations is the process through which one unit (e.g., group, department, or division) is affected by the experience of another.” KT can be measured by changes in knowledge or in performance. There are multiple types of different KM practices: knowledge creation, knowledge transfer, knowledge protection, etc. (Bloodgood & Salisbury, 2001; Wiig, 1997).

Within these, the focus lies on knowledge transfer (KT), and more specifically on intergenerational exchange and transfer. In Ruggles' paper, he explains what firms are doing to manage knowledge and what they feel are the greatest barriers they face in their efforts (1998). The author took a process perspective on knowledge and applied it to what can be managed about knowledge, and proposed eight major categories of knowledge-focused activities: generation; accession; use; presentation; transfer; and measuring the value of knowledge.

The Burg et al. 2008 study provides a literature analysis on solutions concepts and contextual elements which explain the knowledge sharing in an inter-organizational network. According to this study, the knowledge management has to deal with four potential problems such are: motivation, free-riding, efficiency, and boundaries. Furthermore, they discuss *solution concepts* (the means that managers have to influence organizational process), the mechanisms, and tools that managers employ to influence organizational processes. The first group represents *tangible* (manageable) solution concepts as following (personnel transfer among organizations; printed and electronic media; knowledge brokers; direct communication; goal alignment; interpersonal relations; rules and agreements; and partner selection. The second group of concepts reflects on less tangible solutions, such as absorptive capacity, trust and commitment and network identity. All solution concepts listed above depends on contextual elements, including type of knowledge, the core knowledge, network and innovation characteristics.

There are various definitions about KM in the literature. Quintas et al. (1997) states that "KM is the process of continually managing knowledge of all kinds to meet existing and emerging needs, to identify and exploit existing and acquired knowledge assets and to develop new opportunities." Another definition of KM relevant to the space industry is from NASA (2005), stating that "KM is getting the right information to the right people at the right time, and helping people create knowledge and share and act upon information in ways that will measurably improve the performance of NASA and its partners." This exemplifies that KM has become an important strategy for improving organizational competitiveness and performance. KM can propel an organization to become more adaptive, innovative, intelligent, and sustainable (Wong and Aspinwall, 2004) through a better administration of "what it knows-how it uses what it knows-and how fast it can know something new" (Prusak, 1997). An important practice of KM is the ability to transfer knowledge; if knowledge is just a repository of information in a database or in someone's private knowledge domain, then an organization cannot use it to learn (Goh, 2002).

Knowledge transfer within aerospace organizations include the aspects of:

- Culture, people, and processes (Olla and Holm, 2006);
- Future knowledge needs and a plan for filling the gaps between current knowledge and required knowledge (Jafari et al., 2010);
- Long duration of projects (from early conception to the end of a mission);
- Lessons learned from within project teams and organizations as a whole (Olla and Holm, 2006).

Existing KM practices are categorized into three main groups: 1) the lessons learned approach (NASA/CNES/CSA); 2) the organizational administration approach (ESA); and 3) the product feasibility approach. Since there is very limited information on KM practices in the private sector, the following summary reflects mostly KM practices provided by public or government organizations.

<u>National Aeronautics and Space Administration (NASA) lessons learned approach</u>

To enable capturing, analyzing and disseminating appropriately lessons learned, NASA Program and Project Management Guidelines require project teams to capture and apply lessons learned throughout the project development cycle. These lessons learned can be captured and accessed through the NASA Lessons Learned Information Systems (LLIS-llis.nasa.gov), NASA Engineering Network (NEN) or other lessons learned repositories used by the project teams (Liebowitz, 2008).

National Center for Space Studies (CNES)

Rotherburger and Galarreta, (2006) examine the approach of the French space agency, CNES, to manage knowledge in long duration space projects. This approach focuses on the early identification of critical documents to prevent knowledge loss (e.g. forgetting risks that were detected in the early phases of the mission), as well as to record knowledge evolution. The CNES methodology involves three steps: 1) An ontology of criticality of several domains is constructed from different viewpoints (such as electrical viewpoint, mechanical viewpoint, thermal viewpoint, etc). The ontology has the form of a taxonomy of concepts which goes from generic to specific. Concepts for the ontology are extracted from reference documents and reflect an initial shared knowledge on a domain. 2) Technical documents of projects are confronted versus the ontology and sorted, and 3) Knowledge evolutions are extracted and interpreted. Since this approach deals with long duration space projects, it is an ongoing task. The final goal is to allow, as the final stage of the missions will approach, the comparison of the initial technical documentation of a project with the project ontology that new participants will use.

Canadian Space Agency (CSA)

Garon (2006) promotes the CSA “Space Project Management Lessons Learned (SProMaLLs)” as a powerful way to ensure better success both at project and at corporate levels. The projects which benefit the most from lessons learned are those where the project team members have considerable experience and use that experience as source of lessons learned. Unfortunately, such experienced project team members do not necessarily write and share their experiences, and if they do, they are generally either too few, or not detailed enough to be really useful, or not in a format which would be readily available for newcomers in the project to use. This situation is aggravated when there is no policy to manage lessons learned and foster their use. To tackle this problem, CSA established a Space Project Lessons Learned database and management system. The set-up of the database has begun, in Access, with lessons from the Canadian Space Station Program; it is recognised that a web-based approach (such as the one of NASA), with a more active dissemination mechanism, is required. According to this study, complementary activities also contribute to the spirit and knowledge transfer of lessons learned at the CSA. Among them, for instance, was the use of a standard format for all monthly project reports. These reports were presented to colleagues from various sectors, informing them on issues and good ideas, and also seeking their advice, almost in real time. Another initiative was the provision of in-house risk management courses fostering the use of the SProMaLLs database as part of the project approval and planning (and risk mitigation) work.

European Space Agency (ESA)

In 2013, ESA has published a document on their Knowledge Management strategy (Dow et. al., 2013a). According to this document, ESA is pursuing two strategy goals: 1) to establish and entrench a ‘knowledge culture’ within the Agency,” to improve the sharing and use of its knowledge; and 2) to enhance the operational efficiency” in terms of design and implementation of projects.

For this purpose ESA is has five objectives towards the KM practices: 1) identification, preservation and evolution of knowledge (most important objective), e.g. by ensuring that core knowledge and experience remain in ESA after the departure of key staff member; 2) support mission operations by maintaining internal knowledge about long-term projects through generations of staff; 3) facilitate sharing by improving collaboration and thus saving time for newcomers; 4) contribute to the management process by providing staff with access to information, resources, tools and methodologies and merging of processes; and 5) better-informed decision-making through exchange between colleagues.

ESA runs a dedicated central Knowledge Management Office, which is supported by decentralized representatives of the various departments. Besides reviewing the status of the knowledge and defining the Knowledge Management strategy, the team is planning and conducting projects to fulfill the objectives listed above. The Knowledge Management and Education Office is also the point of contact for individual solutions for departments and projects all around ESA (Dow R. M., 2013b). One of their on-going activities is the KM Awareness Campaign. The idea of the KM Culture is promoted within the agency by advertising in videos and on posters. More specific is the Knowledge Capture Process. In addition to the standard handover procedure, the leaving and retiring staff is debriefed in a video recorded interview. The purpose of this procedure is to capture the personal experience and tacit knowledge rather than hard facts or textbook knowledge. Gathered knowledge is to be prepared and made available to ensure that everybody finds the information he is looking for. ESA developed a KM Toolkit (Dow R. M. et al. 2015). It includes a KM Portal, which serves as the interface for the database and a number of functionalities like wikis and a search engine. One of the longer term aims is to create an Expert database, so people can easily find the right person to talk to about specific issues.

NASA feasibility approach

Paxton (2006) and Spear (2000) provide an overview of the NASA ‘‘Faster, Better, Cheaper (FBC)’’ philosophy. The goal of the FBC program is to shorten development times, reduce cost, and increase the scientific return by flying more missions in less time. The impact of the FBC program on KM resides on the fact that mission cadence is a major enabler of innovation and the driver to maintain and develop competence in mission design, management, and execution as well as to train the next generation of managers, engineers, and scientists leaders. According to NASA’s FBC program, a high mission cadence reduces risk because the “lessons learned” are current, applicable, and widely held. Knowledge is more readily disseminated when teams are not held by the long-time scales of the mission life cycle. The time between missions must be short enough that careers span the complete life of more than a few missions.

5.2.3. Research investigation and findings

All correspondents agreed that mentorship was absolutely key to establishing effective knowledge transfer practices within their communities, however, many stated that there was no formal program in place within their organizations, or it was not updated on a regular basis. A key issue appeared to be a communication disconnect between those directly working in KM and KT within their respective organisations, and those who were purely end users or contributors.

All organizations represented in the interviews had some form of knowledge management and transfer, however the practices and methodologies contrasted greatly. Databases in the form of sharepoint, documents, folders, spreadsheets, and other internal websites are available at minimum. Intermediate levels included training presentations, seminars, and the introduction of lessons-learned reviews and documentation of best practices. Advanced levels of effective knowledge management and transfer included regularly scheduled updates to databases where updates were sent out to the organizations. Seminars and presentations delivered to build knowledge throughout a career as well as mentorships, and recorded exit interviews help capture knowledge within an organization.

It was also noted, especially by the more senior people interviewed, that sometimes being able to effectively coach junior employees when to trust their "gut instinct" when information is incorrect, and what type of questions to ask, was even more important that the more traditional knowledge transfer of more informational topics.

A further issue noted was the multiple barriers to effective KM and KT. Many respondents have worked on international teams or provided training/education across cultural barriers and they noted that establishing common grounds for communication was much easier when done in advance versus during the projects themselves. Additionally, many projects ran into problems when some of the technology was defense related, and fell under regulations such as ITAR-restrictions, limiting the sharing of knowledge on an international team. This can also be true within countries where there are distinct lines between the civil and military space sectors.

Another major area of difficulty in KT was methodology. While many organizations would have databases, there would often be little to no guidance on how to effectively conduct research and self-education using them. Given that people respond differently to varying teaching styles there is a tendency amongst organizations to take a "one size fits all" approach to KM. This is especially true in establishing inter-generational knowledge transfer, especially where it is more effective for junior employees to have face-to-face coaching and discussions with the senior mentors in the organization, so they can ask questions and truly gain an in-depth understanding versus purely working with reading material.

Knowledge is a resource very difficult to quantify. The design and implementation of mechanisms to gather and prepare knowledge, like software tools, is important for the future sustainability of any company or institution. However, these efforts only form a framework. The essential task is to fill this structure with input from the knowledge holders. Yet, the majority of scientists dislike this kind of work. Management must find ways to motivate them to do it. Sending reminder notes to the staff and putting trust their personal initiative are often insufficient.

5.2.4. Recommendations

A number of clear improvements to the knowledge transfer process for aerospace organizations are evident from the interviews conducted.

A holistic approach to transfer is required due to the multiple ways in which people effectively learn. Simply storing documents of past projects in an online database, for instance, is not effective. Developing training materials from these in the forms of videos, presentations, and face-to-face counseling presents a significantly more diverse approach and will increase the effectiveness of the transfer.

In many organizations, there are no specifically designated knowledge management experts. Some assign it as part of a multitude of duties, however in this case multiple personnel are needed. By having these designated experts, knowledge management databases and transfer practices will be frequently updated; and if one leaves the organization, they should be given enough time to train a replacement to ensure there are no knowledge gaps.

Communication of knowledge resources is absolutely essential to ensure an effective transfer process. If knowledge management resources are not properly communicated at all levels, the actual transfer is minimal since employees are unaware of what is available and how to easily access it. This also ties back to two previous workshop recommendations - communicating that there is knowledge available in multiple formats for use, and that there are experts who will help them find specifically what they are seeking and in the most effective format for use.

By implementing the above, an organization can begin to build a long term strategy for knowledge management and transfer, not just for current employees but for future members of the organization, thus ensuring sustainable knowledge transfer for generations to come.

5.3. Topic 3 - 5 Years IPMC YP Workshop

5.3.1. Introduction

In this the fifth year of the IPMC Young Professional (YP) Workshop, the Workshop Organising Committee (WOC) directed one of three workshop topic groups to examine the recommendations of past workshops and make recommendations for implementation.

5.3.2. Methodology

The group's work fell into two categories: analysis of past workshop recommendations and recommendations for the workshop in the future.

With respect to past recommendations, the group was tasked with the following primary objectives and/or questions to answer:

- Identify concrete examples of realisations; have the recommendations been proven by practical realisation? Why or why not?
- What would be the first concrete steps to update recommendations for implementation?

In order to accomplish these objectives, the group began with an examination of past workshop reports. The topics addressed in the first four workshop reports were sorted into six themes with a summary created of past recommendations. With the help of current WOC members, the group identified instances where past recommendations had been realised, and conducted interviews with contacts leading those efforts. Finally, the most promising recommendations were identified, along with and a plan to address those topics in the future. Interviews with organizations who had implemented past recommendations provided valuable insight on this topic, along with discussion with WOC members and group discussion and analysis.

5.3.3. Research/Investigation/Discussion

This section contains the results of investigation into each of the six themes identified in the methodology section above. In addition, it contains the group's general recommendations for the IPMC YP workshop in order to improve implementation of recommendations in the future. Workshop recommendations can be implemented in one of three ways: by organisation themselves using internal funds and personnel, by workshop participants who volunteer to stay involved after the workshop, or by workshop participants as their workshop topic. Given that workshop participants provide a large concentration of workforce power as they develop their topics leading up to the workshop, future workshop topics are highlighted as a primary way to not only develop more concrete recommendations based on previous reports, but also to actually implement key recommendations in the future.

5.3.3.1. Theme 1: Mentoring

The topic group "Mentoring" focuses on benefits and methods of mentoring that can help young professionals with career development.

In 2016, the topic of mentoring was not expanded upon because of the focus it been given in previous years, and the thorough coverage of the topic including the development of a business plan during the 2015 workshop. The 2015 mentoring business plan was developed as a way to help an agency have a concrete plan for a mentoring program and apply it to their current business model. While each organization is different, the goals and outcomes are similar, and evaluation of success can be made through utilizing the template. In the years moving forward it is recommended that this business plan be tested and measured, and feedback provided to the IPMC to evaluate the success of the 2015 recommendation. Once the plan is tested, it can be adjusted as needed.

5.3.3.2. Theme 2: Accelerated Learning

The topic group Accelerated Learning focuses on measures to support a rapid and effective engagement and learning of young professionals newly joining an organisation.

The six recommendations outlined in the 2015 IPMC YP Workshop report are of good quality, well researched, reflecting international best practices in the field of accelerated learning. This is particularly true for the *Book of Success* and World Café Sessions. It seems thus sensible to not add additional recommendations in the area of accelerated learning, but rather to investigate the conditions which allow organizations to invest in their implementation and use future workshops to facilitate additional implementation. Workshop delegates identified that the success of proposals would largely depend management support, the culture and readiness to adapt of the respective organizations and the alignment of recommendations to global trends.

Regarding the Book of Success, it could be useful for organizations wanting to implement such a guide to provide them with an easily accessible online template.

It may be of interest to develop the learning partnership proposal further creating the link between accelerated learning of YPs on the one hand and knowledge retention on the other. During the next IPMC YP workshop, it could also be of interest to look into similar programs for STEM students and how they could be optimized during next year's IPMC YP workshop.

5.3.3.3. Theme 3: Exchanges

Since the inception of the workshop, exchanges have been identified as important and mutually beneficial for young professionals and their organizations. Based on the review of the previous recommendations since the first workshop, the following suggestions are made to improve the rate of implementation of recommendations:

1. Communication is critical. The IPMC should be more active in communicating its findings with past participants, members and also the broader public. Representatives should be more actively present at networking events for young professionals, encourage dialogue, create online platforms on social media (e.g. IPMC YP LinkedIn account) and be proactive in highlighting any exchange opportunities it identifies. It may also be advisable for a separate YP Working Group on Exchanges to be created to be responsible for communication in this regard following the workshop.

2. A concrete exchange framework should be considered within the scope of this workshop. The timeline for such a framework would be agreed upon during the 2016 session, drafted and finalized as an IPMC YP Workshop Topic in 2017 with a view to it being implemented in 2018. The framework should take into account the aspects of a successful exchange identified in the 2012 and 2013 reports.

3. The topic of exchanges should be dealt with in every IPMC YP report (it was not dealt with extensively in 2014 and 2015).

5.3.3.4. Theme 4: Motivational Aspects

The Motivational Aspects topic contains recommendations dealing with the factors that motivate young professionals to pursue aerospace careers and thrive in them once they are there.

Information below was gathered in an interview with Kate Underhill, the group leader for the 2015 Aerospace decision factors topic, who has implemented that group's recommendation of a motivational factors survey. As of the writing of this report, the survey had an approximately 15% response rate.

Once this round of the survey is completed, and if the survey is conducted again in years to come, the results will be excellent sources of topics for future IPMC YP workshops. In addition to social media suggestions, an IPMC youtube channel could be influential to clarify questions on student's mind and a networking pool could be created.

5.3.3.5. Theme 5: Promoting Innovation

The theme "Promoting Innovation" contains topics targeted specifically at maximizing the innovation ideas generated by Young Professionals in their organizations. Previous reports in this theme did not go into detail on concrete recommendations.

There would be benefit for the IPMC YP Workshop to develop a business plan and draft an On the Side project template in order to help promote more projects. Additionally, in order to facilitate the use of new IT Tools, YPs should be encouraged and given responsibility for implementing these new tools, whilst remembering the constraints some organizations have with security protocols. To help enable this, the IPMC YP Workshop can implement an online network and discussion groups for sharing information about new tools and how they are used between organizations.

The SpaceUp format is already established and participation should be encouraged within organizations. Additionally, a template for setting up a 'SpaceUp' event within a cross-organisation setting could be developed by the IPMC YP Workshop, with a focus on how to tailor a SpaceUp event to an international setting to maximize innovation across organizational and national borders.

5.3.3.6. Theme 6: Management Approaches

The theme "management approaches" covers all workshop topics targeted at tools, methods and skills required from Young Professionals within the aerospace sector. While this topic is broad, its subtopics and recommendations could be split into three main areas (communication, systems thinking, interdisciplinary knowledge). The most promising recommendation is a future IPMC YP workshop topic to create an initial short series of videos featuring YPs from various disciplines and post them on the IPMC YP workshop webpage on the IAF website.

Another promising recommendation in this area is facilitating development of an elevator speech for young professionals. A future IPMC YP workshop topic could be for the group to develop the complete training content, identify ways to implement the training in an organisation, and identify ways to distribute the plan to organizations.

The proposed system engineering workshop to address the future shortage in skilled system engineers does not offer enough added value yet when compared to internal trainings to improve the skills of available system engineers. A proposed way forward for the workshop would be to assess the potential value and benefit of such a workshop through a dedicated topic group in a future IPMC YP workshop.

5.3.4. Recommendations for the Future of the Workshop

This section focuses on recommendations for the IPMC YP workshop organizers to improve the rate and effectiveness of workshop recommendation implementation in the future. Emphasis is placed on improving three key issues: participation at and follow up after the workshop, the quality of recommendations within reports, and spreading knowledge about workshop findings within various space-based organizations.

Recommendation #1: How to improve participation at and follow-up after the workshop

It is generally felt that strong participation at the workshop and continued collaboration after the IPMC YP workshop would be beneficial for both promoting the workshop and expanding the professional networks of young people working within the space industry.

Increasing participant engagement leading up to each workshop and on the day of the workshop itself includes making potential nominees aware of expected commitment in advance, promoting the current Facebook group https://www.facebook.com/groups/IPMCYPWorkshop/ before and at the workshop, creating a LinkedIn group for participants, and advertising to the participants opportunities to contribute further after the workshop. A video of the event could be made to post on the workshop webpage and use as promotional material.

A midyear review is an ideal way to encourage young professionals to remain involved after the workshop. The annual IAF spring meeting, which takes place in Paris and already involves IPMC members, provides an ideal location for this. A method of choosing future workshop topics is recommended whereby workshop participants gather possible topics from their home organizations prior to the workshop, the topic of choice to be addressed the following year is voted on at the workshop, and the participant with the winning topic is rewarded with participation at the IAF spring meeting, supported by their home organisation who receives the benefit of their topic being addressed by the workshop.

Another way of stimulating future involvement would be to create links between current YPs and future YPs. A more formal introduction would create a comfortable, collaborative environment between the old and new groups. Finally, as an additional motivation to keep YPs involved, there could be a "young professionals award" to reward participants who have contributed outstandingly to group work. Ideas for an award include an IAC invitation on a panel board for the successive IAC, or announcement and recognition of the winner at an IAC YP event the same year. Another potential idea would be for the candidate to "earn" a position in the WOC for the next workshop.

Recommendation #2: How to Improve Recommendations in Future Reports

Recommendations should be followed up by subsequent year's workshop groups. The recommendations exist in order to be implemented, and so a prime priority of the workshop should be to come up with recommendations that it can help implement or at least begin to implement. Each year the report should focus on one "new" topic and two topics to follow up on previous years. It could be sensible to apply the following plan:

- Year 1: The recommendations scope the topic at hand, identify principles to follow and areas of further focus/implementation (as seen in 2012, 2013, and 2014 recommendations).
- Year 2: The second year the group recommends specific implementations based on Year 1 (similar to 2015 recommendations, going into still more detail of specific implementations).
- Year 3: If the recommendation from Year 2 was implementable by the IPMC YP workshop itself, the group addressing that topic in Year 3 would implement the recommendation (i.e. create an interdisciplinary knowledge video series). If the recommendation from Year 2 was for other organizations to implement, the group would follow up and reports on whether the recommendation was implemented. If not, why not?

Recommendation #3: How to Spread Knowledge About the Workshop's Findings

Increasing awareness of the workshop and promoting workshop results would be advantageous, including through participants presenting the findings to their section, management, or organisation and through the workshop's social sites, like Twitter, Facebook, and LinkedIn. The IPMC YP Workshop webpage on the IAF website already exists and could be expanded to further promote the workshop and be a place where recommendations from the workshop and other resources are easily accessed.

5.3.5. Concluding remarks

Based on research in each of the six theme areas, concrete recommendations were identified in past reports and future workshop topics proposed.

Through the research done by the discussion groups it is clear that the Aerospace sector is a very dynamic and active, yet challenging work environment. The YP's desire to grow into this sector is very present and this report shows many opportunities on how organizations can better develop and empower the next generation workforce. The recommendations proposed in this report are intended to promote a platform for the IAF member organizations and continue the dialogue on a bigger scale. By emphasizing qualitative and quantitative recommendations, the IPMC YP Workshop delegates hope to generate continuation of the topics and is looking forward to follow up discussions.

6. Concluding Observations

Every year the IPMC YP workshop topics are carefully chosen in close collaboration with the committee members. The topics represent the interest and challenges that aerospace industry and organisations face on a daily basis.

It is clear that in order to maximize the futures success optimisation, efficiency and improvements of existing methods are recommended. In order to keep up with the rapid developments in the Industry 4.0 is it advised to optimise existing production technologies, improve communication methods and cross link different databases, production subsystems and customer information system. Cost controlling will help with financial management and standardization of interfaces will not only reduce project costs but also improve project agility.

We see these recommendations coming back in the topic for Knowledge Management, where it is recommended to transfer knowledge by communication and developing training materials of different types to ensure the effectiveness of the knowledge capturing and its transfer.

By developing standardization of the knowledge transfer and the appropriate training materials, organisations and industries can begin to build a long term strategy for knowledge management.

Ways to develop these trainings are party discussed in the topic 3, which summarizes to a certain degree the past recommendations of the workshop. We see the significance of mentoring programs being highlighted again, as well as the added value or industry and organisations to promote accelerated learning by means of a learning partnership or sharing knowledge / exchanging information and experiences.

These topics invite the committee members and YP’s to further discuss the future and find a way to implement the recommendations in their respective organisations.

7. List of Workshop delegates

First name	Last name	Company
Peter	Batenburg	NVR
Katia	Belley	CSA
Philip	Bellstedt	SAC
Hans	Brabants	ESA
Peter	Collins	ESA
Davide	Conte	AAS
Antonio Eduardo	Gutiérrez Nava	OHB/SGAC
Joao	Lousada	SGAC
Raghav	Sharma	Xovian
Alexander	Gibson	SGAC
Yoshiki	Matsunaga	JAXA
Volker	Mayer	ESA/DLR
Karina	Miranda Sanchez	ESA
Tetsuya	Ono	JAXA
Megan	Owen	Space Foundation
Daniel	Sagath	NSO/VUA
Stephanie	Wan	SGAC
Elizabeth	Barrow	ESA
Kate	Becker	NOAA
Nick	Fishwick	Airbus UK
Ozan	Kara	KOC university
Bernadette	Maisel	Space Foundation
Nicholas	Puschman	ESA
Sarah	Schernbeck	ESA
Daniel	Schultz	ESA/DLR

8. References

8.1. Topic 1

8.1.1 Agile PM for Space Projects

Backblaze Inc. (2015, July). Application of Scrum Methods to Hardware Development. Retreived from [https://www.backblaze.com/blog/wp-content/uploads/2015/08/Scrum-for-Hardware-Development-V3.pdf]

Boshuizen, C. R., Mason J., Klupar P. and Spanhake S. (2014.) Results from the Planet Labs Flock Constellation. *28th Annual AIAA/USU Conference on Small Satellites*.

Carpenter, S.E., Dagnino A.. (2014). Is Agile too Fragile for Space-Based Systems Engineering? *IEEE International Conference on SPace Mission Challenges for Information Technology,2014*, 38.-45

Chaikin, A. (2012, Jan). Is SpaceX Changing the Rocket Equation? *Air & Space Magazine.* Retrieved from [http://www.airspacemag.com/space/is-spacex-changing-the-rocket-equation-132285884/?no-ist

Couluris, J. and Garvey, T. (2010, Apr). SpaceX Mission Operations. *SpaceOps 2010 Conference*. American Institute of Aeronautics and Astronautics, Inc.

Denning, S. (2012, May). Wikispeed: How A 100 mpg Car Was Developed In 3 Months. Retrieved from [http://www.forbes.com/sites/stevedenning/2012/05/10/wikispeed-how-a-100-mpg-car-was-developed-in-3-months/#63fef8ae3f3e]

ESA/ESTEC. (2015). The ESA Concurrent Design Facility. Concurrent Engineering Applied to space mission assessments.

Graves, E. (2014, May). Applying Agile to Hardware Product Development. Retrieved from [https://www.playbookhq.co/blog/agileinhardwarenewproductdevelopment/]

James, M. (2010. Scrum Reference Card Retried from [http://scrumreferencecard.com/]

Johnson, N. (2011, Oct). Agile hardware development – nonsense or necessity? Retrieved from [http://www.eetimes.com/document.asp?doc_id=1279137]

Layton, M.C. (2015). *Agile voor Dummies (Agile for Dummies).* Amersfoort , the Netherlands: BBNC uitgevers bv.

Morrison, A. and Parker, B. (2013). An aerospace industry CIO's move toward DevOps and a test-driven development environment. *Technology Forecast: Solving the engineering productivity challenge, Issue 2*.

Planet Labs Inc. (2016). Our Approach. Retrieved from [https://www.planet.com/company/approach/]

Van Schooenderwoert, N. (2015, Mar). Yes, Hardware Can Be Agile! Retrieved from [https://www.infoq.com/articles/hardware-can-be-agile]

Vanderbilt, T. (2015, Apr). Planet Labs: the satellite-launching startup that took on national governments -- and Elon Musk. Retrieved from [http://www.wired.co.uk/article/planet-labs]

Wikipedia. (2016, July). Concurrent engineering. Retrieved from [https://en.wikipedia.org/wiki/Concurrent_engineering]

8.1.2. Industry 4.0

BMWI (2013, Apr). Securing the future of German manufacturing Industry. Recommendations for implementing the strategic initiative Industrie 4.0. *Final Report of the Industrie 4.0 Working Group.*

Capgemini Consulting (2014). Industry 4.0 - The Capgemini Consulting View. Sharpening the Picture beyond the Hype. *Capgemini Consulting.*

Deloitte A.G. (2015). *Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies*. Switzerland Report 2015.

Government Office for Science, London. (2013, Oct). The Future of Manufacturing: A new era of opportunity and challenge for the UK. *Project Report 2013*.

INNOspace Masters Satellite 4.0 (2016). New ideas for the next space generation. Retrieved from [http://www.innospace-masters.de/]

International Controller Association (2015). Industrie 4.0 Controlling in the Age of Intelligent Networks. *International Controller Association Report.*

OECD (2014) *The Space Economy at a Glance 2014*, OECD Publishing. ISBN 978-92-64-21099-892 2014 06 1 P

Pultarova (2016, September) *Space agencies must change or become extinct, says ESA head.* Retreived from [http://eandt.theiet.org/news/2016/sep/space-4-0-esa.cfm]

PWC (2016) Industry 4.0: Building the digital enterprise. 2016 Global Industry 4.0 Survey. *PWC Report 2016.*

Roser, Christophe (2015, November). How Industry 4.0 Came into Existence. Retrieved from [http://www.allaboutlean.com/industry-4-0/]

SpaceWorks Enterprises, Inc (2016). Nano/Microsatellite Market Forecast 2016

Tauri Group Satellite Industry Association (2015, Sep). State of Satellite Industry Report 2015. *The Tauri Group*

Tauri Group Satellite Industry Association (2016, Jun). State of Satellite Industry Report 2016. *The Tauri Group*

Wasserman, Shawn (2016, Aug). Top 5 Challenges to Implementing an IoT System. Retrieved from [http://www.engineering.com/IOT/ArticleID/12882/Top-5-Challenges-to-Implementing-an-IIoT-System.aspx]

8.1.3. Standardization

Anderson, Dr David M. (2016). Part Standardization. Retrieved from [http://www.halfcostproducts.com/Standardization.htm]

Botma, P.J. (2016, August 27). Conversational interview.

Bradford, J. , M. Schaer, and D. Talk (2016, May 16). Torpor inducing transfer habitat for human stasis to Mars. Retrieved from [https://www.nasa.gov/feature/advancing-torpor-inducing-transfer-habitats-for-human-stasis-to-mars]

California Polytechnic State University. (2014, February 20). CubeSat Design Specification.

Conte, D., M. Di Carlo, K. Ho

Conte et. al. (2016, September 13) Innovative Mars Global International Exploration (IMaGInE) Mission. *AIAA SPACE 2016, AIAA No. 2016-5596, Long Beach, CA.*

David, L. (2016, August 26). A Minimal Architecture for Human Journeys to Mars (NASA JPL). Retrieved from [http://forum.nasaspaceflight.com/index.php?topic=37925.0]

Day, C. (2010, April 22). Advanced CubeSat Avionics - A Next Generation Approach for Highly Capable and Integrated Vehicles. *7th Annual CubeSat Developers Workshop*.

GomSpace. (2016). Cubesat and nano-satellite solutions. Retrieved from [http://gomspace.com]

GomSpace. (2016). Flight Software Off the Shelf. Retrieved from [http://www.gomspace.com/index.php?p=products-software]

Grulich, M., D. Conte, et. al. (2016, September, 26). Next Exploration Universal Station (NEXUS). *67th International Astronautical Congress (IAC 2016), IAC-16, E2, 3-GTS.4, 7, x34478, Guadalajara, Mexico*.

International Organization for Standardization. (2015, December). Draft International Standard ISO/DIS 17770. Geneva, Switzerland: ISO.

Jordaan, H.W. (2016, August 26). Conversational interview.

Kalman, A.E. (2006). Designing for Success: Choosing CubeSat Components Wisely. *CubeSat Workshop SmallSat Conference*.

Kief, C.J., Christensen, J., Hansen, B., Mee, J. (2010). CubeFlow: Training for a New Space Community. *AIAA/Infotech@Aerospace Conference*, pp.1-11.

Landgraf, M., M. During, and F. Renk (2007). Mission Design Aspect of European Elements in the International Space Exploration Framework. *Journal of Guidance Control and Dynamics*, Vol. 30, No. 5, p. 1261.

McNutt, C.J., Vick, R., Whiting, H., Lyke, J. (2009). Modular Nanosatellites – Plug-and-Play (PnP) CubeSat. *AIAA/7th Responsive Space® Conference*, pp.1-14.

Merrill, R. G., D. Komar, M. Qu, J. Chrone, N. Strange, and D. Landau (2012). An initial comparison of selected Earth departure options for solar electric propulsion missions. *Aerospace Conference*, IEEE, pp. 1–18.

Nohka, F., Drobczyk, M., Heidecker, A. (2012, August). Experiences in Combining Cubesat Hardware and Commercial Components from Different Manufacturers in order to build the Nano Satellite AISat/Clavis-1. *26th Annual AIAA/USU Conference on Small Satellites*, *SSC12-XI-8*, pp.1-6.

Pumpkin. (2003). Pumpkin CubeSat Kit User Manual (REV D2).

Renk, F. (2015, August 9). Mission Analysis for a Human Exploration Architecture in the Earth-Moon System and Beyond. *AAS 15-552, AAS/AIAA Astrodynamics Specialist Conference, Vail, CO*.

Schilling, K. (2015). Standardization of Electrical Interfaces / Modular Bus.

Spencer, D.B., and Vasile , M. (2015, August 9). Earth-Mars Transfers through Moon Distant Retrograde Orbit. *AAS 15-588, AAS/AIAA Astrodynamics Specialist Conference*, *Vail, CO.*

UNISEC Europe. (2015, July 21). CubeSat Subsystem Interface Definition, *v0.4*.

8.1.4. Cost Controlling Policies for Space

Amon, J. (2009, Dec). European space missions given cost warning. Retrieved from [http://news.bbc.co.uk/2/hi/science/nature/8389906.stm]

Barley, B., Bacskay, A. and Newhouse, M.E. (2010, Aug). Heritage and Advanced Technology Systems Engineering Lessons Learned from NASA Deep Space Missions. Retrieved from [http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100040532.pdf]

ESA (2007, Sep). ESA Industrial Policy and Geographical Distribution. Retrieved from [http://www.esa.int/About_Us/Business_with_ESA/How_to_do/Industrial_policy_and_geographical_distribution]

ESA (2014, Nov), Assessment of an X-Ray Telescope for the ESA Cosmic Vision Program, *ATHENA*

CDF Study Report: CDF-150(A)

ESA (2016, Jul). ESA Missions. Retrieved from.[http://sci.esa.int/home/51459-missions/]

Hobe, S., Hofmannová, M., Wouters, J. (2011) A Coherent European Procurement Law and Policy for the Space Sector. *Cologne Studies in International and European Law*. Volume 22.

NASA (2012, Nov). SMD Mission Handbook. Retrieved from [http://science.nasa.gov/media/medialibrary/2013/01/22/Mission_Handbook.pdf]

National Research Council, Committee on Cost Growth in NASA Earth and Space Science Missions (2010), Controlling Cost Growth of NASA Earth and Space Science Missions. Washington, DC. *The National Academies Press*

Reuters / Del Pozo, M. (2010, Jun). Warbus: The Incredible Saga of Europe's A400M. Retrieved from [http://static.reuters.com/resources/media/editorial/20100608/A400M.pdf]

8.2. Topic 2

Argote, L. &. (2000). Knowledge transfer: A basis for competitive advantage in firms. Organizational behavior and human decision processes, 82(1), 150-169.

Bloodgood, J. M., & Salisbury, W. D. (2001). Understanding the influence of organizational change strategies on information technology and knowoledge management strategies. Decision Support System, 31, 55-69.

Dow R.M. et. al. . (2013a). Developing a Knowledge Management Strategy for the European Space Agency (ESA). IAC. Beijing: IAF.

Dow, R. M. (2013b). Knowing More about Knowledge Management at ESA. IAC. Beijing: IAF.

Dow, R. M. (2015). “A Knowledge Management Toolkit Based on Open Source. IAC. Jerusalem: IAF.

Garon, S. (2006). Space project management lessons learned: a powerful tool for success. Journal of Knowledge Management, 10(2), 103-112.

Gioia, D. A., Corley K. G., Hamilton A.L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. Organizational Research Methods, 16(1), 15-31.

Gioia, D. C. (1991). Sensemaking and sensegiving in strategic change initiation. Strategic Management Journal, 12(6), 433-448.

Goh, S. C. (2002). Managing effective knowledge transfer: An integrative framework and some practice implications. Journal of Knowledge Management, 23-30.

Holm J., Olla P., Moura D., and Warhaut M.,. (2006). Creating architectural approaches to knowledge management: an example from the space industry. Journal of Knowledge Management, 10(2), 36-51.

Holm, J. (2005). Effective Techniques for Capturing, Creating and Management Knowledge at NASA. Pasadena, CA: NASA Knowledge Management Team, Jet Propulsion Laboratory, NASA.

IAF. (2013). IPMC Young Progessionals Workshop 2013 Report. beijing, China: International Astronautical Federation.

IAF. (2014). IAF-IPMC Young Professionals Workshop 2014: Workshop Results Report. Toronta: IAF.

Jafari, M., Rezaeenour J., Akhavan P. and Fesharaki M.N.,. (2009). Strategic knowledge management in aerospace industries: a case study. Aircraft Engineering and Aerospace Technology, 82(1), 60-74.

Jafari, M., Rezaeenour, J., Akhavan, P., & Fesharaki, M. N. (2010). Strategic knowledge management in aerospace industries: a case study. Aircraft Engineering and Aerospace Technology, 82(1), 60-74.

Liebowitz, J. (2008). Knowledge retention. Strategies and Solutions: CRC Press.

NASA. (2005). 'What is knowledge management? Retrieved from http://km.nasa.gov/whatis/index.html

Olla, P., & Holm, J. (2006). The role of knowledge management in the space industry: important or superfluous? Journal of Knowledge Management, 10(2).

Paxton, L. J. (2006). Managing innovative space missions: lessons from NASA. Journal of Knowledge Management(10), 8-21.

Prusak, L. (1997). Knowledge in organizations: Resources for the knowledge-based economy. Boston, MA: Butterworth-Heinemann.

Quintas, P., Lefrere, P., & Jones, G. (1997). Knowledge management: a strategic agenda. Long Range Planning, 30(3).

Rothenburger, B., & Galarreta, D. (2006). Facing knowledge evolution in space project: a multi-viewpoint approach. Journal of Knowledge Management, 10(2), 52-65.

Ruggles, R. (1998). The state of the notion: knowledge management in practice. California management review, 40(3), 80-89.

Spear, T. (2000). NASA FBC Task Final Report. Retrieved from http://mars.nasa.gov/msp98/misc/fbctask.pdf

van Burg, J. C., Berends, J. J., & van Raaij, E. M. (2008). Organizing knowledge sharing in networks: the theory.

Wiig, K. M. (1997). Integrating intellectual capital and knowledge management. Long Range Planning, 30(3), 399-405.

Wong, K. Y., & Aspinwall, E. (2004). A fundamental framework for knowledge management implementation in SMEs. Journal of Information and Knowledge Management, 3(2), 155–166.

8.3. Topic 3

Topic 3 have used previous IPMC YP Workshop reports as a reference.

9. Previous Workshop Reports

2012 IPMC YP Workshop Report

2013 IPMC YP Workshop report

2014 IPMC YP Workshop report

2015 IPMC YP Workshop report

IAC-16-E1.5 5 Years IPMC YP Workshop

10. Acknowledgements

The 2016 IPMC Young Professional Workshop has greatly appreciated the support of Boeing and JAXA, who provided funding for the coffee and the lunch. The WOC would like to warmly thank the IPMC, Boeing and JAXA for their five years of continued support to the Young Professionals Workshop.

The WOC is looking forward to the future with the preparation of the next workshops and the continuation of the implementation of previously presented recommendations. The WOC, in close collaboration with the IPMC, strives to advance on the development and empowerment of the next generation space workforce.

11. Announcement Letter IPMC YP Workshop 2017

Sunday 24 September 2017, Adelaide Australia

The International Project/Programme Management Committee (IPMC) Young Professionals Workshop seeks to gather input from young professionals in the international space community to gain the knowledge they need to better develop and empower the next-generation workforce.

IAF affiliated organisations are invited to nominate delegates for this workshop and represent their views in this international forum. The **call for delegates** will be issued in February 2017.

The **delegates** for this workshop are asked to be physically present at the day of the workshop as well as the International Astronautical Congress and would fit the profile of a young professional. Young professionals are typically defined as being age 35 and under and having at least one to two years of experience on a project team and/or in the aerospace industry. A diversity of backgrounds (e.g., engineering, management, science, etc.) is encouraged in order to produce thoughtful and well-rounded observations and recommendations that will be presented to the IPMC. The delegates will be working in teams on the workshop topics via skype, email, webex, etc. prior to the workshop with kickoff planned for early June 2017.

The **2017 topics** for the workshop will be defined by the Workshop Organising Committee and IPMC before publication of the call for delegates.

The 2016 topics were Agile, Low-cost and High-performance space projects, Knowledge management in the aerospace sector and 5 years of IPMC Workshop. The full report of these topics and it's findings and recommendations will be available on below websites in January 2017.

Additional information on the IAF and the IPMC can be found at http://www.iafastro.org/ as well as http://www.iac2017.org/. For last years workshop please visit us at 2016-ipmc-yp-workshop.

Questions on the Young Professionals Workshop can be addressed to ipmc.yp.workshop@gmail.com.

Kind regards,
WOC
Birgit Hartman
Maarten Adriaensen.