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Diversity for a Sustainable Space Future – Opportunities and Challenges for promoting diversity in the space sector

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Abstract

As the global pandemic brought operations of multiple industries to a standstill, the space sector continues to expand in spite of recent lockdowns and restrictions. Since the pandemic commenced, we have witnessed the launch of UAE's Mars mission, the first manned commercial journey to the International Space Station, and the completion of China's BeiDou Global Navigation Satellite System. The pandemic has also accelerated technology uptake on an unprecedented scale, bringing offices to our homes, and in many regions, taking education fully online. On the one hand, the increasingly ubiquitous connectivity (often enabled in part or in full by space technology) has opened opportunities for us to connect globally, and to bring education to previously underserved communities during the pandemic, particularly girls in less developed regions. On the other, according to a report by UNESCO IESALC, gender inequality in higher education persists amidst the pandemic. Women remain underrepresented in STEM, and the figures are more alarming for senior positions. In particular, while we have witnessed increased journal paper submissions from both female and male scholars during the first period of the pandemic, the increase in submission of female scholars accelerated slower than their male counterparts. Such phenomena could be the result of a convergence of factors, including but not limited to increased responsibilities at home (due to the closure of schools and childcare facilities), possible digital inequality, and aspiration gap. There has never been a more pressing time to enhance diversity and representation in the space sector. This presentation argues that Mentorship programme plays an important role in reducing some of the barriers in promoting diversity in the space and technology sector. It seeks to present a working manual of tools to encourage and enthuse the next generations of global women leaders in the space sector. Emphases will be placed on bringing more visibility to roles that might have been previously neglected (due to a focus on upstream aspects in the media), ensuring that contributions from other aspects of the space sector are given due recognition, for example, ground control elements, space data analytics, space education and policy, as well as the utilization of commercial and/or open source data.

Keywords: *Space Diversity, Sustainable Space Future(s), Sustainable Development Goals, Space4Women*

Acronyms/Abbreviations

ERC	European Research Council
ESA	European Space Agency
EVA	Extravehicular activity
IAEA	International Atomic Energy Agency
IESALC	International Institute for Higher Education in Latin America and the Caribbean
ISS	International Space Station
UAE	United Arab Emirates
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICC	United Nations International Computing Centre
UNOOSA	United Nations Office for Outer Space Affairs

1. Introduction

On 21st July 2022, Samantha Cristoforetti became the first European woman to have completed a extravehicular activity (EVA), also known as spacewalk. Her colleague, Oleg Artemyev, with whom she completed the EVA, had previously conducted five similar activity before "spacewalking" with Cristoforetti.[1][2] In a time when societies increasingly recognize the importance of diversity and representation, this is an incredible milestone. At the same time, Cristoforetti's belated EVA reminds us that there is still a lot to be done to enhance diversity and inclusivity in the space sector. To date, only 16 women had completed an EVA, as opposed to over 220 men.[3] [4] Consider also that shortly before commercial space voyages (e.g. Blue Origin, Virgin Galactic) emerged, only 11% of the individuals who had made the journey

to space have been women.[3] The figures are even more alarming when compared with statistics decades ago–women only constitute 20-22% of today's workforce in the space sector–the numbers had not significantly changed from 30 years ago. [3]

2. Path-Dependent Barriers & The Need for "Inclusive by Design"

Space exploration is an area in the space sector where challenges for ensuring diversity and representation are noticeably pronounced. The European Space Agency (ESA) had made the first initiative to recruit parastronauts--astronauts with a disability--into its next cohort of trainee astronauts.[7] Prior to the initiative, a disability would in most instances exclude one's eligibility to become an astronaut. The initiative shows that now there is both the political will and policy priority to enhance diversity and inclusivity in space exploration.

2.1 All-women EVA

In the past, however, even in situations where there was the support to emphasize women representation, there were often delays and path-dependent technical challenges that needed to be overcome. For instance, the first all-women EVA, conducted by Jessica Meir and Christina Koch, was conducted seven months after it was originally planned.[8] The delay was due to a lack of fit spacesuits. Originally, Anne McClain and Koch were to conduct the all-women EVA. While McClain was trained in both the medium and large size of the spacesuits, she discovered that the medium size of the upper torso fit better after her EVA outside of the ISS. She then requested to wear the medium size for the envisioned all-women spacewalk. However, Koch also required the same size in medium.[8] As there was only one medium upper torso component fit for the operation, McClain had to swipe place with Nick Hague for the planned EVA, pushing back the scheduled all-women spacewalk.[8] Wei-Haas notes that while the sizes of modular components of the spacesuits initially run from extra-small to extra-large, NASA had cut the extra-small and small size in subsequent years. As women are smaller than men on average, it was argued that this removal of sizes most prominently affect women.[8] While there had been calls for sustainable-by-design approach(es) to future satellite development (e.g. in introducing refuellable, repairable, and removing satellites)[9], it is an opportune time to also incorporate "inclusive-by-design" considerations into future technical specifications.

2.2 From customization to two-sizes-fits-all

In NASA's earlier years, spacesuits were tailored to the size of each individual astronaut. Subsequently, NASA moved to demand spacesuits to be reusable and modular in nature, allowing different cohorts of astronauts to combine different sizes and modular components into a spacesuit for EVA. Gradually, the customized nature of the spacesuits faded, including the dropping of extra-small and small sizes. The need for the astronauts to fit the mission, and not the other way around, became apparent.[8] Responding to the delay in the all-female EVA, Stephanie Schierholz--NASA spokesperson–said, "When you have the option of just switching the people, the mission becomes more important than a cool milestone."[10]

While all would recognize that safety and the needs of the operation may have necessitated the swipe, it is disappointing to continuously see the lack of improvement in diversity and inclusivity frequently justified away with technical imperatives, especially when the technical preparation could have easily been foreseen and solved. Given that the space sector, and specifically human space exploration, is a sector known to be risk-adverse and built on redundancy, it should not be an excessive demand to have the foresight of preparing two smaller (i.e. medium) size components to be configured for the EVA planned for Koch and McClain.

One point raised in explaining the delay was that McClain was trained for both the medium and large size of the component, and that she had thought she could work with the large size before realizing the medium would be a better fit after her actual spacewalk.[10] In such a case, we see both men and women, regardless of each individual astronaut's shape and size, all trained to fit the same technical specification–sizes in medium and large. As fewer than 13% of those travelled to space were women,[11] this poses the difficult question if an aspiring woman astronaut may have to adapt to a profession, whose practices, equipments and infrastructure were not designed for them.

3. End of the Astronauts? Just as Space Diversifies?

Some commentators have argued that the space environment is hostile to humans, and that the profession of being an astronaut is not one fit for humankind. Martin Rees, along with Donald Goldsmith, had most recently renewed the call against the continuation of human astronauts for space exploration. [12] The argument they put forward is not new. The fact that space exploration poses all kinds of risks to human astronauts has long been registered. These are costly, and dangerous endeavours. However, whether robotics and machines are now technologically mature enough to *fully and immediately* replace human space exploration in the present or very near future, to perform on a par as, if not better than human astronauts, remain debatable. There is certainly the potential to further integrate

elements of robotic operations to reduce risks posed to human astronauts in the future. And given the fact that many recent explorations, including probes and rovers sent to explore Mars and the far side of the moon, suggest that the wisdom of using robotics to perform more dangerous/uncertain tasks is not missing.

The timing when this argument is put forward is perhaps less than ideal: it calls for an end to human space exploration just as major space agencies begun to emphasize diversifying its cohorts of astronauts. (e.g. ESA's parastronauts initiative), and at a time when commercial space tourism near the edge of making space more accessible. If the argument is to end future human exploration now, what discussions and measures must society have now in order to address the lack of diversity in the history of human space exploration?

3.1 Beyond the Astronaut – An inspiration & Role Model

Compared with earlier cohorts of astronauts at the peak of the Cold War, today's role for astronauts go beyond merely fulfilling orbital missions and exploration. In Europe, one of the key duties of ESA astronauts is outreach and community engagement. For example, ESA astronaut of British nationality-Tim Peake–in addition to completing mission-related activities and training, was tasked with a busy schedule of public engagement and outreach activities, including speaking with schoolchildren, young scouts, industry, and the wider public.[13] For his contribution to education and public engagement, Peake was awarded the Rooke Award by the Royal Academy of Engineering.[14] In fact, education and inspiring the next generation were core elements of Peake's *Principia* mission, and inspiring children to go into STEM and space-related careers was one of the key objectives of this mission.[15] Principia's logo, designed by a 13-year-old in a BBC competition, features a bright-coloured falling apple that symbolizes the mission's reference to Newtonian laws of gravity, as well as signifying the educational ambition of Peake's voyage.[16]

Similarly, Cristoforetti, being one of only three European women to have journeyed to outer space, contributed significantly to outreach activities for women empowerment.[17][18] In other words, as technology matures to perform more technically-challenging tasks with high-degree of precision, astronauts over the years have moved to go beyond merely performing technical operations in the hostile orbital environment. They are no longer only trained to complete their 6-month mission to the ISS. Their job does not end when they are not in orbit or training, they continue to perform their duties of public engagement, outreach, and inspiring girls, under-privileged groups, and the next generations for a more sustainable, equal, and responsible environment in science, the space sector, and beyond.

A good astronaut today is not just an individual who can perform instrumental tasks (e.g. science experiments on board the ISS) efficiently and accurately, but a well-round professional who can communicate complex concepts to both young and adult audiences, as well as *educate and enthuse* others to pursue a more sustainable future. While robotics may be more efficient and cost-effective in delivering mission-oriented tasks, they are far from able, let along excelling than their human counterparts, in the latter part of astronaut's duties.

4. Integrating Diversity into the Discussions for Future Human & Robotic Explorations

The paper argues that any call for a reduction in future human space exploration *must* be accompanied by genuine discussions on ensuring diversity in the future of human and/or robotics-only missions. There are two main reasons behind this contention: First, given the small number of astronauts today and in the past, and taking into account the disproportionate under-representation of women in this elite group, it is imperative to be forward-looking to ensure diversity is reflected in future cohorts of astronauts. It would be a responsible initiative to give careful thoughts on mechanisms in ensuring that the proposed reduction in human spaceflights do not further undermine the limited visibility of recognized women role models in the sector.

Second, if human spaceflights are to be replaced by robotic missions, there should be thorough consultations and discussions on the gender dimension of developing these technologies. This has already been integrated and championed by major research councils in allocating research funding. For example, applications for grants under Horizon 2020 of the European Research Council (ERC) are asked to "describe how sex and/or gender analysis is taken into account in the project's content," and responses will be analyzed by the evaluators.[19][20] The spacesuit incident examined above is consistent with previous limitations identified in the fields of engineering and robotics, where the practice of testing using the average sized male had posed problems ranging from vehicle design to road safety. The limits of using a average sized male crash test dummies have long been noted, and crash test dummy has been a widely referenced example in illustrating the failure of integrating diversity into engineering and other research practices.[21][22][23] Robotic space exploration poses further challenges in addressing the gender dimension, as the feedback loop could be long. As the end-users (e.g. astronauts, ground control, engineers) continues to

lack the level of diversity society desires, it can be difficult to identify shortcomings in a timely manner, such as those identified for male crash test dummies. For a start, there is a need to ensure a diverse representation in the engineering and ground control team if human space exploration is to be replaced. This discussion should be brought forward, *ex ante*, rather than *ex post*, and cannot be an afterthought when the argument to reduce human astronauts is being put forward.

If robotics are to fulfil the non-instrumental functions of inspiring the next generation to explore and engage in science, then they should be designed in a way that reflect the core values of humanity. The idea that robotics "can be heroes [too]" is not new.[24] Slakey and Spudis had put forward the concept as early as in 2008, noting that the Mars Pathfinder--a robotic probe on the red planet in 1997—attracts 720 million visits to its website. A proof, they claimed, that suggests "an unmanned mission can thrill the public just as much as a shuttle flight."[24] Although in the same article, the author(s) highlighted that he was personally inspired by Apollo astronauts as a child.[24]

There has been warning that future robotic developments may be "unconsciously designing robots toward current gender stereotypes, [which] may reinforce those stereotypes in ways roboticists did not intend."[25] In light of this concern, a "hippocratic oath" had been proposed for engineers and designers involved in the design of future robotics. The oath calls for the integration of social equality into these future efforts in robotics.[25]

5. Discussions

5.1 Entrepreneurial Spirit & Diversity in the Space Sector

Information gathered for previous researches on the UK space sector suggests that women often need to be entrepreneurial to lead in the space sector. In a study conducted by Space Skills Alliance in 2021, it was suggested that many senior female executives in the sector appeared to have founded the organization they work for.[26] The report referred to an estimation from EVONA, a recruitment agency in the sector, which contends that "female founders account for 70% of women in C-level and senior positions in the space sector."[26] These information reflect that while the sector continues to witness under-representation of women, those who succeeded to reach senior positions often created their own opportunities to lead.

5.2 A Framework to advance Diversity

The above analyses and observations suggest that there remains a lot for the sector to do in the domain of enhancing diversity. From path-dependent technology design that may pose barriers, to creating new opportunities for women to lead, it appears that the evolution of systemic changes often cannot catch up with societal demands for greater gender representation. As information collected from the sector points to women creating their own opportunities to lead in C-suites, there is the understanding that the conventional structure of the space industry alone may not be able to achieve the level of diversity desired. That is why mentoring becomes a critical element in the process to diversify the sector. If most women created their own leadership opportunities in the industry, it suggests that the savoir-faire and intangible knowledge of these trajectories cannot be readily transmitted to the next generation through formal on-the-job training in established companies. Mentoring thus constitutes an important piece for the space industry.

Summarizing major challenges observed, this paper proposes the following elements to be integrated in formal and informal mentoring schemes:

5.2.1 Diversify the pool of role models

Given the exclusive and limited opportunities for the most visible roles (e.g. astronauts) in the sector, the next generation of women leaders would benefit from a much more diversified exposure to various types of roles in the sector. Study conducted by Space Skills Alliance points out that "women in industry are more likely than men to be doing work related to the downstream (such as data processing)," and that they "are more likely to be in educational [roles]."[27] These roles need to be more widely recognized and celebrated. This would mean not only recruiting women in these roles to mentor the next generation, but also having major avenues, such as trade expos, music festival with scientific/educational elements (e.g. Goonhilly festival, Glastonbury) widen their guest speakers invitations to include women in diverging career stages and roles in the space sector.

5.2.2 Encourage aspiration and ambition

Research in the UK has shown that "women are more likely to be inspired at school by a teacher (30%)" than men (21%), whereas "men are more likely to be inspired by the internet (19%)" than women (13%).[28] This suggests that interpersonal interactions are particularly important in inspiring girls to aim for a career in space and/or in STEM, more so than boys. At the same time, the same study concludes that women are consistently paid less than men, and are "less likely to be promoted to senior roles."[29] The study contends that the gender pay gap ranges from £1k for junior positions up to as much as £9k for more senior roles.[29] Many reasons could contribute to these figures. But these numbers

suggest that mentoring, with its unique personal dimension, could be crucial in instilling in the next generation of women in science the aspiration and ambition for fairer remuneration and recognition for their work.

5.2.3. Internationalize mentoring experiences

Existing figures show that only 1 in 5 space professionals are women. In the European context, only one female astronaut is currently on active duty. Given the gradual but long process of enhancing women representation in the sector, leading women figures could be receiving an enormous amount of invitations to contribute to national outreach, mentoring, or educational activities. As such, it is not only important to diversity the pool of role models, (For example, by highlighting the significant contributions from women engineers, academics, and mid-career managers to the space sector) but also advisable to widen the pool of prospective mentors and expertise by anchoring mentorship programmes globally. This would enable emerging leaders to tap into a wider pool of experiences and expertise, ensuring that the limited number of national leaders or more visible figures are not overburdened with requests of more personalized guidance.

5.2.4. Bring discussions on challenges posed by path-dependent technologies forward

The test dummy and the spacesuit size discussion examined above show that technology needs to consider inclusivity at its design stage. Inclusive-by-design discussions would need to be raised for the next stage of robotic and human exploration. There had been equipments and technologies that were designed and developed for the average user, in a time when women were not well represented, or not duly included in certain segments of the sector. The next generation of women leaders would benefit from being aware of potential challenges posed by path-dependent technologies, and have the foresight to prepare to overcome them. At the same time, the current generation of leaders could continue to shape technological developments that promotes inclusivity and diversity.

6. Conclusions

This is an exciting time for the space sector to see a more dynamic and diverse community. The examination above seeks to provide a framework of inquiry and development to enhance diversity in the space sector, increasing particularly women representation in the full spectrum of space activities, both downstream and upstream. Recent mentoring initiatives, such as the global Space4Women mentorship programme by the United Nations Office for Outer Space Affairs (UNOOSA), not only served to diversify the pool of female role models, enthuse and inspire ambition in the next generation, but also internationalize mentoring experiences. At the same time, more awareness and open debates on hindrance to diversity posed by path-dependent technologies are needed, and are yet to be fully developed.

As women remain under-represented in the sector at the moment, it would be advisable for incumbent leaders to be particularly mindful of discussions on inclusivity and diversity in the planning of future technologies and policies. A narrow focus on economic and mission risks often neglect the wider societal contexts and longer term horizon of space activities. Extra attention is thus needed to ensure that path-dependent technological developments that exclude, rather than include, are not perpetuated.

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