International Astronautical Federation

International Astronautical Federation International Project / Programme Management Committee

IAF-IPMC Young Professionals Workshop 2018 Workshop Results Report

Workshop Organizing Committee ipmc.yp.workshop@gmail.com March 2019

Group Photo of the 2018 International Project / Programme Management Committee Young Professionals Workshop delegates on 30 September 2018 at the Bremen Conference Centre, Germany.

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1. Executive summary

The International Programme/Project Management Committee Young Professional Workshop sought to gather ideas and recommendations 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 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 2018 with the nomination and selection of workshop participants who were assigned to working groups focusing on three discussion topics. 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 at the IAC. Following the workshop, the WOC prepared a final report with summary of the results and recommendations.

Topic 1 Continuation of the 2015 IPMC YP "Decision Factors for Aerospace Young Professionals" Survey

This topic was cancelled due to the lack of interest of the delegates to continue the survey and analyze the outcome. As the survey was a success and produced many valuable and detailed recommendations, we strongly suggest to read this report again and take note of the outcome.

Topic 2 Fostering PM in the world of Diversity

In order to define this topic, the delegates have looked at the definition of Diversity and stated that this is ever changing and evolving. It has also been stated that Diversity and Inclusion go hand in hand, but cannot be considered the same. As the delegates in this group were very divers, they looked at themselves and their own experiences in terms of International / generational / gender / social aspects and put together an overview.
The survey they have conducted has resulted in 75 respondents from 19 different countries. The outcome of the survey shows that even the definition of "Diversity" is not the same from one organization to another, nor from one country to another. It also shows that background / generation and culture more important is than for instance disabilities when defining "Diversity". The respondents confirm that while most organisations do have diversity policies in place (83.1%), they are not satisfied with the compliance of these policies (6.1/10). The survey covers many topics and the outcome shows just how diverse the aerospace sector is.

Topic 3 Space 4.0 and the Evolution of the (Aero) Space Sector

Space 4.0 is known for emerging trends in launch vehicle capability, spacecraft miniaturization, demographic change, and internal as well as external technological development, which has heralded an era of rapid expansion, decentralization, entrepreneurial activity, and non-traditional

partnerships. Successful Project Management (PM) in future space endeavors will require new approaches to address the seminal questions of PM.
The delegates have taken a closer look at Artificial Intelligence (AI) and how this will effect project managers. And will AI actually take over or will it make PM more successful? The group has also researched what a successful implementation of AI in PM will require and how this can be best tackled.

Topic 4 Challenges faced by multi-disciplinary teams working on space projects between emerging and legacy space economies

There has been a great discussion about efficacy of collaboration between emerging and legacy space economies, but the main challenge is in the mind-set disparity. Legacy space tends to be conservative in project execution approach resulting in high-cost projects. New entrants are flexible and experiment with adopting unconventional and new strategies for project execution.
This topic is summing up, five levers to improve efficiency of multidisciplinary projects:

- multidisciplinary team, with minimum set of roles and skills depending on the project scope and including other stakeholders;
- process definition, which formalizes the method used for project management and therefore the flow of activities and information;
- information/data model (product definition)

Deciding upfront on the practical details of cooperation among different players, maybe with stronger (legacy) players offering tools and infrastructure to emerging players, can ease integration of team members.

Topic 5 Knowledge Management Practices

Knowledge Management (KM) is a group of practices ensuring the identification, capture, preservation and sharing of knowledge in order to continuously improve the effectivity and efficiency of a given organization in pursuing its mission.

Based on a survey performed, literature reviews, research and interviews performed, the group has summarize suggestions broken down in several subtopics which produced detailed recommendations amongst other:

- Human connection
- Communication and collaboration
- Centralization of documents
- Standardization of Knowledge Management

This topic especially focuses on defining the KM best practices, tools and methodologies in today's aerospace sector and providing concrete recommendations on KM to enable Knowledge Capturing (KC) for the next generation workforce.

2. Introduction

On September 30th, 2018 a group of 38 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 Bremen in conjunction with the 68th International Astronautical Congress (IAC).

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. The 2018 Workshop Organizing Committee (WOC) members were:

- Birgit Hartman: WOC Project Manager
- Marie Botha: WOC Operation Manager
- Peter Batenburg: WOC Logistics Manager
- Elizabeth Barrios: WOC Data Manager
- Kavya Manyapu: Boeing Implementation Manager
- Jennifer Sizemore: Assistant WOC

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 2018 IPMC Young Professionals Workshop attracted twenty nine 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 June 2018. Until the 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

The 2018 IPMC YP Workshop has welcomed 38 Young Professionals, representing more than 16 countries and 15 different organizations (agencies, companies, institutions, etc.).
The average age of this year's workshop was 29,6 years.

Since the first edition of the IPMC YP Workshop in 2012, 232 Young Professionals have attended, and even more have worked on researching topics for the workshop.

5. Topic 2 Fostering PM in the world of Diversity

5.1 Introduction

Diversity has been a matter of increasing importance for organizations across different industries, with renewed interest since the 2000s. The aerospace industry is no exception. With the 2018 International Astronautical Congress (IAC) motto "IAC 2018 - involving everyone" (IAC, 2018), this year's astronautical congress lays special emphasis on the insertion of the new generation, new countries and new companies into the space sector. In this context, topic 2 is devoted to the analysis of diversity-related topics in aerospace, aiming to provide recommendations as to how to implement equal opportunities and representation, harnessing the benefits of having a diverse workforce and mitigating the associated risks and issues.

5.2 Methodology and Logic of the Investigation

Since diversity is broadly and widely discussed topic, the term is often used with variant meanings or nuances. In a first step, this study establishes a definition of diversity, defining different forms of diversity which are relevant for the present discussion. Next, the very important related concept of inclusion is addressed. As a contextualization to the aerospace sector, the views, experience and goals of different organizations on the topic are considered. The view of the workforce is considered by means of a survey. A Strengths-Weaknesses- Opportunities-Threats (*SWOT*) analysis of diversity is then performed to identify associated benefits and risks. Finally, measures to handle and profit from diversity are provided.

Sources for the presented material include an extensive literature review, some organizational policy documents, and an online survey.

5.3 Topic Investigation and Discussion

In a globalized world, diversity is the current reality for most organizations - whether it is acknowledged or not. A basic definition of diversity is the existence of different groups of people within an organization (Diversity, n.d.). The concept sounds deceptively simple. However, this variety has numerous nuances and deep implications for a group's dynamics.

During the past decades, various dimensions and conceptualizations of diversity in the workplace have emerged. Although diversity is an innate characteristic of humans, it was only in the late 1960's to the 1970's that the concept was researched in the context of gender and race stereotypes within the workplace. For the first time, measures like the Civil Rights Act of 1964 in the United States were implemented in order to make it illegal for both private and public businesses to discriminate during hiring and firing practices on the basis of race, color, religion, sex or national origin.

Two major dimensions of diversity can be defined: primary (the aspects that are difficult to or cannot be changed, such as age, race, ethnicity, gender, physical qualities and sexual orientation) and secondary (more changeable aspects, which includes income, education, religious beliefs, military experience, location, parental and marital status) (Loden, 1991). This definition of diversity kept expanding, including more and more aspects constituting differences within a comprehensive range of demographic attributes, such as language, religion, lifestyle or tenure (Kossek, 1996).

Sayers categorizes these attributes into three main categories – primary, secondary and tertiary – mentioning up to fifty possible dimensions and arguing that individuals belong to more than one dimension concomitantly (Sayers, 2017). However, many researchers argued in favor of an even wider definition, including not only culture and intellectual capability (Leonard, 1999), but also a diversity of thoughts and values, which translates into what makes an individual join an organization, promote his passions and have a high level of productivity in the long term, without feeling restricted (The Economist Intelligence Unit, 2014).

Alongside the definition, practices to manage diversity have evolved throughout the last 60 years. At the very beginning (1960s-1970s), the main goal was to establish equal pay and equal human rights for the same work, regardless of the worker's gender, ethnicity, age and other factors not relevant to the job. This was achieved through legislation. Throughout the 1980s-1990s, the focus shifted towards celebrating diversity and guaranteeing that different groups are adequately represented within the organization. The "hard" approaches and quota systems caused intergroup conflicts and consequently a backlash against minorities who were accused of not deserving jobs or promotions. This created poor cultures and climates for establishing equality in organizations. In the 1990s, "softer" approaches became more widely accepted by aligning diversity with business objectives. Celebrating individual differences were recognised to be crucial to getting acceptance of women in top management roles and in non-traditional occupations (Sayers, 2017).

In the modern world's workplaces, the individual's identities and characteristics create a variety of perspectives aiming to solve a problem or task in team collaboration. Cross-cultural issues may further improve the effectiveness of a project and organization. Therefore, applying and understanding effective diversity management is one of the main challenges in organizations. Openness to new and organization-specific aspects of diversity is key for its successful management (Hyland, 2015).

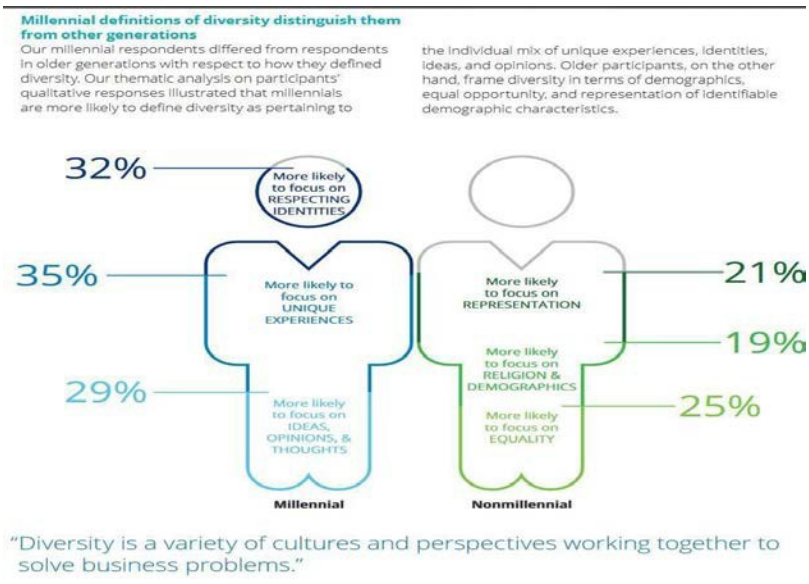

Figure 1 - Generation's different views on diversity. Reprinted from The Radical Transformation of Diversity and Inclusion: The Millennial Influence (page 4) by Deloitte, 2018. Copyright © 2018 Deloitte Development LLC. Reprinted from (Deloitte, 2018a)

The literature review shows a significant evolution of the diversity definition, as well as of the methods and practices to manage it throughout its history. As the delegates are young professionals themselves, they find it important to also cover another perspective, which is how diversity is understood by different generations. The above figure depicts how non-millennials (a group comprising both Baby boomers, born between 1946-1963, and Generation X, born between 1964-1979) see diversity through the eyes of equal representation and demographics, while millennials are more inclined to focus on a diversity of thought in the workplace (Deloitte, 2018a).

5.4 Space Organization's View and Management of Diversity

Inclusion: making Diversity count

For an organization to be able to profit from it's diversity, an appropriate inclusion atmosphere needs to be established. As discussed by Sherbin, diversity means the mere presence or representation of different groups, whereas inclusion goes deeper. Inclusion is the act of implementing and incorporating the diversity into the organizational structure. It requires, among other factors, eliminating discrimination and guaranteeing that the groups belong in the organization and play an active role, with equal opportunities for development: "Diversity is being invited to the party, inclusion is being asked to dance." (Sherbin, 2017). Since representation is a prerequisite for integration, promoting diversity is certainly still relevant, but it should not stop there: The different groups need to be integrated into the organizational structure, which requires a proactive approach, with constant monitoring and, if necessary, adaptation of the initiatives. Moreover, diversity initiatives should avoid stigmatizing the minorities which they seek to promote (Callender, 2018).

The usual focus on diversity instead of inclusion is easily explained by the fact that the former is straightforward to measure, whereas the latter is subjective and hard to reliably quantify. Inclusion issues are often not reported, especially in poorly inclusive environments, e.g. for fear of retaliation or because the complaints are not believed to be handled effectively. Few complaints regarding inclusion matters often does not mean a lack of problems. Especially in the absence of a diverse leadership (Hewlett, 2013), minorities are less likely to get support for their ideas and may face other biases, which can significantly hamper their progress within the organization. Measures to counter this are discussed in Section 4.2 of this document (Recommendations).

Identifying and correcting these biases against minorities in the organization is key (Callender, 2018), (Williams, 2014). They are often subtle, but can also be corrected in non-alarming ways. For instance, (Williams, 2014) reports that an organization traced the reason for men being hired with higher salaries than women to their increased likelihood to spontaneously negotiate the salary: Explicitly stating that the salary was negotiable in the application documentation lead to the correction of the lower salary bias against women. Diversity programs that don't address (or inadvertently confirm) biases may be inadvertently trying to "fix" minorities to fit in the workspace, which induces non-authentic behavior and reduces inclusion. As an example, Deloitte (2018b) shows that a significant number of employees (more than 60%) hide or feel uncomfortable about certain personal details.

The “uncovering talent” approach, promoting authenticity in the workplace, has been developed to help promote bonding not just within, but also across, groups. One powerful — yet simple — approach is to encourage leaders to “uncover” themselves and act as an example of being comfortable about their personal details (race, age, education, family status, etc). (Deloitte, 2018b) reports that 17% of respondents made aware of the approach actually “uncovered” and brought their whole personalities to the workplace, which resulted in higher productivity and more energy.

Promoting engagement for diversity and inclusion activities within the workforce is essential towards managing the increasingly diverse aerospace workforce. Recent research on the topic (Dobbin, 2016) indicates that the most common initiatives have poor effectiveness as their focus remains at avoiding lawsuits. The reason is that the programs often focus on policing employees and frequently convey negative messages, and thus are seen as invasive and threatening to majorities. Voluntary participation and a positive message of helping the organization is said to be more productive. Fostering contact between the majorities and minorities within the workforce is also a simple and powerful measure. Task forces composed of voluntary managers and minority representatives followed closely by senior management have been reported to be highly effective. All of these raise awareness and give participants the sensation of personal involvement while simultaneously boosting engagement.

Comparing and Contrasting Diversity in Different Space Organizations

Taking advantage of the fact that the topic team consisted of young professionals from various space organizations around the world, it was compared how these space organizations address, manage and implement diversity. Summarizing the latest trends of these organizations approaches for diversity from the viewpoint of young professionals. As mentioned in Section 3.1, the definition of diversity is very broad; therefore, the present analysis concentrated on the types of diversity that all of these space organizations actively addressed, namely: (1) international/intercultural, (2) generational, (3) gender, and (4) social diversity. The general strategies for inclusion which each organization adopts are very similar. However, there is a difference in the degrees of maturity and success amongst the different organizations.

As for the international/intercultural aspects of diversity, most government organizations face barriers when addressing the employment of foreigners, as would be expected. For generational diversity, every organization has programs to encourage the mixing of the generations and tries to tackle the issue of knowledge transfer. For gender diversity, all organizations now make efforts to increase the number of female engineers and scientists. Finally for social diversity, all organizations implement the same strategies for work-life balance, such as telework and flextime. These strategies seem to work well around the world and are consistent with the main points of the third paradigm of diversity management.

Results of Survey across Space Organizations

In order to get some insight into the way members of aerospace organizations view diversity, the group resorted to an online survey, shared in newsletters and by email (Kangsan, 2018). A total of 75 responses were collected from at least 37 different organizations in 19 countries. The sample is recognized not to be statistically relevant in deriving recommendations for the whole aerospace industry.

The results are nonetheless an interesting illustration of how diversity is seen and what the perceived problems in real-world aerospace organizations are. Most participants are from the US (40.0%) and Europe (42.0%), with replies from all continents except Oceania and Antarctica. They are mostly from government agencies (38.7%), Non-Profit Organizations (NGOs) (21.3%) and academia (20.0%); the majority identifying their position as employees (46.7%) or managers (22.7%).

Most replies identify diversity with variety and representation of different groups of people, identifying aspects such as gender, social strata and ethnicity; but also experience and ways of thinking. Generational, background (e.g. engineering, PR, etc) and intercultural differences were identified as the most relevant for the aerospace sector; whereas physical and mental disabilities were the least relevant.
The vast majority (89.3%) indicates that their organization implements diversity-related activities, very often with an organized policy (83.1%). The most cited methods were recruitment (73.3%) and Media/PR (57.3). The most frequently mentioned diversity promotion methods were an open recruitment policy, community/university outreach programs and gender-related hiring restrictions or goals (favouring women). Even though most participants indicated that their organization tracks diversity (57.3%) and the overwhelming majority (88.4%) believes that management is using the results of this tracking, many participants mentioned that they do not fully understand exactly how these results are used. This could make the case for better communication of the goals and a clearer description of the adopted measures. Participants generally agree that this tracking is beneficial to the organization (87.5%).

As a rule, participants agree that diversity is beneficial to their work (score 8.0 out of 10). The most frequently mentioned benefit is the presence of new perspectives, which allows a problem to be more thoroughly analyzed (increased “collective intelligence”) and leads to creative solutions and new applications, fostering innovation. A more interesting and agreeable work environment, with increased spontaneity, satisfaction and productivity for minorities is also mentioned. When asked what is the most important measure that should be applied in the aerospace sector to foster diversity, most participants mentioned increasing women’s representation in STEM careers and intergenerational cooperation, alongside diversifying recruitment sources, promoting exchange programs and unbiasing hiring procedures (including
e.g. blind curriculum analysis).

The average score for the satisfaction with the diversity implementation is, however, 6.6 out of 10 (0 being extremely unsatisfied and 10 extremely satisfied), indicating room for improvement. These included: a diversity policy which is well-intentioned but overly theoretical, ineffective or inconsistent; excessive focus on PR and visibility (with little added value in practice); neglect of relevant aspects of diversity (e.g. promote gender and generation but forget different backgrounds and ways of thinking) and the impression that the organization is too large to change. Some responses also indicated promotion of diversity in terms of e.g. recruitment but a lack of inclusion, in terms of not creating an environment in which minorities can neither act spontaneously nor advance to mid- and senior level executive positions.

5.5 SWOT Analysis of Diversity

SWOT Analysis

Understanding the opportunities and risks related to diversity is an important first step towards establishing methods and recommendations as to how to handle it in the context of project management. In the following, Strengths and Weaknesses are understood as positive and negative aspects which diversity brings to an organization; whereas Opportunities and Threats relate to the external scenario and the management and implementation of diversity. The aspects identified by the group are summarized in Table 1.

Advantages and Opportunities

Diversity enriches an organization by providing different experiences and points of view, which can translate not only into new ideas but also into more thoroughness and creativity in solving problems. This leads to a positive correlation between diversity and the return on investment (Rock, 2016). The reason is namely that diversity pushes workers out of their comfort zones, which has salutary challenging effects: improvement of self-scrutiny, awareness of biases and openness to new viewpoints. In addition, a diverse workforce may provide additional understanding of a broad range of needs, making an organization more responsive to its customers with an increased insight into the market, including niches and new opportunities.

A diverse environment is also more welcoming for minorities who might otherwise feel unwelcomed. Moreover, an organization which is open to cooperation is more likely to find national and international partners, boosting its capability for large projects.

The Diversity Charter (Charta der Vielfalt e.V, 2018) is an example of a German initiative to promote diversity in companies and government organizations, including the German Aerospace Center (DLR), which alludes to the aforementioned advantages. The increased creativity and capability of innovation are particularly relevant for the highly competitive aerospace sector, which is reliant on constantly evolving and competing technologies. In spite of the high technological and capital barriers for new entrants, disruption and establishment of new niches is recognized as an important initiative, promoting an increased importance of competition and innovation in the future.

Strengths (internal gains) • Workforce with different perspectives • Increased situational awareness • Improved understanding of and access to niche markets • Increased creativity and innovation potential • Increased opportunities for individuals to learn from each other • Cooperation within and outside the organization • Welcoming environment, increased job satisfaction and retention of minorities (gender, ethnicity, nationality…)	**Weaknesses** (internal risks) • Potential for conflicts due to different working methods, values and expectations • Need for arbitration of conflicts • Potential for miscommunication and miscoordination • Slower dissemination of information • Reduced team cohesion and time efficiency for specific tasks (esp. routine ones) • Increased time/financial costs due to misunderstandings and conflict management
Opportunities (external/environment gains) • Positive public image as open and future-oriented organization	**Threats** (external/environmental risks) • Government regulations enforcing diversity (e.g. quotas)

• Inclusion in trend towards increased international cooperation as transportation/communication improves • Welcoming environment fostering recruitment and retention of talent • Inter-organizational/international cooperation, allowing more ambitious projects than individual organizations can afford	• Government regulations reducing diversity (e.g. international embargoes, ITAR regulations) • Negative public image as excluding organization, a possible barrier to employment/retention of minorities and inter-organizational cooperation • Aging workforce, leading to loss of know-how • Missing of talent due to quotas

Table 1 - SWOT Analysis of Diversity.

It is worth stressing that inclusion is a requirement to obtain the aforementioned benefits. For instance, an organization in which the opinion of the majority or a particular group is followed with little room discussion will hardly rip off the benefits of the different viewpoints, however diverse it may be.

Disadvantages

In spite of its clear advantages, diversity has implications for projects and the management of the workforce. Though diverse teams may achieve more far-reaching results, smaller and more uniform teams are easier to motivate and are able to operate faster and more predictably towards a specific goal. Moreover, different expectations and thinking patterns often lead to conflicts and miscommunication within diverse teams (Böhm, 2015), or deadlocks in decision-making (Stevenson, 2018). The advantage of creative thinking is not always relevant, especially for routine tasks which benefit more from standardization. Diversity in the work methods is not always positive, as many initiatives to promote an uniform company (or project) culture show. This means diversity is not a silver bullet, but rather suggests that proper (and strategic) management is necessary and must be fitted to the task at hand. Next, some disadvantages brought on by diversity are addressed in more detail.

Miscommunication

Miscommunication in several forms is a common problem in a diverse team. Different people have different codes for written language, making it difficult to anticipate exactly how the receiver will understand the information (e.g. an "!" could refer to enthusiasm or to anger). A difference in knowledge between the two parties (e.g. usage of an acronym) can also prevent information from being delivered effectively and thus create frustration.

Cultural differences are also a driving factor for miscommunication, as they result in different communication codes and behaviors that could lead to significant offenses. For instance, many foreigners don't know that Japanese business etiquette places a high value in the exchange of business cards, which should be swapped simultaneously and not merely stowed away, as this is a sign of disrespect.

Understanding and adapting to the interlocutor is the key. In a virtual/remote communication environment, a brief video introduction or results of Belbin or MBTI (personality) tests could allow a better understanding of other teams members, and thus allow better communication. Additional benefits include identification of the strengths and weaknesses of team members.

Moreover, introduction to codes and behaviors of different countries would avoid miscommunication and make a better impression to a customer upon first contact, showing a will to adapt to their cultural norms. Awareness of the different communication styles and openness to contact and clarification can also go a long way towards avoiding miscommunication and subsequent conflicts linked to this issue.

Harassment and Culture-related Conflicts

In various international projects, discrepancies in interpersonal communication and behaviors invariably arise, ranging from different degrees of punctuality to significant intentional offenses. These disparages could include undermining a person's culture or nationality; excluding an individual from projects or overall coordination due to age or gender; withholding information due to the professional background, or simply excluding individuals based on their geographic location and the difference in time zones. Only in relatively recent years has society witnessed a growth in the outcry against discrimination based on race, gender, nationality, and age.This means many of these points are yet to be fully addressed in the workplace.

Conflict management

A diverse team is expected to show differences in the way of thinking, understanding or values. As mentioned, this can be positive, but could also lead to conflicts. In the same way communication styles differs, different approaches exist to solve conflicts. Thomas lists five unique approaches which include: Competing, Accommodating, Avoiding, Collaborating and Compromising (Thomas, 2002). Collaboration is the ideal way to approach conflict management, as the others could lead to frustration and one of the parties judging a solution unfair. It is important to be aware of the conflict, to be able to understand its context, and to be able to monitor the interactions taking place, to ensure that all involved parties can express their points of view in a rational way. Then, the Thomas-Kilmann Conflict Mode Instrument (TKI) tool allows for choosing a strategy suited to the personality of the conflicting parties. Agreeing on a forward process and evaluating the progress such a process then leads to a solution. Evaluating lessons learned can lead to preventive strategies and a "conflict code" for future issues.

5.6 Diversity-related Risks

This section considers some diversity-related risks. They are also potentially negative but differ from the previous disadvantages in the sense that they are not necessarily a consequence of diversity itself. The first is the risk of insufficient workforce renovation, which is rather an opportunity cost in the case generation diversity is not adequately implemented. The second regards quotas, which may arise as an external imposition to organizations.

(Insufficient) Workforce Renovation

As discussed in the SWOT analysis, workforce renovation remains an important topic in aerospace (SSPI, 2016), (AWN, 2015). This is a considerable risk, since as ("What Every Leader Needs to Know About Retaining Millennials", 2018) the millennial generation (1980-1996) will make up to three quarters of the global workforce by 2025.

Quotas

An important form of external diversity-related risk for organizations takes the form of government regulation. This includes restrictions on hiring such as quotas or industry-specific regulations such as ITAR-restrictions. Examples include gender-quotas ("Ten years on from Norway's quota for women on corporate boards", 2018) and forcing managers to distribute openings in cohesion with national policies on background, health, or generational differences.

Quotas are often a double-edged blade, as they potentially offer contributions to individual projects by enforcing diversity and subsequent inclusion, but also presents risks. Benefits are especially true for self-imposed quotas, since organizations aware of their reality and needs can better adjust their internal policies. Examples of sectors considering quotas include tech companies and STEM institutions.

On the other hand, quotas simultaneously discourage or even prevent companies from hiring those candidates best suited for a specific job, which can be a significant logistic restriction for project managers. This is especially true for uncritical or externally-imposed quotas, which disregard specific aspects of the organization or project. Even for self-imposed quotas, a good project coordination should attempt to evaluate in which cases quotas are necessary; for example, if there is already a diverse balance of gender and educational background, but not of nationalities, this discrepancy should be recognized and acted upon. They should moreover be realistic - considering e.g. the availability of underrepresented groups in the workforce and not in the general population - and weight or counterbalance the potential stigma on the competency of the affected groups (Callender, 2018).

5.7 Concluding Remarks and Recommendations

Overview of Results

Diversity is a very broad and multifaceted topic, and the different dimensions (e.g. culture, gender, social status) have received different amounts of attention in different times. It is still continuously evolving, alongside the identification of individuals with particular groups. Nowadays, organizations in aerospace and other fields have dedicated policies to manage their diversity, with different degrees of maturity and success. Underrepresentation of women, as so far typical for STEM careers, certain ethnic minorities and of young professionals are still points of concern. However, majorities are also diverse, and the concept should not be oversimplified to dealing with minorities.

Diversity has widely recognized benefits such as fostering creativity and innovation; and creating a more welcoming atmosphere for minorities. In order to fully benefit from diversity, it is, however, necessary to implement inclusion i.e., assuring the different groups are integrated to the work environment and have active voice. Mere representation is a prerequisite but not the final goal. Managers and the workforce should be aware of the benefits of diversity and the risks of unconscious biases. Inclusion as a key for higher satisfaction and performance of the workforce is necessary to turn diversity into an asset instead of a burden. This has the potential to ease project management and increase project’s success rate.

Diversity also has downsides and creates risks which should be mitigated. For instance, different priorities and communication styles may lead to (time-costing) miscommunication and deadlocks when making decisions. Different expectations and misunderstandings also often lead to conflicts. Cooperation, however, is a simple and effective way to make “strangers” become “equals”.

Recommendations

Inclusion

Where to start? (Understand the context of the organization and how/why diversity matters in it.)

- Foster a discussion on the topic: What forms of diversity are relevant for the organization, and why? In which way is it currently present and what should change? Tools to raise awareness include: stories or interviews, minority role-models and success cases from other organizations.
- Monitor the organization: measure minority attrition, establish anonymous surveys and hotlines to report issues, seeking genuine feedback. Establishing more than one way of giving feedback helps to reach different audiences and ensures more parties feed safe to share information. Inform how the feedback is used.

What comes next? (Establish the base for a long-term commitment and pursue changes).

- Promote diverse leadership and foster leadership's commitment to inclusion. Managers should be educated on the topic and lead by example, with transparency towards all stakeholders, where the transparency can be reached through social media.
- Identify the organization's biases against certain groups and propose action.
- Train and inform workers to establish an inclusion culture, encompassing both top-down initiatives (e.g. push emails from influential figures) and everyday activities. Make sure there is palpable action and it is not seen as merely a vague good intention or a PR stunt.

Long term goals. (Change the perspective and adapt the actions to the environment).

- Promote a general shift in perspective: organizations should recognize and maximize the competitive advantage gained from being diverse, instead of showing a "humanitarian" concern for minorities, shadowing meritocracy.
- Set focus on equalizing the representation of different groups to the availability in the workforce, so that inclusion in STEM leads to more equal representation in the long term.
- Promote continuous adjustments in the inclusion practices, to adapt to changing identification with groups. Provide regular feedback, for medium and long-term monitoring of the implemented measures and how the organization is changing in response to them.

Recruiting and retaining young professionals (mostly millennials, born in 1980-1996)

- Avoid perception of career stagnation and improve work-life balance with e.g. flexible work hours and job perks. Be open about growth opportunities and consider the increased voluntary attrition as the new normal, don't try to force loyalty.
- Provide more frequent feedback young professionals can act upon.
- Establish an "inspiring" corporate brand, i.e. a leader in the segment, or an "innovator"/"disruptor". Charismatic staff members within the organisation could be given a media platform to share activities (no only regarding inclusion, but also general interest) with the public and the general staff.
- Embrace usage of social media and online platforms, as these are frequently used to get impressions about the organization. The right "digital footprint" (e.g. tweets and posts from managers) can help the organization.

Harnessing the advantages of diversity (with inclusion) for creative thinking and Innovation

- Give team members some room for decision-making and acting on initiative, leveling importance of opinions. Share success between the team and foster two-way feedback, i.e. both

giving ideas/suggestions and hearing reports on their implementation.

Diversity comes at a price, act to counterbalance the difficulties created by it

- Raise awareness of the miscommunication risk, incentive feedback and establish communication standards.
- Establish impartial and methodical ruling and set a point of contact for solving conflicts.
- Avoid keeping minorities in "niches" but instead foster mixed working groups. Encourage social interaction outside the immediate project to enrich understanding of differing paradigms.

6. Topic 3 Space 4.0 and the Evolution of the (Aero) Space Sector

The space industry is facing exciting times ahead, "a time when space is evolving from being the preserve of the governments of a few spacefaring nations to... diverse space actors around the world, including the emergence of private companies, participation with academia, industry and citizens, digitalisation and global interaction" (ESA, 2016). Dubbed Space 4.0, this confluence of emerging trends in launch vehicle capability, spacecraft miniaturization, demographic change, and internal as well as external technological development has heralded an era of rapid expansion, decentralization, entrepreneurial activity, and non-traditional partnerships. Successful Project Management (PM) in future space endeavours will require new approaches to address the seminal questions of PM (Cooke-Davies, 2002):

1. What factors are critical to project management success?
2. What factors are critical to success on an individual project?
3. What factors lead to consistently successful projects?

The investigation focuses on four emerging topics related to PM and Space 4.0, namely:

1. Artificial Intelligence
2. Model Based Systems Engineering
3. Disruptive Technologies & Businesses
4. Demographic Trends & Inspiration

6.1 Research & Analysis Methodology

Befitting the spirit of Space 4.0, many different sources of information were incorporated during the course of the research, from traditional literature and web searches to in-depth interviews with subject matter experts. The following report offers the distillation of these varied perspectives on PM & Space 4.0 along with the groups own personal insights from experiences in the space sector and beyond. Each of the four subtopics is treated independently and recommendations are included within each section.

6.2 Artificial Intelligence

Even though the application of Artificial Intelligence (AI) software to project management dates back as far as 1987, AI is only now really taking off. From software development to construction to logistics and finance, every company has projects that need planning, managing, and monitoring. But the PM tools that are used are often complex, designed for specialists, and provide only rudimentary forecasting of potential problems.

The key question then becomes: could AI-powered decision support systems and automation improve project success by reducing cost and schedule overruns, analysing risks, preventing mistakes, and improving efficiency?

Evolution of AI in PM

Over the years AI has become associated with different terms ranging from cognitive computing and machine learning to natural language processing. What they all have in common is the idea that machines could one day learn by themselves much like humans do, rather than merely following pre-specified instruction sequences or acting in accordance with a pre-programmed rule set (what is classically termed "automation") (Lahmann, 2018). To date, PM has focused on automation of tasks that are routinely carried out, requiring a certain degree of standardization. Then the first phase of prospect of AI evolution in PM will be followed by next key elements:

- Integration & Automation;
- Chatbot project assistants;
- Machine learning-based PM;
- Autonomous PM.

In view of foregoing, the AI will change the project delivery methods and, in general, the evolution of PM. But during this evolution it is important to remember that project managers will also stay relevant in the age of AI, if they focus on work that emphasises human skills.

Infusing AI techniques into PM phases

Algorithms tell computers and other machines how to think and act intelligently and many tools and techniques, such as Knowledge Based Expert System (KBES), Artificial Neural Network (ANN), Genetic Algorithm (GA), Fuzzy Logic (FL) have been studied in order to achieve AI goals. These techniques can be and have been used in several applications in PM enabling better project performance. So, AI can make the life of project managers less (or maybe more) miserable. (Hamdy K., 2017). As an example these techniques can be implemented into PM to achieve goals in design conception, project planning, cost estimation, as well as risk and performance management.

SWOT ANALYSIS

The advantages of AI have been presented in the context of PM, but threats and weaknesses are also present and should be accounted for.

Internal origin (Attributes of the organization)	
STRENGTHS (+)	**WEAKNESSES (-)**
- Reduce costs and mistakes, time to treat project/clients requests - Facilitates routine operations - Analyze risks - Improves the analysis method - Keep projects on time and on budget	- No human creativity - Not able to balance the capabilities and emotions of diverse set of humans (empathy) and lead them toward success - Require special training for the team (online courses, corporate training) - Require continuous monitoring/adaptation - Additional research needed into ethical, legal, and social aspects
External origin (Attributes of the environment)	

OPPORTUNITIES (+)	THREATS (-)
- Integration with Apps not used in PM field (e.g., Even.com predictive budgeting tool) - Incorporate AI into PM portfolio as a way of facilitating predictive steering of complex transformation projects - Global cloud services	- Significant disruption to business models - Requires a large investment - Over-reliance on AI as a sole source of truth - Security, reliability and confidence in the AI system - Development of standards and platforms for testing

Table 2. SWOT analysis of AI in context of PM

Conclusions & Summarized Recommendations

In summary, it can be said that project management covers many disciplines, only for some will AI be able to assist or take over. The main key of AI is to focus on ensuring that the strategy around it feeds into company larger business strategy, always taking into account the convergence of people, process and technology (Harvard business review, 2018). And project managers, who take the lead role in this strategy and project developments, will be assisted by AI, but not replaced. It means that "cognification" of AI will lead to alteration of job roles, rather than their elimination. By respecting a good balance between the roles of AI and PM such strength points such as reducing of cost and mistakes, time management and keeping the projects on the budget will help to succeed in the project. In the same time, the AI implementation in the PM requires a company-wide transformation and large investments and specific knowledge of project managers.

As recommendation, it can be said that the company that wants to work with PM tools based on AI should be ready to invest in

- (the best) data scientists who have skills focused around machine learning to build your applications; solution architects who oversee enterprise implementation;
- systems engineers who ensure the appropriate infrastructure is in place to support those applications;
- and business advisers who understand specific factors within the data and the business value that will be derived from the application is the main thing your company must do.

Concerning the process of AI implementation the managers have to be sure that expectations/roles between developers and IT are be clearly defined and agreed upon. Make sure that users understand the expectations of working with output from the AI applications, and create a simple process for capturing input so the solution can be tailored for more accuracy and increased relevance to meet each business need. In this case the training/seminars conducting prior the implementation of AI will allow you to set proper expectations on what each team member should achieve.

Finally, AI technology implementation strategy is the simplest part because the main barriers often sit within people and processes. Therefore in order to maximize the ongoing innovation and value creation form AI deployments, the company must develop trusted, scalable and flexible data and analytics environment in the company (Harvard business review, 2018).

6.3 Model Based Systems Engineering

Model Based System Engineering (MBSE) is rapidly becoming a day-to-day engineering practice which improves upon traditional document-based System Engineering (SE). MBSE provides a manageable and appreciable representation of a product throughout the process of specification, design, integration, operation, and validation. It is based on three main pillars which can be summarized as language, tool and methodology (Badache N. & Roques P., 2018). Multiple companies have adopted MBSE, ranging across a variety of industries, including space systems (23% of companies), aircraft (20%), defence (20%), automotive (7%), and other (30%) (Dvorak, 2013). Examples of companies are ESA, NASA, Northrop Grumman, Thales, Raytheon, CNES, and others; most of these companies also implement MBSE into their own Concurrent Engineering Center (CEC) tools.

MBSE benefits for project management (PM)

MBSE presents many acknowledged benefits, which could be adopted for project planning, implementation and PM, including:

- Consistency;
- Traceability;
- Reuse;
- Information sharing;
- Knowledge capture.

Furthermore, MSBE provides benefits across the entire life cycle of a project (Hause, 2013). Project managers are also able to track project status by continuously checking percentage completion of tasks (Bajaj, 2016) and MBSE supports management in PPBE (Planning, Programming, Budgeting & Execution Process) activities and decision making.

MBSE maturity status and prospects

MBSE is still in an early stage of maturation according to International Council of Systems Engineers (INCOSE) data (Chakraborty, 2016). INCOSE estimations predict that the capability and the usage of MBSE in both large and small scale production will greatly increase in the next 10-15 years, however the transition to model-based disciplines remains a challenge. The following changes are recommended to facilitate the SE transition to MBSE:

- Encourage widespread adoption of MBSE within organizations across industry sectors
- Improve practice of:
    - Modeling languages: Continue to improve in terms of expressiveness and function precision
    - Methods: Provide more adaptability to a diverse range of application domains
    - Tools: Integrate with other multi-disciplinary engineering models and tools
    - PM Tools: Define Project management models and tools
- Provide a workforce that is skilled in the application of MBSE

MBSE interoperability issues

The full benefit of MBSE will only be realized with collaboration processes that are themselves supported by interoperable MBSE platforms, including modeling, simulation, and collaboration activities. The report focuses on the modeling interoperability activity of MBSE since it needs to be improved first. Current solutions for resolving the model exchange issue are reviewed by (Lu, 2018) and summarized as the following:

- Linked data;
- Meta-model integration;
- Tool-based integration.

Currently, each tool and organization has its own proprietary model and language, thus, in the short term, it is recommended using mediators between tools instead of creating a single standard that all tools should comply with. This hybrid solution can be achieved using linked-data, meta-model, and tool-based approaches. Eventually, when there are semantic MBSE models and standardized API, a globally harmonized dataset can be used within and across the various MBSE frameworks. Harmonizing global product data also enhances Data-Driven Design (D3) by enabling advanced learning algorithms to scan knowledge graphs. Thus, benefitting from automatic feasibility detection at component, subsystem, and system levels.

Conclusions & Summarized Recommendations

MBSE contains three main elements (i.e. the language, tool, and methodology) which need to be developed further in parallel to mature this methodology. .Above all, model execution is a critical element to apply MBSE, All MBSE tools enable element reuse, connect design elements, and provide an effective means of knowledge capture. But, MBSE is still at an early stage of maturity. This is the reason why MBSE interoperability, as well as the transformation from SE to MBSE, currently produces many issues, with expected resolution during the next 10-15 years. To succeed in the transformation to MBSE and the potential evolution towards Model-Based Project Management (MBPM), concrete recommendations include:

- Develop guidelines and training for implementation of MBSE initiatives
- Assist potential future users with implementation of MBSE (e.g. in smaller companies)
- Further stimulate the development of common standards for language, tools and methodology for easier implementation throughout the space sector (e.g. include them in ECSS or NASA PM Handbook)
- Define standards, tools and methodology specifically for MBPM. This can be defined in collaboration with e.g. the International Project Management Association (IPMA) for instance for:
    - Common Project planning, scheduling and resource allocation
    - Risk management and linking it to system design and task
    - Project Breakdown Structure linking to system design and project planning
    - PM views of the overall system model (e.g. quick overview of technical project status, current issues and budgets)
- Intensify collaboration with INCOSE and Object Management Group
- Support of a step-wise introduction of MBSE & MBPM into projects for smooth transition and paradigm shift (shadow-engineering as possible first step)

- Benefits need to be verified and communicated to improve acceptance of MBSE & MBPM

6.4 Disruptive Technologies & Business Models

What are disruptive technologies? Will prominent space businesses have to cope with these new tides? And what changes are needed in order to survive the Space 4.0 era in terms of business strategies, supply chains, and PM? In this section, it is analyzed what the impact is and benefits are of disruptive technologies on aerospace PM. Then, the discussion on new business models that space businesses today should adopt as needed within a changing industry. Finally, the report explores the supply chain sector in Space 4.0 and discuss how current suppliers can adapt to new trends.

Disruptive Technologies for PM in the Space Sector

The space sector is by nature risk averse. Hardware must be able to survive the rigorous space environment and in-orbit maintenance is seldom possible. Traditionally, the reputation risks and accountability factors present in large space projects have significantly limited adoption of new technologies. Unbound by these constraints of the traditional approach, Space 4.0 companies have embraced a wave of disruptive technologies which are driving the space industry to be more efficient and market oriented, leading to lowered costs, reduced lead time, and improved performance.

Disruptive technologies are divided into two categories: technologies significantly driven by aerospace applications, e.g., reusable spacecraft, additive manufacturing (3D printing), in-situ resource utilization (ISRU), nanosatellites; and, technologies driven by other industries such as the Internet of Things (IoT), Blockchain, Cloud solutions, and video game devices.

- Disruptive technologies in the first category affect risk management in space projects as they are not yet backed by an extensive proof of usage and reliability. A more proactive risk management is necessary to assess and classify the potential benefits and risks compared to traditional technologies as well as to successfully mitigate any identified risks (Ganguly, Nilchiani, & Farr, 2017). However, effective PM usage of Commercial-Off-The-Shelf (COTS) components can make use of economies of scale to mass produce satellites cost effectively.
- Space 4.0 PM also needs to innovate in the second category of disruptive technologies:
  - The Waterfall Development Cycle is being replaced by rapid iteration and early development of minimal viable prototypes. Project funding needs to account for agile and iterative processes (e.g., Git, Scrum) as well as for continual upgrades throughout the mission lifecycle (Mittman, 2018 and Wolgast, 2018)
  - Blockchain can be used to verify project documents (Ulmer, 2018)
  - Cloud based solutions enhance concurrent development of a space project by reducing lead times, offering higher flexibility, facilitating documentation, and enabling geographically dispersed teams (PMI, 2018)
  - IoT contributes to the interconnection of development and testing equipment, reducing reporting effort and making production more agile through the digitization of logistics (Roma, Design 2 Produce, 2018)

- Graphic Processing Unit (GPU) computing enables massively parallel simulations and rapid training of machine learning algorithms (Wolgast, 2018)
- VR/AR systems can be used for spacecraft assembly, on-orbit maintenance, scientific team collaboration, and operations planning (Wolgast, 2018)

To incorporate the benefits of disruptive technologies and to collaborate with Space 4.0 industry, a common framework of standards, guidelines, common interfaces, and cybersecurity should to be established. For instance, ESA develops Electronic Data Sheets to represent data interfaces of electronic components for electronic data exchange among parties (Prochazka, 2017).

Disruptive Business Models

The space market is no longer the sole domain of big players who produce, own, and operate satellites. Accelerated by affordable launch opportunities and the standardization linked to the CubeSat form factor, companies and startups offer commercial services driven by disruptive technologies and business models inspired by Internet entrepreneurs. For example, mega-constellation projects like OneWeb plan to deliver low cost, globally available internet services, relying on networks 100's of satellites (Henry, 2018). In short, Space 4.0 is defined by rapid innovation, lower costs, rideshares, commercially available parts, and agile development.

To adapt to the changing Space 4.0 market, new PM practices are needed to:

- Address complexity as a function of interfaces;
- Seed a broad spectrum of technology start-ups (entrepreneurial / pre-revenue);
- Investigate data providers as supplemental sources of scientific information;
- Incorporate decentralization at various scales.

Supply chain and supplier certification in Space 4.0

Long-established space companies are based on low volume, high cost, and high reliability systems. To achieve target quality standards, space agencies and prime integrators establish tight requirements for their suppliers, entailing extensive documentation, certification, and quality controls. Traditional suppliers that want to enter in the Space 4.0 market need to adapt their production line to solutions with lower costs, higher volumes, and shorter lead times (Olofsson & Orstadius, 2018). On the other hand, new Space 4.0 companies are intrinsically based on mass production and a "good-enough" quality approach:

- Supply Chain for Small Satellites;
- Supply Chain for Launchers;
- Space Logistics and Sustainable Supply Chains.

Conclusions & Summary Recommendations

Disruptive technologies encourage innovation, fast-paced development, low cost, and more customizable space projects. Successful PM in Space 4.0 will place greater emphasis on decentralized cooperation, standardization of essential interfaces, and leveraging developments coming from outside the traditional aerospace field. Moreover, Space 4.0 will be market-driven with companies aiming to achieve a "good-enough" quality at a reasonable price. COTS parts developed for commercial companies can be leveraged, but there remains a clear need to monitor their on-orbit performance.

Finally, there are no well-founded PM studies with project metrics or lessons learned for the application of disruptive technologies for space missions. Many institutions have not yet made valuable information publicly available.

It is therefore recommended to:

- Further promote standardization within the industry as is happening for the Cubesat sector.
- Continue and improve the monitorization and documentation of the in-orbit performance of COTS parts.
- Perform an evaluation study of successes and failures in disruptive technologies and approaches. Moreover, a space-sector conference for exchanging the experiences and lessons learned is highly desirable.
- Take full advantage of cloud solutions for sharing data/services among stakeholders and incorporate decentralization at various scales.
- Seed a broad spectrum of technology start-ups (entrepreneurial / pre-revenue companies).
- Investigate data providers as supplemental sources of scientific information.
- Address complexity as a function of interfaces. In particular, develop missions based on standardized interfaces between sub-systems, and, whenever possible, adopt a more flat organizational structure instead of a top-down authority.

6.5 Demographic Trends & Inspiration

While the phrase “rocket science” is synonymous with difficult challenges and high technology, various sectors have outpaced the space sector as the most "technologically advanced" domain, particularly robotics, information technology, and the Internet of Things. At the same time, many companies and agencies struggle to attract young professionals and retain top talent in the space industry, hindering efforts to adapt to Space 4.0 (Aviation Week, 2017 and Tellier, 2017). Recruitment and retention efforts are hampered by the perception that the space sector is inherently slow-moving and that success is limited to existing players. On the other hand, natural excitement for space exploration, the existence of engaging technical challenges and the potential to create major impacts on the world all present opportunities. Above all, the importance of new workforce technologies and business processes should not be overlooked when seeking to attract and retain the top talent for Space 4.0.

Engagement and Inspiration via Crowdsourcing

Institutional programs like NASA’s Center of Excellence for Collaborative Innovation (CoECI) offer access to curated communities of expertise by issuing challenges to solve difficult and focused problems (Buquo et al., 2018). In addition to their high-impact, low-cost track record of technical success, these public challenges elicit responses from people of all disciplines and backgrounds (approximately 70% of all challenge solutions come from outside the technical domain of the issuer). When feasible, PM practices should incorporate these crowd-sourced initiatives, especially as they open opportunities to work with, train, and potentially hire highly capable people with little prior space experience.

Infusion of Best Practices from Other Industries

PM should observe and adapt technologies from other industries and not reinvent solutions that already exist. For example, Virtual Reality/Augmented Reality technologies are currently being widely implemented in the videogame industry and also in medicine and construction projects to improve the visualisation and perception of the planned end product and thus improving the end result. Applying such cutting-edge technologies from outside aerospace to challenging projects within the space sector would increase "space" appeal, for example to computer scientists and others interested in information technology (Wolgast, 2018). Likewise, modern PM processes make aerospace companies more attractive to a younger generation, e.g., going paperless and remote work. Environments like Git and Slack encourage agile development, flattened hierarchies, and the sense of a "digital commons" where all contributions are encouraged and recognized (Mittman, 2018). Additionally, many tech companies actively encourage employees to spend a percentage of their time on "non-project" work experimenting with new processes and technologies, even when the pay-off might be uncertain or in the indefinite future.

Mentoring and Peer-Networking

Cultures of mentoring and life-long learning are a key aspect of successful PM, especially in the rapidly changing Space 4.0 environment. Experienced staff can give guidance and motivation to young professionals while sharing best practices and important context for institutional processes. In turn, early career professionals are often more attuned to the newest advancements and are enthusiastic to experiment with evolving technology. Accordingly, PM should promote cross-generational partnering within projects to capitalize on the relative strengths and experiences of different age cohorts. Likewise, strong peer support networks, for example the New Researcher Support Group at JPL, help with employee retention by fostering a sense of community, promoting collaboration, and providing access to informal institutional knowledge. In addition to improved outcomes on existing programs, these approaches help prepare motivated teams of young professionals, ensure demographic stability within the industry, and generate new project concepts that lead to future space mission development.

6.6 Conclusions & Summary Recommendations

In order to manage the industry shift to Space 4.0 and improve project efficiency, companies and organizations within the space sector should focus on:

- Engagement and Inspiration via Crowdsourcing
- Infusion of Best Practices from Other Industries
- Mentoring and Peer-Networking

Incorporating certain practices may require adaptation to meet the realities of the space sector, including cultural (or even legal) restrictions within companies and space agencies as well as differences in project goals, structures, budgets, and time constraints. However, the proposed policies contribute to a culture of openness, innovation, and enjoyment; adopting these practices within PM would change the image of traditional space companies/organizations and help them be seen as attractive, forward-thinking career opportunities for young professionals.

Concluding Remarks

Space 4.0 is globe-spanning phenomenon, represented on every continent and composed of organizations scaling from the largest governmental agencies and most venerable companies to the newest start-ups and most intimate university research laboratories. As such, it is difficult to adequately summarize all the trends and opportunities for the future of project management.

However, throughout the investigation a few cross-cutting themes have been identified, summarized as follows:

- The importance of the human factor within project management, even as artificially intelligent assistants and model-based approaches increase in capability
- The importance of interfaces between systems and organizations, particularly in terms of addressing risk via standardization and interoperability
- The need to capitalize on trends, technologies, and processes coming from outside the traditional aerospace sector
- The opportunities for greater efficiency, innovation, and job satisfaction afforded by decentralized technologies and work practices

7. Topic 4: Challenges faced by multi-disciplinary teams working on space projects between emerging and legacy space economies

7.1 Introduction

Space projects have increasingly become more globalized and multi-disciplinary. It is obvious that promoting mutual understanding between new space and legacy space players is of prime importance, as the total amount of resources that could be leveraged into space activities are currently limited.

There has been a great discussion about efficacy of collaboration between emerging and legacy space economies, but the main challenge is in the mind-set disparity. Legacy space tends to be conservative in project execution approach resulting in high-cost projects. New entrants are flexible and experiment with adopting unconventional and new strategies for project execution.

The research in this report aims to capture the complexities of working on space projects within multi-disciplinary teams, and to propose solutions (including project management methods) that might assist to bridge the gap between legacy players and new entrants from emerging space economies.

7.2 Scope, Objectives and Methodology

The goal of the research is to identify areas and methods of optimized collaboration between team members working on the same projects from either emerging space economies and/or legacy space economies, ensuring ease of integration of first team space project team members.

The scope of the research includes both:

- survey of current status with associated challenges, and
- suggestion of new management methods and economic leverages to improve cooperation.

Objectives:

- Status quo awareness of the heterogeneous space sector i.e.:
    - highlighting and explaining differences between legacy and emerging space players
    - describing the characteristics and prevalence of multi-disciplinary project teams
    - contextualizing the challenges in a specific economic environment
- To propose new project and risk management methods
- Recommendations on leveraging the new space economy

The methodology adopted in this research is based on multiple literature review of existing space programs in public and private sector and on interviews with leaders in the space sector such as project managers, executive and senior level management and other players who are or soon to be involved in space activities.

7.3 Diversity in background: challenges and opportunities

Overview

In the field of space exploration, it has been often discussed that many situations exist where legacy space players are at an advantage than the new entrants from emerging space economies in terms of project execution. But SpaceX, for example, has established an impressionable position as a new entrant, which demonstrates that new space economies and unconventional project execution strategies contributing to a project's success can be a much needed creative force to boost space industry through innovation. Project consortia and project teams are becoming increasingly complex and variegated as there is diversity in the background due to multidisciplinary and heterogeneous provenance of project team members.

This section presents the status quo awareness of the heterogeneous aspect of the aerospace sector. To this purpose, this section puts its focus on defining five challenges, that can be transformed into great opportunities for the future.

Disparity in mindset

There seems to be a large disparity in mindset between experienced members in legacy space economies and new entrants to the space projects. Legacy space tends to adopt well-established technology to ensure reliability and assurance, as evidenced by the fact that there is a tendency for the established space agencies to be focussed on mission success more than the newly developed epoch-making innovation.

Furthermore, legacy space players tend to see new space players as high-risk partnerships as they are not always tested or qualified, hence the first contracts that they are willing to give to the new space players are for non-flight equipment, often electrical or mechanical ground support equipment. This is, however, in many cases not the expertise of the new players as they had no occasion or opportunity before to participate in the testing of satellites(say). A better approach would be drawing on their strengths (which could be in electronics or mechanical design) as done for similar market areas. Changing the mindset of established players towards new space players gives great benefits in order to promote better cooperation possibilities in a project.

Technical challenges

There seems to be a large disparity between experienced members in legacy space economies and new entrants to the space projects from the perspective of technical readiness as follows:

- **Practical knowledge and experience**

New entrants are required to start from scratch in comparison with the ones involved in previous space projects. The experienced members have a huge advantage in terms of practical knowledge and technical experience in areas like system design, analysis, assembling, qualification tests, packing, launching and on-orbit operations. From an engineering standpoint, accumulated knowledge on failure information during development and tests on the ground as well as on-orbit operations plays a vital role to design systems or components with lower risk of potential failures on orbit.

- **Opportunity for on-orbit demonstrations.**

What seems to be lacking for new space economies is opportunity for on-orbit demonstrations. For space missions, there is a high possibility that the components could face unexpected errors on orbit even if they passed through all the qualification tests on the ground, mainly due to the unpredictability of space environment, such as thermal-vacuum and radiation. The new players need to obtain a chance to demonstrate their technology in space to be entitled as "flight proven" which proves its survivability in space environment.

- **Capacity for long-term research activities**

What seems to be lacking for new space economies is capacity to invest resources for long-term research activities. New space companies are required to invest huge amount of resources into research in order to accumulate their basics at an early stage.

Management process maturity

Legacy space economies adopt well-established project management processes, such as phase transition method, which requires phase-by-phase decision making, following a V-model development cycle. This method divides the entire project in separate periods, each one initiated and terminated by a formal review. Another effective method is adopting the industry standards such as European standard ECSS-M-ST-10C "Space project management. Another example comes from NASA Single-Project Program Life Cycle as per NASA/SP-2014-3705 "NASA Space Flight Program And Project Management Handbook".

This management method brings great benefits to the projects as it ensures resources and commitment by the top management in the long term. Traditional methods, however, could be a double-edged sword, because they require a costly overhead: the decision-making process is long and complex, and plenty of effort is needed to get approval by the reviewers.

Conversely, decision-making process of new entrants is relatively quicker. They are not biased nor limited by the need to abide to a common practice, such as strict project management requirements that legacy space economies have built up and followed for several decades, but this may affect the cost of quality. Nimbleness and flexibility are the key factors not only to develop a system in a shorter period of time but to keep up with the newly developed technology in the rapidly evolving world. Considering the circumstances mentioned above, new space could be a strongly efficient and creative force for the space activities ahead of the times.

Economic Challenges

Revenue in space sector: Around $60 billion was spent by public actors in the space sector in 2016 and it is estimated to reach about $80 billion by 2026 (Euroconsult, 2015). Comparatively, the private sectors invest only around 10% of these estimates (Blakemore, E. 2015). Even if this share could change, space is fundamentally a public venture. For example, per 100 launches a year, about 75% are public launches funded mainly by US, China, Russia and Europe.

Profitability is not the key priority although cost efficiency is always evaluated when a program or a space service is initiated. Looking at the main space sectors, the strategic motivation has always prevailed, and it will surely remain that way in the next decade. The will to master the whole value chain with their strategic link (Military observation and telecommunication satellites, Launchers capacity and more recently global positioning systems) enables, as a second step, to develop a commercial economy and increasing revenues.
The Galileo EU global positioning system is symptomatic of this state. At the beginning of the program, EU had the wish to elaborate a public-private partnership. At the end, public EU investments has been the only source of investments in order to secure EU strategic autonomy (Euractiv, 2007).

In the 90's, there was a sudden increase in the demand for telecommunications (TV and telephone mainly), leading to an exponential increase of broadband supply and private space actors on telecom satellites, which have been the main driver to the space economy until now.

In the 2000s, the commercial revenue tended to increase with the emergence of first constellations and micro launchers private prospections. But this tendency later collapsed and has only recently begun to remerge, thanks to satellite data connectivity, with its potential global coverage and mobility uses which make space-based systems interesting when compared to terrestrial technical solutions.
The "entrance ticket" thanks to launch service price reductions, technology miniaturization and satellites manufacturing industrialization, is now cheaper than in the past and the current economic change towards smaller satellites would invite more and more private actors to expand the space economy and make it profitable.

- **Regimes and policies**
  - Involvement of an increasing number of space-faring nations investing in the acquisition of turnkey space capabilities or even in the development of a domestic space industrial base.
  - Demand for supportive policies from governments as well as agencies (innovative public procurement and support schemes). The trend is towards an adaptation of the public intervention model to make room for a more leading private sector.
- **Funding and astro-preneurship**
  - Reliance on substantial private investment from different sources (venture capitalists, business angels, private entrepreneurs)
  - Quest for a new breed of venture capitalists/entrepreneurs, knowledgeable about space business.

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- **Players, business models and value proposition**
    - Emergence of non-space companies, including large ICT companies in particular, which are entering the space market.
    - Adoption of innovative business models, often addressing new space markets or creating disruptive solutions for existing space markets by introducing new technologies, methods and processes.
- **Markets and products**
    - Birth of new industry verticals and space markets targeting the provision of new space applications (global connectivity, geoinformation services, space tourism, space mining).
    - Appearance of lower cost microsats (<200kg) that can provide data of significant commercial interest.

There are challenges in making collaborations between new players (business model based, non-space) and space agencies profitable.

Several startups and SMEs play a significant role on the space market. They are involved in the supply chain and can help to provide more innovative and fast solutions to the rising challenges. On the other hand, they are often facing challenges unlike the ones usually anticipated in other markets. Some of these challenges are:

- Cultural gap between Space actors and the other industries nearer of the society or the customer;
- Understand one another's need;
- Make different technologies or technical interfaces work together;
- Continuing evolving technology vs stable or slow technology evolution because of satellites life cycle durations or qualification validation requirements;
- Different visions: short/medium vs long term in most of the space projects;
- The development duration reference is also structuring. Developing a launcher or a spaceplane requires minimally 5 years. It is not always the case in the non-space player;
- Launchers requirements specificity;
- Risk and ROI need legacy actors with an institutional business model but in contrary are having difficulties to think about establishing an industrial strategy and not just on a lobbying spectrum. When a non-space player wants to invest in Space, they always needs to consider and explain the space actors it's stand on the risk of not reaching a proper ROI, as the outcome always takes time;
- Regulation or normalization can be different.
- Legacy space is extremely cautious about high risk appetite in new space. On-orbit failure may result in reputational damage on a corporate level.

Political Sustainability

As of now, space activities are driven dominantly by governmental policy as evidenced by the fact that space policy in legacy space economies has been deeply affected by the political situations. Political changes illustrate a common phenomenon happening in legacy space economies which changes strategies every 4 to 5 years affecting technological progress.

Ensuring long-term sustainability is the key factor toward successful space exploration by taking mitigation measures to protect space industry from impacts caused by political changes. All these effects play down from top to bottom into projects and the way they're executed and hence an impact on the industry overall.

7.4 Leveraging diversity in space projects

Overview

The objective of this section is to recommend practices to better capitalize on heterogeneous project teams. This is achieved by:

- proposing new project management and risk management methods;
- suggesting ways to leverage the new space economy.

Also, proposed solutions to the major challenges mentioned in the previous section. The findings hereinafter presented are based on sound literature review, but also on interviews with leaders and managers in the aerospace field and on first-hand experience of the IPMC YP Topic 4 delegates

Project management methods to improve multi-discipline teams and projects

Multidisciplinary capacity can be defined as a minimum viable kit of assets to enable work on a space project. Multidisciplinarity (or interdisciplinarity) involves the combining of two or more disciplines, i.e. highly specialized fields of knowledge, into one activity. (Pickering, 2017) Such an approach breaks the separation between traditional domains and competencies: it is about creating something new by thinking across boundaries. Traditionally, multidisciplinary aspect is often associated with technical or engineering activities. Designing a spacecraft is an apt example of a complicated technical challenge that requires large interdisciplinary engineering teams with several specialties because the product itself has a large variety of technical aspects and great complexity.
Importantly, this is not confined to only technical aspects but extends to project management, which brings along quality assurance, reliability, risk and cost management.

To properly handle both technical and non-technical aspects, three "philosophies" are usually considered: concurrent engineering, agile approach and multidisciplinary project/program management.
When considered collectively, they address all the main factors impacting project execution efficiency.

Concurrent Engineering (CE) is a systematic approach to integrated product development that emphasises the response to customer expectations. It embodies team values of cooperation, trust and sharing in such a manner that the decision-making is by consensus, involving all perspectives in parallel, from the beginning of the product life-cycle. (Pickering, 2017)
Essentially, CE provides a collaborative, cooperative, collective and simultaneous engineering working environment. Concurrent engineering is well suited for the development of complex hardware design projects, as evidenced by the fact that it has a long history of successful applications in the space field since the late 1990s. However, at the time being, complexities in system modelization plus computational and data management limitations have restricted its usage to early product lifecycle phases.

Agile describes an approach to project management in particular to software development in which requirements and solutions evolve through the collaborative effort of self-organizing and cross-functional teams and their stakeholders. It advocates quick sprints, adaptive planning, evolutionary development, early delivery, and continual improvement, and it encourages rapid and flexible response to change (Agile Software development, 2018). Agile is an umbrella word and underpins a broad range of development and management frameworks (Ghosh, 2004) (Rigby, Sutherland, Takeuchi, 2016) (Alexander, 2018) (Rigby, Sutherland, Noble, 2018). Agile is traditionally associated with software projects, simply because space-qualified hardware cannot be delivered in agile fashion (Rigby, Sutherland, Takeuchi, 2016) (Alexander, 2018). Information can be delivered in agile manner, and traditional space projects are mainly information-driven as imposed in the phase-transition method where technical reviews, such as SRR, PDR, CDR, QR, FRR, are required at each stage of the project. Importantly, the need for quick, custom-oriented information availability is paving the way for the adoption of agile methodologies in space companies and agencies (Rigby, Sutherland, Noble, 2018).

The goal of Multidisciplinary Project Management (MPM) is to ensure successful delivery of a project through effective handling of a multidisciplinary project team. Indeed, project management is multidisciplinary in nature (Ebi, 2016) (Murray, 2005) (Hopeman, 2016) (Cheng-Yong Huang, Ding-Bang Luh, Chia-Hsiang Ma, Ming-Hsuan Hsieh, 2012). A project team may comprise various professionals, consultants, contractors, middle level manpower and labourers. While a team is drawn from within an organisation where members may know each other in some cases, the team might be a mix of people from within the organisation and outsiders. Multidisciplinary Project Implementation Units (PIU) or Project Management Teams (PMT) or Project Management Offices (PMO) are key elements in successfully managing execution of complex projects (Ebi, 2016) (Murray, 2005). Awareness for this kind of concept is stronger in emerging economies and in non-space fields such as construction, energy and consultancy, simply because MPM has become the de-facto standard for legacy space players and they consider the application of multidisciplinary way of thinking to be routine.

CE, Agile and MPM are used to enhance efficiency of heterogeneous teams and they all include the following key elements.

1) The multidisciplinary team is the set of people contributing skills to the project. It includes individuals with traditional engineering and technical skills, as well as ones with management. The idea is that even those disciplines that were traditionally involved at a later stage of the process shall be given the opportunity to participate from the beginning and to identify trends that might later invalidate the design..

2) The process is the formal representation of how the implementation status of the project evolves, from the initial one (very low level of definition, few details, course description) to the final one (higher level of definition, lot of details, fine description. Defining the appropriate process is core to proper project management and strongly depends on project scope and complexity.

3) The information/data model refers to the creation of a consistent set of design parameters and the way they are defined and exchanged throughout the duration of the project.

This enables configuration control and at the same time quick iterations for design evolution (any change which is introduced can immediately be identified and its impact can be collectively assessed). The goal in having a good data model is to be able to perform several design iterations so that different design options can easily be analysed and compared with.

4) The IT hardware-software infrastructure and

5) the facility are the practical tools that physically allow project execution (see for example (Cheng-Yong Huang, Ding-Bang Luh, Chia-Hsiang Ma, Ming-Hsuan Hsieh, 2012), (de Wolf, 2017)). Multidisciplinary design activities are conducted in sessions: most often these are plenary meetings in which representatives of all engineering domains participate, from the early phases (requirement analysis) to the end of the design (costing). Project management activities and project reviews also require frequent plenary gatherings. It is obvious that proper location and tools are needed to enable co-location and co-operation.

Those above are the five key levers to improve project efficiency when dealing with complex heterogeneous teams. The first two elements (team and process) are mandatory and will be explored in detail later in this report. The other three (data model, IT infrastructure and facility) are regarded as optional in principle but are essential and almost unavoidable nowadays.

Setting up new methods and tools to manage complex multi-disciplinary projects, possibly encompassing both legacy and emerging space players, is an investment. As such, it shall be based on a good understanding of its potential return and the associated risks.
Therefore, the remainder of this section:

- gives recommendations on project management methods and platforms, to mitigate risks associated with new entrants to space projects,
- summarizes the benefits of having a well-managed heterogeneous team, detailing the unique value proposition brought forward by new entrants from the emerging space economies and by multi-disciplinary teams

Project management methods and platforms that will mitigate the risks associated with new entrants to space projects

In the space sector, legacy players still set the trend and rules for management of risk. This has reverberations in new players as well, since they are part of the same value chain. In fact, new entrants to space projects shall usually abide by industry standards and best practices. However, there is a difference in how risk is perceived and managed in legacy space as opposed to emerging space.
Project risks affect project cost, schedule, scope and quality. Legacy players put particular emphasis on project scope (technical content and performance). From a technical standpoint, aerospace projects conform to project specific risk policies. There are risk management practices defined to identify, assess and reduce the project risks in a systematic way.

In new entrants, risk evaluation and risk management are less skewed towards the technical side. When looking at the triple constraint of PM, for new entrants cost and time are as pressing as quality.

- Cost. For an emerging player risks are often associated with their funding opportunities and political backing. In contexts that are heavily reliant on governmental support, often projects start out well, but quickly lose momentum: development starts to take longer, there are budgets issues, and investors drop out since not enough tangibles would get generated by then. From a risk management point of view, new entrants face this situation by nurturing political backing and by adopting a "fail fast" approach (they look for short development cycles and quick ways to show success). In contexts that are less governmental and more commercial, the focus is on ROV.
- Time. New entrants are more willing to compress the schedule and quicken their timelines. In planning and execution, they start with a waterfall approach at very high level (to get a quick idea of the big picture and make sure all pieces are taken into account); then they switch to Agile and evolutionary spiral process.
- Scope. As mentioned before, new entrants usually start from projects of limited scope, for which success or failure can be ascertained quickly. Small projects are managed with new methodologies for lean enterprises, such as SAFe (Scaled Agile Framework). From a technical standpoint, access to skills is another risk, especially in certain geographical areas and depending on the size of the company. The same is true with access to information or network (due to regulation restrictions).

Project management tools and platforms can help manage risks. Legacy players use sophisticated and integrated PM tools (such as Microsoft Project), CMS tools (such as SharePoint) or PLM tools (such as Teamcenter). On the other side, emerging players often start small by exploiting tools for task allocation (such as Asana or Slack), tools for timesheets (e.g. Teamwork) and Kanban tools (e.g. Trello). This is mainly due to two reasons: 1) new entrants start by extending to project management those tools they already use at engineering level and 2) licenses for top-level tools are too expensive.

Unique value proposition by new entrants from emerging space economies

The legacy space economies tend to be conservative. One of the most problematic aspect of legacy space is slow decision-making process mainly due to strict requirements and local rules that legacy space members have painstakingly built over generations and followed for decades. While this process might make it possible to reduce the risks of failures on orbit, it requires more time, monetary and human resources to meet the requirements.

New entrants, however, show enthusiasm about accepting new ideas and innovative approach to solving problems, especially in case of satellites miniaturisation and the trend to use COTS components. According to the Deloitte Report (Deloitte, 2016), the sharing economy has disrupted a number of industries with lightning speed in that emerging players (such as Uber) have upended the orthodoxy of legacy players (e.g. traditional taxi business) within a short period of time.

- New entrants can add supply of new disruptive technologies e.g. Uber
- Cost effective and decreased costs (Lighter satellites)
- Diverse teams with diverse knowledge
- Need for the use of space technologies especially in Africa and other emerging nations (sustainable development goals)

As noted by Salim Ismail, Founding Executive Director, Singularity University, the internet has created an environment where a “viral loop” can generate demand at near-zero cost, and new entrants can add supply to a platform for far less than traditional players. The new entrants from the emerging space economies are capable of being creative force for the space program.

Unique value proposition brought a multidisciplinary project team

Multidisciplinary teamwork can bring unique value proposition to the outcome of a project. The distinctive benefits are detailed in the following list, also includes all research evidence and referencing.

1. Improving teamwork efficiency through co-engineering, via:
    - Better communication;
    - Efficiency boost;
    - Time and cost savings;
2. Improving products at the physical and functional interfaces among disciplines, via:
    - Breakthrough innovation;
    - Information availability;
    - Stakeholder inclusion;
    - Infrastructural cross-fertilization;
    - Built-in elicitation of hidden constraints;
3. Leveraging inter-organizational cooperation at all levels, by:
    - Sharing organizational burden;
    - Pooling knowledge;
    - Achieving higher engineering or scientific value;
4. Upskilling staff, by:
    - Complementing undergraduate education;
    - Honing soft skills;
    - Developing human resources.

7.5 Coexistence in prosperity: ways to leverage the new space economy

New space entrants objectives

The definition of successful project for new entrants from an emerging space economy can be described as the sum of different aspects:

- Corporate sustainability. Even if governments or billionaires invest huge resource in space projects at an early stage of the project, the company shall rely on a business model to ensure corporate sustainability. It would certainly be a project which allows the company to raise money, as for the emerging space economies positive cash flow is really important.
- Innovation / development of a new product.
- Scientific improvement. For a Company, contribution to basic research in technological fields leads to improved efficiency in engineering development and to possible patents, safeguarding against technological obsolescence and lack of competitivity. At governmental/agency level, the same achievement can have tangible effects on population well-being by improving aspects of their daily life, create jobs, bring economic growth, contribute to national assets / security, secure global competitiveness and the nation’s presence on global scene by creating the capacity to face the technological challenges of the future.

- Corporate image / vision. The space field is still perceived by general public as extremely challenging, while at the same time being fascinating. Succeeding in a space-related project can increase the company's perceived prestige and valor, especially if it contributes to the sustainable development goals.
- Mergers & Acquisitions. If a Company develops niche expertise in space applications, it becomes valuable as possible strategic acquisition for a bigger company or corporate targeting portfolio expansion in that particular field of expertise.

According to the NASA Office of the Chief Technologist (NASA , 2014), across the USA individual states have recognised the economic benefit of space activities within their borders and have invested in infrastructure such as spaceports, provided tax credits, and passed legislation to attract new space business. The benefits include high-paying jobs, high-tech activities that generate secondary benefits, and the prestige associated with space.

The South African National Space Agencies (SANSA, 2018) echoed the same benefits that the NASA report highlighted, which according to SANSA Annual Performance Plan (APP) indicate the following to be very important to a successful space economy. Hence a successful project according to the APP and the Emerging Space Report would include the following:

- Infrastructure development forms the critical backbone for the national space programme. This is especially important for the efficient and effective delivery of products and services, across the space value chain, through to the end-users.
- The development of space applications that can address national/regional challenges and provide decision support tools for government.
- Skills development and knowledge transfer from the legacy economies.
- The transfer of technical capabilities from the design to the manufacturing processes.

In addition, a case study of the QB50 project funded by the European Union shows how SCS Space and CubeSpace new entrant from an emerging economy managed to successfully execute the project that enabled skills/knowledge transfer, testing infrastructure and collaborations of multi-disciplinary teams.

Space sector demand and revenue

The information above shows a variety of reasons behind private and public investment in space initiatives. At this point, it is interesting to understand what is the return of investment in such initiatives and if the space sector is actually revenue driven.

Telecommunication as the locomotive

Since the 1990s, the telecommunication satellites industry, pulled by the global telecommunication demands has known a residual market share but remains still substantial comparatively to the other space sectors (The Tauri Group, 2013).

For the next decade, spatial solutions especially with the emerging of high broadband internet will remain cost relevant and revenue-driven for global service need, low-populated density coverage area or latencies issues (Rash, W., 2018).

New space revenue-driven appetite: startups and billionaires?

The appetite for space of the new US billionaires increases this trend since they are capable to spend as much as rich countries to develop their own space activity. At the time of writing, Jeff Bezos intends to spend more than Europe in the Launcher industry (Bhardwaj,P., 2018).

Legacy space agencies

As it can be noticed regarding the development of commercial interest in space, legacy space agencies, especially NASA are working to develop a commercial and profitable environment by supporting the intervention of new entrants.

The European space agency are also looking to develop space business but are lacking in "Pioneer" billionaires interested in investing in Space.
They develop their own startups ecosystems in their countries but also develop collaborations for future business also outside their frontiers. Bellatrix Aerospace, an Indian startup is currently working with DLR and CNES (Dasgupta, A., 2018). Europe is still a big market and develop international collaborations for future global business now is essential to still exist in the future when the global economy would not depend essentially on the Europe economy.

Russia is currently more focused on consolidating its space industry and are not generating new entrants. However, thanks to its Soyuz reliable and low-cost launch service, Russia capitalizes on its former investments to generate revenue (Arianespace contracts and International Space Station supply)

JAXA has a less-pronounced space business approach and is more focused on its strategic needs but is also targeting a cost optimization, especially regarding launch costs (Nikkei staff writers, 2018).

Emerging countries are not outdone

ISRO for example does not support its startup ecosystem as of today and focuses on consolidating an established industry but their old traditional nature make the space activity really closed to the society. A much larger part of the population in India knows well the ISRO activities and uses their expertise daily. Yet, the Indian startups ecosystem is the second largest after the Silicon Valley.

China invests massively in every space domains and more than catching the occidental advance, prepares its industry to rule the commercial war against the US. The economic efficiency has not been the ultimate goal yet but shall prevail in the near future (Erwin, S. 2018). Concerning the International Traffic in Arms Regulations (ITAR) issue their stringent presence in the global space market intends to offer a complete turnkey space solution from the satellites manufacturing, its launch and the associated services.

Space demand evolution for the near future

Current trending space markets are: space mining, IoT, autonomous vehicles or space tourism. But their potential profitability shall be demonstrated and may not be a short or mid-term solution.

However, one can say that the current main demand for space remains telecommunication, geolocalization and observation services. Science activities through Agencies budgets is still maintained at an important scale as well.

Launch price reduction and service flexibility and availability improvement

With the achievements of SpaceX, the launch sector industry is drastically shifting to a price reduction objective going with a more versatile and flexible launch service. Falcon 9 and Falcon Heavy catalogue prices are pulling the competitors to fit their offers. Ariane 6 for Europe, H3 for Japan or Russian launchers are targeting a launch price reduction and improves their launcher concepts to be more attractive in the launch service market (Inomata,R., 2017; Henry, C. 2018) . However, the leverages to reach the new target costs are plurals and each one has not the same degrees of freedom to reach it. Launch cadences, institutional open or not markets sizes,, the organisation, the launcher design and technology, including reusability aspects are the main leverages to play a role in this competition. Blue Origin, as a new entrant has the ambition to compete and adds up to the list. What is sure for the near future is that the offer will largely be more important than the demand (Mosher, D., 2018).

Mass production of small satellites and constellations

It is then evident that there is a particular trend towards small satellites, this trend is no longer considered as university students projects but also an industry need while the demand for large geo satellites might diminish with time. The current interest is also towards constellations of small satellites changing drastically the economic and technical challenges.

This different mind-set is expected to change the way the industry performs, from a satellite-unique project approach to mass production. This kind of companies (there are also spaceX, telesat, SES, etc. moving forward) are asking their suppliers to quote for hundreds or thousands of the same spacecraft components and therefore suppliers are more focused on automatized production and cost and time effective development processes.
Legacy space entities are responding to this shift as fast as possible, for example, Honeywell Aerospace has established an incubator within the space department. This incubator is called the greenhouse is largely meant at speedy developments with an outlook to mass production of parts aimed to the constellation and small satellite markets.

A small launch service industry?

The owners of satellite constellation or small satellites would want to determine their own orbit instead of tagging along with a launch for larger satellites and would then need a dedicated launch for satellites replacement. This is especially relevant for the fact that constellation will mostly operate on low and medium earth orbit for which most of the current launchers are ‘oversized’. This leaves a market opportunity for micro launchers and naturally reusable launchers to also decrease the costs per launch for small satellites in a dedicated mission.
Some emerging space industries are developing solutions with the help of their agencies (Romania, Spain and Portugal to name the European actors shows). However dozens of microlaunchers are currently been developed and only few actors may survive (Dy, D.,Perrot, Y., Pradal, R., 2017).

Emerging economies

The emerging space economies may have today two big responsibilities: support developing the economy on their own country as they provide valuable contribution to other's industries technologies and resources. It increases internal demand while leveling up to the achievements and autonomous competences of the legacy space economies (Sinha, A.,2015).

In India, the government is strongly supporting the development of the space Indian sector and in result of this development, more and more private space startups are emerging in following the worldwide demand and assisting the progress of outer space exploration. (Sharma, D. C, 2017).

The main leverages for a new space economy

- Maintaining or increase institutional investments in Space

In the last decade, new private actors have emerged challenging the traditional space economy through low cost models and new space programs. The space public investment has lived growth-stagnation phases since the 80s and the last stagnation phase starting the last decade is an additional driver to increasing private-funds-seeking-actions. (Bochinger, S., 2015).

- Create and believe in new markets especially autonomous vehicles and IoT
- Surfing on the telecommunication broadband demand

The demand of broadband continues growing exponentially as the cost of access to space decreases. Therefore, telecommunications market continues to present one of the best opportunity of space investment, even if a considerable market share of the broadband supply will remain terrestrial. Since the data/broadband demand increases, space telecommunication sector necessarily provides access to under-covered regions (Stanley, 2017).

- Expand space solutions and data to society

In this frame, emerging economies such as India, may play an important role helping establishing a new economy since they are culturally focusing on simplifications of processes, cost reduction and space democratization.

- Follow and pull the launch price reduction and more generally decrease the non-recurring cost by simplifying procedures and encouraging innovations
- More focus on small satellites industry, since it decreases the hardware and launch cost and enables simpler missions.

The Earth observation largely performed only by big satellites formerly can now be expanded by coverage and occurring frequency thanks to CubeSats or small satellites constellations.

- Implement Space passion to the society

It should be noted that USA is more ambitious for space manned-exploration than European countries. The disruptive visions of Musk, Bezos or Branson anticipate the future of a humanity living and making business, in orbit, in Mars or on the moon. They all witnessed the first US footsteps on the moon and they are all native or adopted Americans, embodying the pioneer spirit. They think that the US shall keep the hegemony in space and, most important point, they are billionaires with a big space appetite. They also know how to conjugate their visions with their current and future business models. In Europe, many of these precepts are not fulfilled. European billionaires are not interested in space and may not be so interested in technology as it once again depends on political interests.

- Simplify regulation and space interlocutors

As Europe is a multi-country organization and not federal, it does not have an equivalent of FAA regulations and, even if ESA does coordinate most of the European space activity, there are too many “small” interlocutors to speak with, when in the USA, you can knock on the doors of one big NASA with a budget, infrastructures and patents to share.

- Promote multi-disciplinary projects and encourage new entrants to the space project team

Except for the main space Agencies and original space companies, all space actors had once been a new entrant to the space project team. SpaceX, strongly supported by NASA development contracts, now claims to lead the innovation in launchers reusability and launch price reduction. One witnesses now that many space agencies have encouraged the birth or the development of a lot of new space actors. Different goals can be cited: space race, technology maturation, innovation acceleration, science diffusion and improvement, access to space cost reduction and lowering the entry barriers, etc. NASA has especially been always at the forefront of this enterprise, but other worldwide space agencies have walked in their footsteps and are not outdone.

Different leverages can be used to promote multidisciplinary project achievable for new entrants: Funding, make at disposal resources, data, licenses or share science, knowledge, technologies. The availability of some infrastructures is also a key resource for many new entrants and the certainty of selling the service or products to the Space agency as a first customer helps to consolidate its business plan. Space agencies also facilitate a space activity in a secured and regulated environment frame. The bottom line is that innovation is always supported. It has helped the emergence of disrupted innovation in term of technology, organization or business models.

To name but a few, the young initiative “Federation – open space maker”, launched in 2017 by CNES can be highlighted since it is not only business-oriented. It has the ambition to create and support an ecosystem capable of fostering new, collaborative space concepts by giving the right conditions for nurturing open source space projects in fablabs, makerspaces, hackerspaces and other collaborative creation structures and involving citizens in building our future world with open hardware.

The increased number of investment funds dedicated to startups creation or development begins to be noticeable in comparison to the established space programs endowment. ESA Business Incubation Centers, created in 2000, have supported more than 650 startups and more than 150 new start-ups are taken in yearly.

7.6 Conclusion

This report presented the challenges faced by multi-disciplinary teams working on space projects between new space and legacy space economies. The overview of the current status has been carried out by:

- highlighting and explaining differences between legacy and emerging space players,
- describing the characteristics and prevalence of multi-disciplinary project teams,
- contextualizing the problematics in a specific economic environment.

The goal was to identify areas and methods of optimized collaboration between team members working on the same projects from either emerging space economies or legacy space economies, ensuring ease of integration of first team space project team members.

Therefore, the report also proposes the solutions (including project management methods and economic leverages) that might help bridge the gap between legacy players and new entrants from emerging space economies. This has been done by merging and cross-checking literature with interviews to top managers and with experience of team members.

Summing up, five levers can be used to improve efficiency of multidisciplinary projects.
The minimum viable multidisciplinary capacity is defined in terms of:

1. multidisciplinary team, with minimum set of roles and skills depending on the project scope and including other stakeholders (product owners, customer representatives, scientists…)
2. process definition, which formalizes the method used for project management and therefore the flow of activities and information.

Concurrent development of the solution, agile and robust communication and data exchange are also of paramount importance. For this reason, it is worth highlighting that there are additional assets which can enable or improve the work of a multidisciplinary team on a given space project:

3. information/data model (product definition)
4. IT hardware-software infrastructure (network and tools)
5. facility (physical or virtual)

Deciding upfront on the practical details of cooperation among different players, maybe with stronger (legacy) players offering tools and infrastructure to emerging players, can ease integration of team members.
The leading entity in project management (agency, prime contractor etc.) has great responsibility in shaping and setting up points 3 to 5 to fully exploit the added value brought by working with a multidisciplinary team, while at the same time mitigating its adverse effects.

The following recommendations are made:

1. Project management and risk management methods:
    - Consciously act on all five levers for improved efficiency and reduced risks (team, process, data model, IT infrastructure, facility).
    - Create the project team with the open goal to include all the different stakeholders in the process (project sponsors, domain experts, customers, users, architects and engineers). It is important that all the different interests are represented.
    - Build diverse and multidisciplinary teams to able to bring unique added value to project results.
    - Use concurrent engineering methods to fully exploit the value of multidisciplinary teams.
    - Create shared platforms to boost information availability and improve coordination and awareness between team members.
    - Adjust the level of project management overhead according to project phase and project scope (importing agile methodologies from other fields).

- Deviate from the standard phase-by-phase development process, if possible, or find new ways to optimize its evolution and duration while still complying to its structure (embedding concurrent engineering and agile sprints in the classical “V-method”).

2. Ways to leverage the new space economy:
    - Push forward cost reduction: reducing launch service cost, development costs, considering the advantage of mass production and small satellites, sponsoring usage of COTS components (to improve budget sustainability).
    - Legacy space players to change the paradigm based on which new contracts are assigned to emerging players (by leveraging their core skills, not by assigning corollary tasks such as GSE development).
    - Agencies and companies to foster educations and experience in management and system engineering class in the emerging spacefaring nations.
    - Agencies to develop a commercial and profitable environment by supporting the intervention of new entrants (fundings, transfer of knowledge, availability of in-orbit demonstration opportunities, support initiatives for R&D activities).
    - Agencies to allow and support commercialization / privatization of space initiatives, e.g. partaking in public-private partnerships to ensure long-term sustainability of space business.
    - Agencies to take mitigation measures to protect space industry from impacts caused by political changes.
    - Legacy space players to centralize their investment in the development of platforms so as to promote new entrants in the space industry as a drive for global economic development of this sector.

8. Topic 5 Knowledge Management Practices

8.1 Introduction

Knowledge is an understanding gained through experience, study, training, or sharing, which establishes a basis for judgment and the potential for action. Knowledge only happens in the minds of people and it involves both abstract concepts (such as truth, beliefs, judgements, mental models) and practical concepts (such as methods, skills, experience, know-how). It may be codified and formalised through records (explicit) or not (implicit or tacit) (ESA Knowledge Management Policy, 2017). Hence, Knowledge Management (KM) is a group of practices ensuring the identification, capture, preservation and sharing of knowledge in order to continuously improve the effectivity and efficiency of a given organization in pursuing its mission. In this report, the term "organization" will be used to similarly talk about an agency, a company, a start-up, etc, if the context does not require a clear identification.

This report especially focuses on defining the KM best practices, tools and methodologies in today’s aerospace sector and providing concrete recommendations on KM to enable Knowledge Capturing (KC) for the next generation workforce.

This topic comes from the clear fact that, nowadays, the community of experts working in aerospace industry is getting older, increasing the risks of not maintaining the level of expertise in an organization. This raises the need to transmit the knowledge to the younger generation (Christiaan D. Stam, 2009).

In a first section, the applied methodology in the preparation of this workshop is presented. Then, a focused reading of previous IPMC Young Professional workshop reports as well as a brief overview of relevant documents exploring the KM practices is performed through a general literature review. The following part is the core of this report. It contains the results of a survey on KM, created and distributed to a wide audience in all kind of organizations. The results are then interpreted in order to conduct a gap analysis and extract concrete recommendations on KM. Finally, as a mind opener, an insight on creative aspects in KM as well as the influence of Artificial Intelligence (AI) and Model-Based Systems Engineering (MBSE) can have on KM, will be briefly discussed.

8.2 Former IPMC Workshop Results and Literature Review

The objectives of the 2016 working group on Knowledge Management in the aerospace sector were very similar to this year's topic. The goal was to identify and assess the existing KM practices in the aerospace industry and propose recommendations for the future. The 2016 group performed 36 interviews mainly in public organizations and, with less success, in the private sector, since they appear to be more conservative and less willing to divulge information on their KM practices. The results mainly focused on Knowledge Transfer (KT) as it seems to be the central problem in keeping and sharing the knowledge through different workforce generations. Here are the main outputs of the IAF (2016) study:

- A majority of interviewees said that a mentorship program is key in KT.
- A large variety of KM is present between organizations. It goes from documents, internal websites, to training presentations, lessons-learned reviews and mentorship programs, besides many others.
- KT is very important but experienced interviewees stated that more than the "Know-What", the "Know-How" is even more important to teach to the new generation.
- To share knowledge can be very difficult in big international teams working on a project.
- People learn effectively in different ways. This means that an organization should not focus only on a single type of knowledge transfer.
- Having the best KM practices is good but you need to have motivated employees willing to extract their knowledge and format it (prepare documents, presentations,...) in order to have an effective KT. How to motivate them is a key problem.

From these results, clear recommendations were stated by the working group:

- Develop training materials such as videos, presentations, etc in addition to the usual written documents.
- Whatever organization should have a structured KM section with knowledge management experts in order to create and work on clear database and transfer practices.
- To ensure an effective KM and KT, all employees need to be aware of the knowledge resources available in their organization and how to access them.

These different points listed above give a big picture of the KM state in the aerospace sector. The present document is performing a wider survey, reaching agencies as well as the private sector through big companies and start-ups. The number of collected replies allows to perform a quantitative, and brief qualitative, study on KM in the aerospace sector.

Besides these various facts about KM, one needs to think about the importance of KM and subsequently about what kind of knowledge or which specific knowledge should be captured and transferred. It's obvious that KM does not mean managing everything that is known in an organization. A lot of knowledge is useless, or too costly, for individuals or their organizations. This is the conclusion of Quintas et al. (1997) which raises the question: How can we create and focus on certain knowledge for certain purposes to keep the maximum learning efficiency?

8.3 Research

Following the exploration of the past IPMC reports, a wider survey with precise and simple questions has been conducted to explore the current state of KM in Space Industry. Corresponding questions were constructed in a way that statistical/graphical studies could be performed (i.e. rating or multiple choice questions). In the idea of a Gap Analysis, these questions are useful in determining the Current State of KM. Additional open-ended questions were added to the survey in order to explore the Desired State of the Gap Analysis.

In 3 weeks, 152 participants took the survey from which 116 complete and relevant answers could be analysed. From the open-ended questions only, the following figure was created showing the most wanted features in KM.

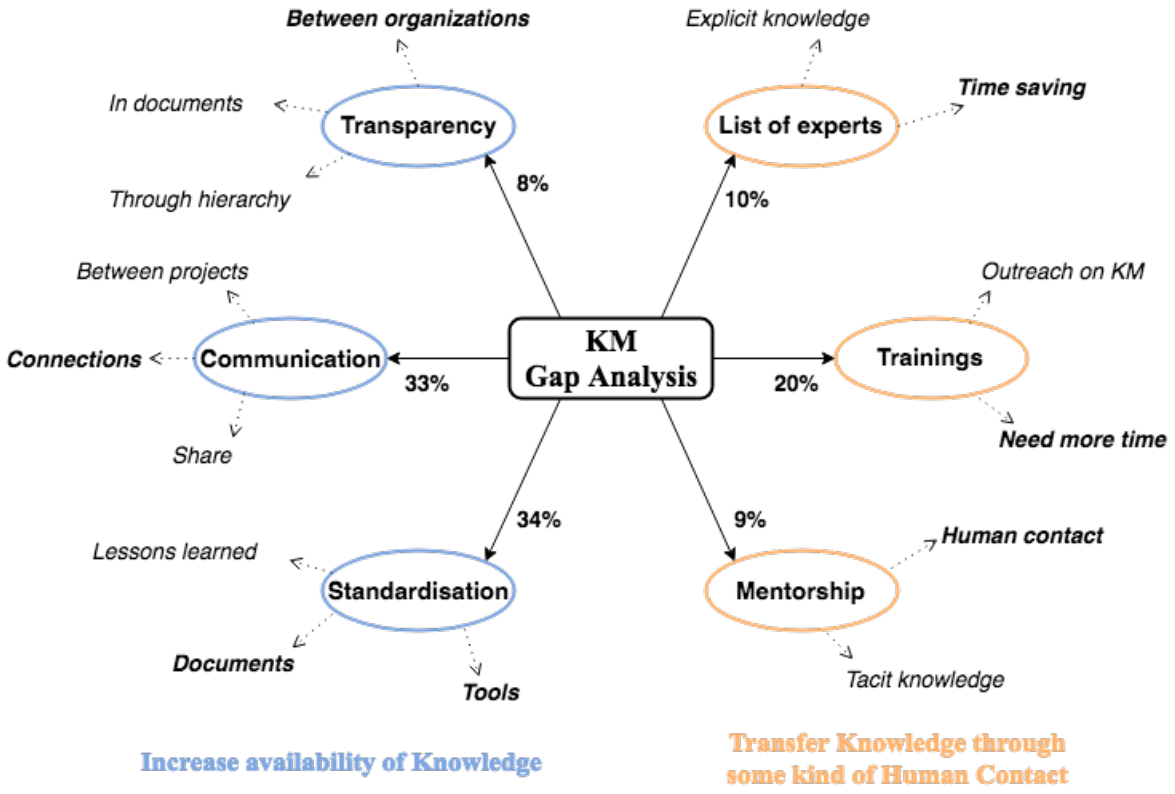

Figure 2: Gap Analysis based on the 116 relevant answers from the survey. The percentage is the approximate occurrence of each subject in these 116 answers.

The above figure shows the biggest gaps that currently exist in KM in the space sector. Each answer given by a survey participant has been carefully read and classified. Six main gaps were identified: Standardisation, Communication, Trainings, List of experts, Mentorship and Transparency. Each survey respondent could give more than one answer corresponding to these different gaps. The occurrence of each gap within the 116 survey answers is shown by the percentage on the arrows, i.e. these percentages correspond to the number of time each gap was mentioned in the pool of participants.

Looking at the big picture, these six gaps show mainly what has been found in the past IPMC Workshop reports and in the recent literature. Everything can be summarized by the need to increase the availability of Knowledge and the need of more human contact in order to transfer knowledge in an efficient way.

Based on these results and on the rating and multiple choice questions from the survey, a few interesting points were raised. In addition to the survey answers and in order to have a better view on these points, additional interviews were performed with people which agreed to do a follow-up of the survey. The next sections will detail these hot points and present results from the survey.

Accessibility of Explicit Information for Young Professionals vs Non-YPs

YPs find it much more difficult to access explicit knowledge than their Non-YP colleagues. This is less so the case for tacit knowledge.

Concrete problems to be tackled:

- YPs are commonly newer in their organisation than their Non-YP counterparts, and as a consequence have less network, knowledge of the organisation structure, and knowledge of and access to databases.

Discussion:

The survey investigates the ease of finding explicit and tacit knowledge. This goes somewhat counter to other investigations into the ease of accessing explicit and tacit knowledge, although there is no actual data from other studies. Where other studies may find that tacit knowledge is harder to acquire than explicit knowledge, the survey results show that tacit knowledge is easier to find than explicit knowledge. This may be explained by the nuanced difference in the use of the words *acquire* and *find*.

The finding that those with less experience in an organisation have more problems navigating the structure of the organisation is not an extraordinary finding in itself. However, the fact that one of the clearest findings of the survey analysis, it being issues with identifying sources of explicit knowledge, speaks for stronger focus on a seemingly trivial problem. The aerospace sector could motivate and remind their experienced employees to be more conscious about mentoring and sharing tacit knowledge by generally bringing the need and request for mentorships up for discussions. Maybe initiating programmes in which YP's take over responsibilities from experienced employees step by step as an assistant, as an alternative to mentorships.

Further, making the structure of information in the organisation more easily navigable, would make it easier for all, not only YPs, to access the necessary knowledge. It is clear that databases are the most widely available, and in survey comments and follow-up interviews it was widely commented that the ease of finding documents would improve the experience as a newcomer greatly.

Concrete suggestions:

1. There should be a focus on integration of YPs, to facilitate access to network and internal structure of the organisation, such as mentorships and placement rotations.
2. There should be unified tools to access explicit knowledge. E.g. one, easily maneuverable database, or a set of databases with documents separated in an intuitive way.

Accessibility of Knowledge in Agencies

The accessibility of knowledge and data in space agencies was investigated in comparison to non-agency organisations. Agencies in space industry are of special interest since the most experienced ones look back on a broad history of lessons learned. They have potential in building databases and platforms which embrace the continuous improvement of KM.

In the conducted study, it was possible to collect information about the affiliation of 52 percent of the participants. Of this group 46 percent stated to work for a space agency and 54 to work for industry, consulting firms and universities. Comparing the results of how these two groups rate, the handling of knowledge management at their workplace shows that the average rating (1 being very poor and 10 being perfect) is very similar (Agency/Non-Agency: 5.4/5.6), but the variance is lower for Agency staff (Agency/Non-Agency: 3.1/4.5). Agency employees give knowledge management at their workplace a mediocre rating while non-agency employees tend to give a very high or a very low rating. The average rating of 5.4, however, outlines that knowledge management at space agencies should and can be improved.

The agency employees who took part in the survey and additional interviews indicate that they perceive a lack of guidance towards available information. Structured information, such as databases and lessons learned exist but they are hard to find and/or access. Because there is an abundance of structured data in agencies, it appears that a lack of central signpost and easy access are weak points in their KM. From additional interviews with agency staff, it became clear that a huge variety and depth of knowledge, arising from many years of programs and kept in unstructured ways and forms, can be incredibly difficult to navigate. It was also noted that knowledge sharing between different programs and centers is difficult because each program and center can be siloed and work largely independently from each other. There was a strong desire to bridge this gap and have knowledge shared between different programs and centers.

Concrete problems to be tackled:

- In agencies: No central information and knowledge repository nor awareness of the available K.
- In agencies, projects are highly independent and it makes knowledge sharing difficult.
- Inequality in awareness on available KM tools.

Discussion:

In general, it became apparent that the existence of information and databases does not pose a problem for space agencies. On the contrary, there seems to be a vast collection of information from decades of space programs. However, through conducted interviews following the survey it became clear that many agency staff feel frustrated with the lack of guidance and accessibility to internal reservoirs of knowledge. On this level, the rather mediocre rating agency staff gave knowledge management at their organisations can be explained by the dissatisfaction caused by spread-out databases without a central point of guidance and the bureaucratic way the data is administered, which makes it difficult to access it. On the upside, these shortcomings can be improved easily and significantly by implementing a central sign-post to all available information (such as sharepoint, internal wikis, google scholar like tools etc.) and facilitate the access to existing databases.

Concrete suggestions:

1. Create an organization-wide central online portal (similar to sharepoint, intranet or others) to collect all possible documentation and making it available to anyone in the organization as well as enhancing the transparency.

2. Invest in the development of central portals that are tailored to enhance transparency, easy to use and surpass existing commercial options.

3. Proper training and courses on pre-existing KM tools.

Knowledge Management in Start-ups vs other Organisations

Another significant part of the responses from the survey is the fact that start-ups are rated lower in their overall knowledge management than other organizations, but it was not clear from the survey results as to why that was the case. The topic team contacted a survey respondent to interview who self-identified as working in a startup with less than 400 employees and that was founded less than 10 years ago.

From his personal experience, he noted that the major reasons for the lower overall KM rating in start-ups were a general lack of resources in KM, difficulties in detecting direct financial benefits and priorities in other areas. He also mentioned, that it might be easier to contact responsable people in a start-up for a direct exchange of knowledge and therefor KM seems not to be a significant enough problem to be taken care of.

Concrete problems to be tackled:

- Clarifying what are the benefits of KM for start-ups?

Discussion:

The main principles (valuable information and knowledge) for start-ups are yet to be identified and established. This is why more weight on creativity and ideation could potentially mean the most benefit in KM for start-ups. Using ideation tools like e.g. cloud-based innovation platforms or organizing creativity workshops for providing different problem solving tools could boost the necessary creativity in order to generate valuable knowledge.

It could be very interesting to implement a KM system in the earliest phase of a start-up company for comparing the emerged quality with the quality of those KM systems, which were developed in more mature states of agencies. In case the quality is raising significantly the earlier such a KM system is implemented, it could be identified as a clear and distinct source of improvement for start-ups.

Concrete suggestions:

1. Give workshops on problem solving tools for generating knowledge (which in addition motivates human contact)
2. Create list of experts
3. Develop cloud-based innovation tools

List of Experts & Mentorships

Figure 3 shows the occurrence of the available, in blue, and most wanted KM tools, in red, extracted from the 116 most relevant survey answers.

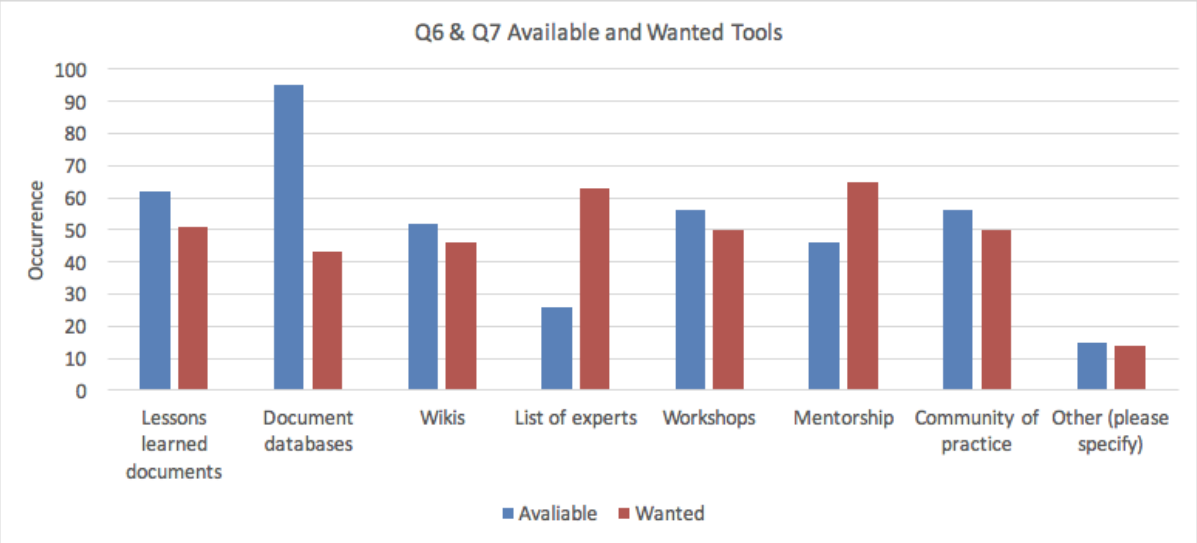

Figure 3 : Occurrence of "Available" and "Wanted" KM tools among all survey participants.

As expected, the most available tools in KM can be found in document databases and lessons learned documents. However, the need of standardisation of these documents is clear.

On the other side, the most missed and wanted KM means rely on human contact with the need of more mentorship programs and list of experts.

Concrete problems to be tackled:

- Lack of human contact for efficient knowledge transfer. Most importantly, mentorship programs and list of experts are missing the most.
- Current KM tools appears to be to focused on wide variety of documents without a clear schematic and standardisation.

Discussion:

First of all, human contact is a key part since knowledge results from a learning (or studying) process which is more efficient when the learner is guided by a teacher. A mentorship program seems to suit very well this lack of human contact. However, the mentor needs to have very good teaching skills to have an efficient knowledge transfer. This is why, aside the development of an organization-wide concrete mentorship program, trainings on "how to teach" should be given on a regular basis. These trainings should be mandatory for mentors and highly recommended for anybody else. In summary the human contact, if well organized, can lead people in an organization to embrace a more open culture and improve interpersonal skills. Also, to further increase human contact, communities of experts (or list of experts) can help every single employee, not only YPs. This would be useful on an everyday basis if a (tacit) knowledge is missing.

On the other end, an easy way to transmit information goes through documents. However, to transmit knowledge through reading materials is not trivial. The survey and interviews show that all platforms and softwares aiming to centralise the information and the knowledge are often messy and not user-friendly.

Mentoring programs are most successful when the matched mentor pair make a real connection. Through interviews the following best practices for setting-up a mentoring program were found:

- Establish a formalized program that continues for nine months to a year.
- Set the context and expectations for the program - that the mentor will provide coaching, connections, input on organizational culture, tacit knowledge and advice for problem solving - not just advice for career advancement.
- Provide tools and training monthly - bring all mentor pairs together to learn about critical thinking, knowledge capture and sharing, creativity and innovation etc.
- Assign projects that will benefit the organization for mentor pairs to complete.
- Remember that mentoring is a two-way street. Mentees can ‘mentor-up’ with knowledge they want to share.

Concrete suggestions:

1. Give trainings on "how to teach" to people;
2. Develop a mentorship program with experienced people and good teaching skills;
3. Create list of experts available to anyone in an organisation;
4. Create standard ways to express information and knowledge in a more interactive learning process.

Collaboration and Communication Tools

The biggest gaps in Knowledge Management relate to communication (33%) and standardisation (34%) of documents and tools.

Main concerns regarding communication point that it is challenging to have a clear idea of what competences and experiences people may have in an organization and how to contact them.

Having a more defined picture of these points would allow collaboration between projects, resulting in a sharing of knowledge and therefore a gain of time.

Additional interviews indicate that a large amount of documents is available in most organizations, but that they are quite difficult to access. Centralization tools are sometimes available, but it seems that they are complex to use and disorganised. Combined results show that document databases are currently the most common form of knowledge in organizations, there is therefore a strong potential for improvement in the standardisation process.

Concrete problems to be tackled:

- Lack of communication/connection between people
- Poor standardisation of tools and documents

Discussion:

Communication is a key part of any organization willing to develop complex projects. Most of the time, facing a problem in the everyday work leads to communication, either through discussions with more qualified people or through the reading and studying of documents and papers. Therefore, it seems crucial that anyone in an organisation should know where to find the right people to contact or the relevant documents to read.

As expressed by a few of the interviewees following the survey, people may want to find their missing knowledge or information on their own due to the fear of disturbing others. This problem can be solved by the creation of a list of experts (volunteers) who can be reached for any kind of question in their field. Furthermore, it raises the question of the communication tools to use: emails, open-chat platforms, forums, phone, etc.

Besides the direct contact between employees, a large amount of documents are usually available. However, as explained previously in this work, most of the time, all those documents are not easily reachable and spread on multiple servers or archives. Having a centralized tool containing, in a transparent and standard way, all kind of documentation available in an organisation can greatly increase its effectiveness by making knowledge easily available and by saving employee's time looking for answers. One can even think about a centralized tool using search engines based on AI to deliver the most relevant document according to the user's query and preferences.

Concrete suggestions:

1. Mapping of competences
2. Improved communication tools/informations
3. Better standardisation of documents
4. More efficient database centralization tools

Human Interactions

One of the most recurring needs expressed on the survey was the need to increase human interaction in knowledge management and shift from impersonal tools (database, wiki) to more interpersonal tools (workshops, trainings, communication tools, direct exchanges with experts).

However, workshops do not seem to lack in Knowledge Management, even though demand on human interactions has been expressed, as well as a better identification of experts within companies. Training sessions are highly demanded and approbated but seems to suffer from a lack of funding. In addition, the expressed needs of knowledge sharing interpersonal tools may suggest a will to rebalance tacit knowledge over purely explicit knowledge.

Concrete problems to be tackled:

- Underrepresentation of human interactions in knowledge sharing.
- Lack of training fundings.
- Imbalance between tacit and explicit knowledge, linked to companies' preference for databases.

Discussion:

It is clear that for companies, databases and wikis are the most efficient to implement, in terms of cost. However, only explicit and factual knowledge can be effectively transferred via those means, and valuable tacit knowledge, personal experiences, and advices may be filtered by company's preferences for these tools.

Efficient and low cost solutions to increase human interactions exist and are highly appreciated. The Sweden Fika Break Time is a way to take a break that enable people from a service or different services to interact and connect. The discussions do not revolve uniquely around work and companies that have adopted the Fika break time usually dedicate a room for it. In addition to human interactions and both explicit and tacit knowledge transfer enhancement, Fika break times contributes to relaxation and integration within services. As exemple, the Sweden Space Company has a permanent video-conference running between its two primary break room in Stockholm and Kiruna.

Concrete suggestions:

1. Create "TEDx" like talks given by experts to share their personal experiences in an informal way, to transfer more tacit knowledge as well as identifying experts.
2. Trainings and Workshops are aprobated and should be subjected to more investments.
3. Privilege human interaction, with expert, with other service, by increasing the exchange people may have between one another (for example, use of synchronised break time and common areas between different services, creating dedicated rooms to enable informal discussions, etc...)

Additional Best Practices

The last question of the survey was deliberately left open-ended, asking directly the surveyed professionals what solutions may improve KM in their company. It was intended to allow professionals to provide their personal suggestions regarding the KM policy to which they are subject. Moreover, available and wanted KM practices, participants could enter new practices not present in the multiple choice list. Only a few participants chose to write down something new but the answers were interesting.

The following list is a summary of all the suggestions expressed, whether in the survey or during interviews, that are not already covered by previous topics but where cited more than once.

Professional suggestions summary:

- User friendliness of intranet and KM tools
- More performant databases
- Clear roadmap of recommended competences, trainings or experiences needed to access some positions
- Online courses and video trainings on specific subjects like lessons learned
- Lectures given by employee on free subjects related to work or not
- Increase funding for advertisement on KM
- Development of AI as "work assistant" in order to quickly find more relevant information and knowledge.

8.4 Future in KM

In this chapter the different aspects of the creation and innovative management of knowledge, arising from the process of solving problems and reaching out for new achievements like those in artificial intelligence are highlighted.

Creativity/Ideation in KM

Big milestones, like the mission of making humans an interplanetary species and travelling to Mars, are actions which force us to solve problems no engineer was trained for. This process, like any other pursue for innovation, requires creativity. Inspired by Albert Einstein's philosophy that "logic will get you from A to B, but imagination will get you anywhere else", it is possible to introduce the notion of creativity. It is essential not only to allow, but to actively promote creativity in order to achieve groundbreaking and vivid innovation.

One possible approach to do so is called "Convergent Divergent Thinking". In a study conducted by Dijksterhuis et al. (2006), participants tend to make the best decisions when the given information is limited and the decision making process happened in a liberated and conscious way. On the other hand, they were more likely to choose the best option in a complex situation, after a period of distraction. Other results in neuroscience (Kasof, 1997; Ansburg and Hill, 2003; Carson et al., 2003; Fink et al., 2012; Young, 2018; Wegbreit et al., 2014) suggest as well, that being creative in finding solutions 'strategically' versus 'through insight' is associated with different neuro-cognitive processes: Solving through insight is neurologically more connected to broad and non-focused attention, or 'divergent thinking', whereas solving through analytical strategy is connected to a narrow focus or 'convergent thinking' (Kasof, 1997; Ansburg and Hill, 2003; Carson et al., 2003; Fink et al., 2012). Convergent thinking describes the process of discrete, systematic and focused problem solving: Out of multiple possibilities in a distinct framework, the task is to come up with the precise best one. On the other hand, divergent thinking (also referred to as "lateral thinking", like e.g. "brainstorming") captures the unfocused and creative process of problem solving where unexpected connections are drawn.

Various applicable techniques for enhancing the ability of divergent thinking exist. E.g. “Divergent Modifiers” by the Marconi Institute for Creativity (Agnoli et al., 2014, Corazza et al., 2013), which is implemented by the model “DIMAI”, describing the creative thinking process, based on five mental states: Drive, Information, Movement, Assessment and Implementation. This technique gives a guideline on triggering a broad way of thinking by evaluating an idea w.r.t. any system of values, in a structured way.

Further, in the framework of this report the Design Thinking will be introduced. It is an alternative methodology for resolving a broad scope of problems of the design process. Design Thinking commonly uses brainstorming to leverage divergent thinking and explore a wide variety of solution concepts before converging via interpretation and experimentation.

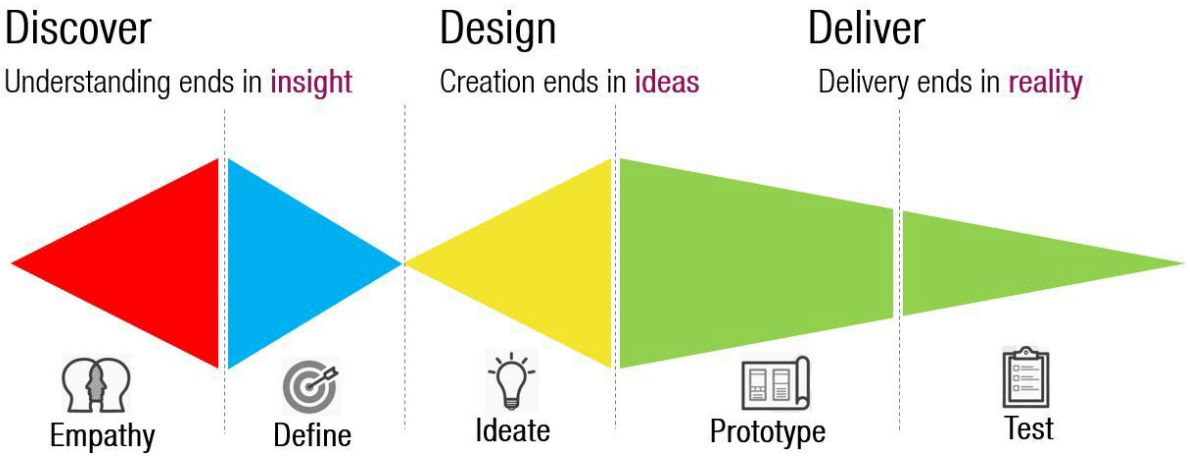

Figure 4: Design Thinking Process Depiction

Design Thinking can be used within the context of KM in order to define problems whilst keeping the focus on the value it brings to the end user. It enables Knowledge Management processes to both understand and take into account the inherent human element and to define the problems at hand that KM may be trying to solve within a specific context. Many aspects can be brought together (especially people and processes) via Design Thinking in order to reach effective decisions.

Model-Based Systems Engineering (MBSE) in KM

As the world increasingly turns to easily usable digital tools, there has also been a shift in the Systems Engineering world to a more versatile way to share data. Model based systems engineering is a new systems engineering methodology that employs a domain model to define the system and exchange information between collaborators. These models can be used in a variety of different areas – requirement management, behavioral analysis, verification, architecture synthesis, concept of operations, etc. and links together existing MCAD, ECAD and other design models (Hart, 2015). It differs from the traditional systems engineering approach in that it does not rely on external documentation that can take significant time to update and distribute to collaborators.

As MBSE is primarily a method of data transfer, it was investigated in this paper as a possible best-practice for Knowledge Management. While MBSE has been applied to many space projects to date, it is still a relatively new process. There are many advantages to MBSE, including:

- Models provide an efficient way to explore, update and communicate system aspects to stakeholders, while significantly reducing or eliminating dependence on traditional documents (Scaled Agile website, 2017)
- Quickly implemented changes, unlike traditional document-based approach (Scaled Agile website, 2017)
- Reusability, Traceability, Reliability, Consistency
- Ability to query the model, and then automate document generation from the model as needed
- Less subject to interpretation compared to explanatory text of documents

MBSE could be advantageous to Young Professionals specifically in that once team members are trained in the methodology, MBSE offers the possibility to introduce new team members faster and more efficiently. When information is stored centrally in the model, less time is needed to locate that information. The system is also digital, which could be preferred by Young Professionals. The speed of MBSE is also an advantage for YP, who are often eager to quickly implement changes on a project – the project process becomes more organized and fluid, rather than the more stagnant document-based methodologies.

It is clear that if used correctly, MBSE can be a powerful tool for space projects and programs. Many companies as well as space agencies consider MBSE the tool of choice to tackle the complexity of space systems development, which is why it is integrated into space projects with increasing frequency. However, it is not tied directly to the KM community in its traditional sense. Traditionally, KM uses practices such as lessons learned and case studies to transfer knowledge, which are compiled in some sort of database. There is currently no evidence for MBSE providing a way to draw upon these documents or databases. In one of the few scholarly sources on the topic, Gardan and Matta say that their study "observed that knowledge management is rarely addressed through MBSE in order to improve the workgroup management and their intellectual production" (Gardan & Matta, 2017) .

So could MBSE still be used as a best practice in KM? Chances are good that MBSE will contribute to KM, when it is utilized as a tool like lessons learned or case studies. It is also worth outlining that MBSE in space engineering is still very much in its infancy. First it has to overcome the usual obstacles (interface standards, software standards, reluctance etc.) and it has to be used widely enough in space industry, to make strong predictions about its influence on KM. In the survey conducted by this group, there was a strong desire among the respondents to be able to share data more freely between projects. This group would like to suggest sharing MBSE models between working groups to assist with knowledge transfer. This could be done by compiling a directory, database or "wiki" of sorts that would link workers to different MBSE models so that they could be viewed by those working on other projects. MBSE is a powerful tool, and if it can be incorporated successfully, it seems like it could significantly enhance KM.

AI in KM

Artificial Intelligence (AI), as stated by the Encyclopedia Britannica, is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings, i.e. that can adapt to changing circumstances.

By being able to mimic "cognitive" functions that humans associate with other human minds, AI could potentially be implemented at all steps of the KM Cycle to perform the following functions, i.e: Acquisition, Organization, Dissemination, Use, Share and Creation of knowledge. The main idea is to use AI to convert knowledge into database and then connect people with this database through intelligent agents.

Analyzing in more detail the gap between the tools currently in place and the tools that people would like to use in their organisation, the development of the following AI applications are suggested:

- Mapping tools: to answer the need for more human contact and experience expressed in particular through expert lists and mentorship.
- Communication tools: to connect employees with each other once competencies have been identified.
- Lessons learned documents generation tools: that can provide some documents highlighting the main figures, methodologies and issues extracted from past projects.

All these tools could be grouped into a single tool, which would also address the issue of disorganization in Knowledge Management tools and practices, which can be a real barrier to their use. The resulting tool could then rely on AI in conjunction with more traditional and already existing search engines. The future of KM might therefore be a human-machine interface based on language and text (processing and recognition) answering employees questions, performing actions and providing them with appropriate and personalized content: expert contact or applicable lesson learned documents. Some similar projects are already studying the integration of AI to support concurrent engineering sessions (Murdaca F., Berquand A., Riccardi A., et al. (2018), Artificial Intelligence for Early Design of Space Missions in Support of Concurrent Engineering Sessions), precisely where knowledge sharing is put at the centre of the design process.

Nevertheless, some limitations can be identified and need to be highlighted:

The nature of Knowledge is divided into two categories: Tacit Knowledge (TK) and Explicit Knowledge (EK). As per definition, part of the TK, especially Collective Tacit Knowledge (CTK), the knowledge embedded in culture and society, is impossible to retrieve.

Humans have the capability to process multiple viewpoints into a single viewpoint, taking into account their own experience and feelings. This dynamics of cognition is a black box and cannot be computed, as machines do not experience events or emotions. As a consequence, it is currently impossible to produce a physical theory of the mind to obtain a fully functioning cognitive computing system. This is particularly a limitation concerning the development of tools capable of generating lessons learned documents.

8.5 Conclusion and Recommendations

Based on the survey and interviews performed, it resulted in the following suggestions.

Human connection:

Develop a mentorship program with experienced people, capable of building relationships and with good teaching skills

Create “TEDx” like talks given by experts to share their expertise as well as personal experiences in an informal way, to transfer more tacit knowledge. In addition this could be a way to automatically identify a list of experts without further effort.

Privilege human interaction, with expert, with other service, by increasing the exchange people may have between one another (for example, use of synchronised break time and common areas between different services, creating dedicated rooms to enable informal discussions, etc...)

Human interactions are among the most requested improvements in Knowledge Management, whether it involves mentoring, trainings or workshops. People are more eager to benefit from personal and professional experiences that from documents and databases. Human contact seems to be the preferred way to transmit knowledge within an organization.

Communication and collaboration:

There should be a focus on the general integration of YPs, to facilitate access to network and internal structure of the organisation, such as mentorships and placement rotations.

Improved communication tools / informations

Communication and collaboration between employees are a key factor in the success of organizations. This aspect is even more important when it comes to the integration of new talents: the easier it is, the shorter the adaptation period and therefore the faster the employee is autonomous. An effort must therefore be made to ease the access to networks, within the organisation but also between organisations/sites, and to capture the internal structure of the organizations. AI is also a facilitator for KM, especially for communication and collaboration aspects, and should therefore be encouraged to a greater extent to facilitate the human decision-making process.

Centralization of documents:

There should be unified tools to access explicit knowledge. E.g. one, easily maneuverable database, or a set of databases with documents separated in an intuitive way.

Create an organization-wide central online portal (similar to sharepoint, intranet or others) to collect all possible documentation and making it available to anyone in the organization as well as enhancing the transparency.

More efficient database centralization tools

The above suggestions all acknowledge that there is a custom of having various access points for documents in the same organisation, and that this creates problems.

There are currently applied tools to solve this, such as sharepoint or intranet solutions, though most large organisations have documents over several databases. In the research through survey and interviews, there is no strongly recommended tool. However, there are some points mentioned that are common on the topic of document access. The lack of transparency itself makes it difficult to know what is accessible, documents remain unknown unknowns. When you can easily ask around and get access the problem can be solved quickly, but for newcomers access to such network in itself can be difficult. The positives of centralised document tools is transparency, ease of access, and integration of newcomers. All of these speak for time saved for the organisation. The negatives would be difficulties of limiting access where necessary, possible search speed issues in huge databases such as those agencies would have, and that documents could get lost in the masses unless they are marked well.

Trainings and workshops:

Proper training and courses on already existing KM tools.

Give trainings on "how to teach" to people

Training and Workshops are aprobated and should be subject to more investments.

When employees are trying to get into existing KM systems, a proper training could boost the efficiency in doing so and flattening the learning curve. This and a wider range of workshops could enhance human communication. Other than that, a more dense connectivity among different departments is not only beneficial to KM but to the organization as a whole. For example the KM system could be linked to HR in order to ensure a common new hire orientation with an additional focus on experts in different workshops and seminars. As a very positive side effect, the foundations of the organizations, as well as the organization's commitment to KM would become more clear and homogeneous. In case people are identified with potential in improving teaching skills, a focused, but passive (in order to make an effort in only those situations, which require a helping hand in e.g. mentorships) support could boost the process. Even though these investments are not resulting in immediate profit, it is fundamental to make long term investments and have a long-sighted view on stability.

It is crucial not only to ensure that achieved knowledge is being captured and efficiently inherited, but also to promote continuous exploration and innovation. The presented approaches “Convergent/Divergent Thinking“ and “Design Thinking“, among other Agile Thinking techniques can be implemented into companies and agencies by organised workshops and seminars. In addition, this could have a positive effect on enhancing the communication and connectivity between people.

Accessibility of competencies:

Create list of experts available to anyone in an organisation.

Mapping of competences, "roadmap" to access certain positions.

The very specialized expertise in space industry could be shared a lot more efficiently, when the corresponding experts can be identified with the least amount of effort. The recommendation is to establish and support online communities of practice where like-minded groups gather to assist each other. An organization could adopt the concept of a list of experts which makes it easy to ensure the connectivity and use of potential. In addition a navigation enriched by e.g. text mining tools in AI would also allow to map competencies in different desired manners by simple machine learning algorithms. It is critical to set expectations for these communities.

Standardization of KM:

Create standard ways to express information and knowledge in a more interactive learning process.

Better standardisation of documents.

Standardization is a common way to bring structure in complex processes and facilitate exchange and interchangeability. In the field of knowledge management standards are a crucial step in order to store information in an organised manner and hand it on efficiently. Interviewing participants, it was found that in many organisations no such standards exist whatsoever, which creates frustration and makes it very difficult to implement centralised tools, like e.g. organisation-wide interactive learning processes. At this stage it is a strong recommendation of this report to develop and implement standardisation processes for information in any form in order to rapidly improve KM. A practical example and a quite promising form of information storage standardisation is the use of MBSE models instead of documents.

All the suggestions made during the Gap Analysis concerning Knowledge Management, summarized in this report, require long term investments. Indeed, as highlighted throughout the entire report, more efficient Knowledge Management tools and practices increase communication and collaboration between employees. They simplify the access to databases, training and workshops. Information is being shared and accessed easier, resulting in shorter design processes. Organizations therefore are more responsive and efficient. With more effective tools in KM employees will feel more empowered, considered and more able to share knowledge.

9. 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.

Several IPMC committee members have volunteered to function as mentors to the topic groups and support the Workshop Delegates throughout their discussions and research to come to the most optimal conclusions and recommendations while receiving live feedback from the mentors. The support has proven to be much appreciated and valued by the delegates and the recommendations reflects this. We thank them again for their effort.

The WOC invites the IAF's IPMC committee members and the Young Professionals to further discuss the findings of these and previous topics and find a way to implement the recommendations in their respective organisations. The recommendations are evident, well thought out and based on the examples, experiences and input from today's way of conducting and developing business.

10. YP delegates organizations

First name	Last name	Organization
Narayan	Nagendra	Satsearch
Jessica	Bain	Boeing
Shahrzad	Hosseini	Association of Space Explorers
Praskovia	Milova	Association of Space Explorers
Lilli	Bullinger	Association of Space Explorers
Florian	Marmuse	SGAC
Abdelfattah	Mostafa	SGAC
Swetha	Kotichintala	SGAC
Tadeusz	Kocman	SGAC/Syderal Polska
KangSan	Kim	SGAC
Samantha	Testa	NASA
Felipe	Queiroz de Almeida	DLR
Ting	Peng	DLR
Daniel	Voigt	DLR
Stephan	Jahnke	DLR
Kobkaew	Opasjumruskit	DLR
Tatsuya	Taguchi	JAXA
Jun	Shimada	JAXA
Mark	Fittock	OHB System AG
Jeffery	Stuart	NASA JPL
Fabio	Fabozzi	Agenzia Spaziale Italiana
Olga	Diaz	CNES
Leonard	Pineau	CNES
David	Gaudin	CNES
Pauline	Delande	CNES
Antoine	Carre	CNES
Yeon Ju	Choi	KARI
Busisiwe	Nkonki	CSIR
Andreas Lyder	Pedersen	ESA
Andra	Cutuhan	ESA
Harish	Grandjean	ESA

Malgorzata	Solyga	ESA
Max	Braun	ESA
Eleonara	Zeminiani	TAS
Cigdem	Avci Salma	ESA
Sergio	Bras	ESA
Lionel	Metrailler	ESA
Alice	Pais de Castro	ESA

11. Workshop Reports

The full IPMC YP Workshop 2018 Reports can be accessed here. These reports contain the full details of the individual research.

Previous workshop reports can be accessed via the IAF website, here.

12. Acknowledgements

The 2018 IPMC Young Professional Workshop has greatly appreciated the support of Boeing and UAE Space Agency. The WOC would like to warmly thank the sponsors 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.