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Interdisciplinary Workshop on Human Habitation Concepts for Interstellar Space-Travel

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Abstract

Crewed interstellar space-travel as the biggest *what-if* of future human spaceflight confronts us with challenges of time, distance and life support, and raises significant human factor issues (e.g. isolation and confinement, radiation, weightlessness) which are exacerbated by mission duration. Yet, with the departure from the well-known and familiar, developing human habitation concepts for interstellar space-travel can also serve as a way to foster creativity and out-of-the-box thinking: the topic provides challenging problems to solve and very few exemplary projects. Additionally, the subject's high level of complexity requires the willingness to depart from traditional disciplinary territories.

The presented work will give an overview on past and present space-related interdisciplinary workshops, summer schools and design studios for PhD and master students from European universities. It provides insight with regard to the potential benefits of interdisciplinary approaches at the very beginning of design processes, and introduces the concept for an interdisciplinary student workshop on human habitation concepts for interstellar space-travel aiming at stimulating the student's creativity and generating ideas for fully self-sustaining space habitats that have complex ecosystems, simulated gravity, and could potentially preserve human life in outer space for several generations.

Keywords: interdisciplinarity, student workshop, human spaceflight, space habitats, interstellar space-travel

Acronyms/Abbreviations

BMSTU - Bauman Moscow State Technical University
EAC – European Astronaut Centre
ESEC - European Space Security and Education Centre
ESTEC - European Space Research and Technology Centre
EVA – Extravehicular activity
ICE - Isolated, confined, extreme
ISRU – In-situ resource utilization
JSC – Johnson Space Center
OEWF – Österreichisches Weltraumforum/Austrian Space Forum
SICSA - Sasakawa International Center for Space Architecture

1. Introduction

For humanity to venture out into or even out of the solar system requires not only to tackle the technological and logistic challenges of long-duration space travel. Interactions between humans and their environment – particularly in habitats that are characterized by confinement and isolation and the extreme environment they are protecting the inhabitants from (e.g. danger or extraordinary threats to health and life) – are highly complex, and have to be taken into account in the space habitation design process.

Habitability of spacecrafts will be one of the most critical human factors technologies for future long-duration human spaceflight. The "ultimate challenge", with a time perspective extending far – probably centuries – into the future, are generation ships for interstellar missions. Keeping humans alive, healthy and motivated on a spacecraft for generations depends, among other requirements, on a reliable closed-loop life support system, artificial gravity, human accommodations and requirements for habitability and safety, but also on social cohesion and fostering human inventiveness, discovery and creativity.

All those challenges will be significant for the future of human spaceflight in general, and designing complex systems that are able to solve them is an inherently interdisciplinary task. Particularly during the concept development phase, the transfer of information, ideas and opinions between disciplines is critical, to eliminate or extenuate obstacles emerging at later stages of the design process, when the designs are much less flexible and redesigns involve far more resources.

Non-traditional disciplines are becoming increasingly important in human spaceflight and if we want to foster innovation in this area, students need to be prepared for the challenges of working and communicating productively in interdisciplinary teams. Student workshops are an important means to train young people for those challenges. Those workshops should address not just students from traditionally space-related disciplines, but all disciplines relevant to extended human spaceflight need to be involved (e.g., engineering, life sciences, architecture, industrial design, natural and social sciences).

Following a summary of past interdisciplinary workshops, this paper summarizes the benefits of interdisciplinary experience, particularly in tertiary education, and introduces the concept for a future student workshop on the subject of habitation concepts for interstellar space-travel.

2. Examples of Interdisciplinary Academic Programs and Student Workshops

2.1 ESA Habitat Workshop 2005 [1,2,3]

2.1.1 Organisation, duration and location

The five-day-long workshop at Erasmus Centre of the European Space Research and Technology Centre (ESTEC), Netherlands, was organised by the Moon Mars Working Group and sponsored and hosted by ESA/ESTEC in support of the Aurora Moon Mars Exploration program.

2.1.2 Topic(s)

New habitat design concepts for Moon, Mars and Phobos surface bases

2.1.3 Participants

Thirty postgraduate students and young professionals in the fields of architecture, engineering, industrial design, life sciences and natural sciences. Participants were assigned one of the five design teams before the workshop.

2.1.4 Experts

The five design teams were supported by a group of ten organisers from the Moon Mars Working Group and fifteen experts from ESA, academia and industry, with varying backgrounds supplying constructive advice where needed. An expert jury including both executives and scientists from ESA and industry evaluated the designs.

2.1.5 Aim and Scope

One aim of the workshop was to deliver innovative habitat concepts and identify key challenges of habitat design in extra-terrestrial settings. The other aim was to demonstrate the benefits of involving various disciplines known to have important input in habitat design from the very beginning of the design process.

2.1.6 Output

The novel approach of the workshop led to innovative concepts (In-situ resource utilization (ISRU), inflatables, flexible base layouts, robotic assistance, etc.) as a stepping stone for further work, which links to interplanetary roadmaps of space agencies around the world. Following the workshop, multiple papers on the results and lessons learned were published [1,2,3].

2.1.7 Interdisciplinarity

This workshop promoted so-called “big interdisciplinarity” (collaboration between distant disciplines). The workshop brought together engineers, architects, life scientists, natural scientists and industrial designers working together in teams. Traditionally such studies apply a sequential approach, but in this workshop participants worked concurrently from the beginning of the concept phase. Each of the five six-person teams consisted of one architect, one engineer, one physicist and one participant from a human factors discipline at least. Students were selected for multidisciplinarity and multinationality.

2.2 STAR Design [4,5]

2.2.1 Organisation, duration and location

Every year for two to three weeks the cooperative STAR Design between NASA Johnson Space Center and Lund Institute of Technology takes place at NASA Johnson Space Center and SICSA (Sasakawa International Center for Space Architecture), Houston, Texas.

2.2.2 Topic(s)

Topics change each year. In recent years, participants have studied Mars, low Earth orbit and the International Space Station, the layout and design of a possible lunar base, and they have worked on the development of innovative crew habitation systems and elements for deep space exploration.

2.2.3 Participants

Annually, ten architecture and industrial design students from Lund Institute of Technology take part in the program.

2.2.4 Experts

Students are supported by experts from NASA and SICSA.

2.2.5 Aim and Scope

The aim of the program is to expand the developmental knowledge of design in extreme environments and get scientific and engineering input.

2.2.6 Output

The expected outcomes are design concepts focussing on space environment, human needs and the resulting challenges for crew and spacecraft design.

2.2.7 Interdisciplinarity

In this program, architecture and design students get the opportunity to learn and work in an engineering-dominated environment.

2.3 TU Vienna Space Architecture Design Studio – Destination Moon [4,6,7]

2.3.1 Organisation, duration and location

The design studio took place during one semester at Vienna University of Technology, Austria, and was organised by the Department of Building Construction and Design of Vienna University of Technology.

2.3.2 Topic(s)

Future research base on the Moon

2.3.3 Participants

27 students (architecture and aerospace engineering) were working in teams of up to four people.

2.3.4 Experts

Participants were led by the organising experts in architecture for extreme environments, building technology and design. Over the semester, students had input and feedback from human system integration experts, flight psychologists, industrial designers, policy makers, astronaut trainers, radiation protection experts, physicists, astronomers, biomimetics experts, physicians, astronauts and bioregenerative life support experts.

2.3.5 Aim and Scope

Accompanied by theme-specific lectures and workshops with space experts from ESA, DLR, NASA, UNOOSA and more, the students were challenged to analyse selected topics related to building on the Moon, develop a settlement strategy and design and pursue a research station on the Moon.

2.3.6 Output

The design studio output were visionary concepts for a lunar research base, provision for programmatic needs and human factors and safety issues for habitats in extreme environments. Following the design studio, a booklet on the workshop and its results was published [7].

2.3.7 Interdisciplinarity

Complemented by an exceptionally broad spectrum in disciplines of experts that gave input and feedback to the participants, architecture (the majority) and aerospace engineering students were working together in design teams.

2.4 TU Vienna Space Architecture Design Studio – MASH [4,6,8]

2.4.1 Organisation, duration and location

The design studio took place during one semester at Vienna University of Technology, Austria, and a simulation happened over the period of a month near Erfoud, Northern Sahara, Morocco. The Department of Building Construction and Design at Vienna University of Technology was the organiser of the studio, and the simulation in the Sahara was organised by the Austrian Space Forum (OEWF).

2.4.2 Topic(s)

Deployable emergency shelter for Mars

2.4.3 Participants

Twenty-five master students (architecture and engineering) were assigned to one of three groups. During the research phase at the beginning of the semester, each group focussed on one of the following topics: activity-based spatial analysis, deployable structures, and specific features. During the simulation, three students were embedded into a multidisciplinary simulation team of the Austrian Space Forum (OEWF).

2.4.4 Experts

The students were led by the organisers, who are experts in architecture and habitability in extreme environments, deployable structures and adaptable and flexible habitation design. They were supported by medical consultants from the European Astronaut Centre (EAC), consultants for prototyping, experts for the AOUDA space suit and analog astronauts.

2.4.5 Aim and Scope

The design studio aimed at challenging students to define design criteria for specific scenarios of a crewed Mars mission, and give them the opportunity to prototype their designs and subject those prototypes to field testing and operational evaluation.

2.4.6 Output

Output of the design studio was the design, 1:1 prototyping, and field simulation (human testing and occupancy evaluations) in the Sahara desert of a portable and deployable shelter for EVA (extravehicular activity) emergencies on the Martian surface. All projects were published [8].

2.4.7 Interdisciplinarity

Architecture (the majority) and engineering students were working together on the designs and prototyping. To broaden the interdisciplinary aspect of the studio, they had input and feedback from experts in disciplines, such as medicine and spacesuit design, and from analog astronauts of the Austrian Space Forum (OEWF).

2.5 International Youth Summer School: "Space Development: Theory and Practice" [4,9]

2.5.1 Organisation, duration and location

Every summer for two weeks, the summer school takes place at Bauman Moscow State Technical University (BMSTU), Russia. The BMSTU is the organiser of the event and is supported by the Russian Ministry of Education and Science, and Roscosmos.

2.5.2 Topic(s)

Scientific team projects on varying space-related topics (e.g. manned Mars mission)

2.5.3 Participants

Approximately one hundred students take part each year. They come mostly from engineering disciplines, but the summer school is open to interested students from other disciplines as well.

2.5.4 Experts

At the end of the two weeks, the participants present their work to external experts including industry professionals, cosmonauts, and BMSTU professors.

2.5.5 Aim and Scope

The main aim of the summer school is to provide students with the opportunity to interact with experts, discuss achievements and issues of space programs of the past year, to expand their professional network and produce successful team projects. The social aspect, as well as visiting companies, important space sites and museums plays an important role in the summer school.

2.5.6 Output

The team projects mostly reach a detailed schematic design stage [4]. Many former participants now work in the space industry.

2.5.7 Interdisciplinarity

The summer school addresses mostly engineers, but it is open to other disciplines (e.g. architecture and industrial design students) as well.

2.6 ESA Concurrent Engineering Workshops [10,11]

2.6.1 Organisation, duration and location

The four-day-long workshops at ESA's European Space Security and Education Centre (ESEC), Belgium are organised by the ESA Academy programme.

2.6.2 Topic(s)

Various space mission concepts

2.6.3 Participants

Fourty-four engineering and physics masters or PhD students from ESA member or associate states take part in each workshop. Participants are divided into teams of two to three students, covering one of the following disciplines: structures and mechanisms, configuration, power, thermal, altitude and orbit control systems, propulsion, optics and sensors, trajectory analysis, and communications and data handling.

2.6.4 Experts

ESA experts

2.4.5 Aim and Scope

The aim of the workshops is to complement university education by familiarising students with the concurrent engineering approach and its benefits. After the workshop, participants will be able to use the Open Concurrent Design Tool (OCDT) and identify design drivers.

2.6.6 Output

The output should be, in iterations, a subsystem concept (within the small team) and, at the end, together with all other groups, a finalised mission concept.

2.6.7 Interdisciplinarity

The workshop fosters collaboration between similar disciplines (i.e. engineering). While the concurrent design approach forces the engineering students to interact with participants from other engineering disciplines, the problem-solving tactics and design approaches of those disciplines are very similar. However, the workshop is a great opportunity for engineering and physics students to gather experience with concurrent design.

3. The Benefits of Fostering Interdisciplinarity

The manifold complex issues and research fields our times – and even more so the future – hold for us can often not be addressed in purely disciplinary ways. They require linking and integrating technologies, professions, and academic schools of thought from various fields – each with their different perspective and methodologies – and sharing ideas and insights to reach appropriate solutions [12].

Moti Nissani [13] raises the following ten points about the importance of interdisciplinary knowledge and research:

1. *"Creativity often requires interdisciplinary knowledge.*
2. *Immigrants often make important contributions to their new field.*
3. *Disciplinarians often commit errors which can be best detected by people familiar with two or more disciplines.*
4. *Some worthwhile topics of research fall in the interstices among the traditional disciplines.*
5. *Many intellectual, social, and practical problems require interdisciplinary approaches.*
6. *Interdisciplinary knowledge and research serve to remind us of the unity-of-knowledge ideal.*
7. *Interdisciplinarians enjoy greater flexibility in their research.*
8. *More so than narrow disciplinarians, interdisciplinarians often treat themselves to the intellectual equivalent of traveling in new lands.*
9. *Interdisciplinarians may help breach communication gaps in the modern academy, thereby helping to mobilize its enormous intellectual resources in the cause of greater social rationality and justice.*
10. *By bridging fragmented disciplines, interdisciplinarians might play a role in the defence of academic freedom."[13]*

Because PhD and master students are at the first, formative stages of their career, expanding their horizons beyond often highly specialized studies, placing their academic field in context and challenging them to communicate effectively with people from different disciplinary perspectives should be particularly beneficial [14].

There are several ways how to approach organising interdisciplinary meetings for students in tertiary education or early-career researchers. Brindle et al. [14], when describing their approach to fostering interdisciplinary skills in early-career researchers, emphasise the importance of physical encounters to encourage participants to interact and learn from people with different disciplinary background. In particular they describe "cultivation encounters" and "development encounters". "Cultivation encounters" have the objective of exposing researchers, which are not yet working in interdisciplinary fields to other disciplines and help them understand and interact with those disciplines. "Development encounters" are aimed at producing concrete outputs, new ideas and initiating interdisciplinary projects [14].

The authors of this paper consider it very important to give masters and PhD students the opportunity for exposure to other academic disciplines, face-to-face exchange, and they think it is particularly useful to provide a chance to try actively collaborating in interdisciplinary project work. Interdisciplinary student workshops can be a useful instrument to bring people together, develop new ideas and generate concrete outputs that are relevant to each of the participants' discipline. At the same time, cultivating interdisciplinarity promotes essential skills in informed and engaged citizens: scrutinising, assessing, and synthesising information from manifold fields and sources for the purpose of reaching reasoned decisions [13].

4. Workshop Topics to Foster Interdisciplinarity in Space Education

To promote genuine interdisciplinarity, workshop topics should be high-level broad research challenges that are of interest to and approachable from a broad range of different disciplines. In addition, they should facilitate the generation of ideas and concrete output, without curbing creativity and enthusiasm. A narrowly defined topic that, from the outset, only attracts or even allows participants from a small range and number of disciplines, will likely only promote "small" interdisciplinarity – collaboration between similar disciplines. While the offer of "small" interdisciplinarity workshops for students and postgraduate researchers in relation to space is quite large, they almost exclusively attract students from typical space-related disciplines and offer well-tried topics with limited potential for innovation. The opportunities for workshops that foster "big" interdisciplinarity – collaboration between distant disciplines – on space-related topics is rather limited. However, it is particularly important to foster collaboration and communication skills between distant disciplines as well, because non-traditional disciplines (e.g., life sciences, space architecture) will become increasingly important in future human spaceflight. Furthermore, those non-traditional disciplines bear the potential of bringing innovation to the field.

It is important to find "big" interdisciplinarity topics that are able to generate enthusiasm, promote creative ideas and innovation, while being a valuable learning experience to the participants and producing useful output for the organizers and space community. At the same time it is important to make sure that, when leaving well-trodden paths and working with unusual topics, the abundance in creativity does not come at the cost of scientific soundness and the output is valid. It is therefore important to provide guidance, expert input and feedback to the students.

In space missions, the broadest spectrum of mission relevant disciplines can most likely be found in human spaceflight. One of the biggest challenges for the future of human spaceflight is the design of habitats for long-duration human missions. Human needs and requirements have to be taken into account from the earliest stage of mission planning and have to play a key role in overall mission architecture and spacecraft design to guarantee health, safety and productivity of the crew to successfully reach mission goals. This process ideally involves engineers, space architects, (life, natural, but also social) scientists, designers, and more.

Lunar or Martian surface bases have recently become quite a popular topic for design challenges and workshops directed at students, early-career researchers and young professionals. Also more "exotic" topics like missions to the Martian moons or manned asteroid-mining missions have come up as design challenges in the recent past. They mostly focus on innovative crew habitat concepts (ISRU, inflatables, flexible base layouts, robotic assistance, etc.), provision for programmatic needs and human factors issues, and developing settlement strategies and designs. The complexity of those tasks requires the students to adjust to designing for humans operating in reduced gravity and premises a very broad knowledge base in human factors, engineering, physics, materials science, etc.. In addition, the participants have to work on scales from the overall picture to small details, which can be difficult to balance. Yet, important topics – admittedly also the hardest to solve – like closed-loop life support, radiation protection and artificial gravity are often not sufficiently tackled in the outcomes, because resupply and limited mission duration can be used as a loophole.

The topic of human interstellar space-travel could be considered the "ultimate challenge" and there exist no such loopholes for designs in this scenario. Even though it is rarely ever touched in habitat design workshops, studios or competitions, it is certainly a subject that encourages visionary thinking, generates creativity and innovative ideas, as it is highly complex and contemporary, cutting-edge technology is far from rendering such an enterprise possible. While it can be considered reasonable to assume human missions to the Moon or to Mars could be taking place within the next decades, humanity is many times further from realising human interstellar travel. But even if the time perspective for these processes extends far into the future, most of the fundamental problems to be solved here are crucial for all extended human spaceflight missions and many are highly relevant for life on Earth – both now and long into the future – as well.

5. Design Approach and Interdisciplinarity

While similar disciplines (e.g. various engineering disciplines) frequently have very similar approaches to identifying and solving problems, "distant" disciplines often differ strongly in their problem-solving and design practices. To facilitate understanding between the different design approaches during a workshop, the practices need to be assessed.

5.1 Engineering approach

In system engineering – the traditional engineering approach to designing space missions – the aim is to assemble all mission elements/sub-systems/functions into one holistic design. System and sub-system requirements are derived from mission goals and a trade-off process establishes the priority of the requirements [4]. Efficiency and economy is the constant focus in integrating all the sub-systems into one system. Traditionally, human requirements for inhabited space systems beyond basic safety and reliability were not taken into account. This produced problems once the system (e.g. International Space Station) was operational. For future long-duration missions this cannot be a sufficient approach for habitation design, as inadequate living and working environments for astronauts put a risk to or impede on the crew's health, productivity, and general well-being [2].

The too narrow requirements and constraints focus omits important human based operational requirements and human factors issues and rule out innovative out-of-the-box approaches to habitat design. Attempts to improve habitability in late design stages of a space habitat – when a project has already lost much of its flexibility – are often much less effective and costly [2].

5.2 Concurrent engineering

The concept of concurrent engineering is defined by two fundamental ideas. First, to boost productivity and quality of the outcome, design activities should happen concurrently. This way, faults can be detected and corrected early in the design process, when the design is still flexible and costly redesigns during stages that involve a much larger amount of resources (complex computational models, manufacturing, etc.) can be prevented. And second, from the early design phases on, all elements of a mission/product/system's life-cycle (from function determination to disposal and recycling) need to be taken into account thoroughly [15].

The actual benefits in concurrent engineering are achieved by opening up the design process and sharing information much more efficiently. It is therefore important, that early design reviews are conducted, efficient communication between collaborators is established, and the necessary tools used in the design process (e.g. CAD) are compatible for efficient exchange of information (e.g., data, models) [15]. However, concurrent engineering for space systems predominantly connects engineering disciplines, which are fairly similar in their problem-solving and design approaches.

5.3 Space architecture approach

The principal focus of space architecture is designing to support humans living and working in space. Until now, only a small minority of space systems are habitable, and they involve rather primitive habitation. With increasing mission duration, traveling distance, and changing crew sizes and mission goals such habitation does not suffice any more [16].

Characteristic for the space architecture approach is the linking of engineering thinking with significant consideration of habitability and human factors, which play an important role in architecture. In addition, various disciplines which are not traditionally space related (e.g. life and social sciences), but nevertheless relevant to human spaceflight, are taken into account from the earliest design phases on [6]. Contrary to the linear, quantitative systems engineering approach, the iterative, qualitative space architecture approach envisions an integrated design solution, from overall picture to detail, and manages different discipline analyses to reach that goal [16].

A significant benefit of the space architecture approach is that the requirements and constraints for the designs of missions that rely on humans working effectively and being dependable are significantly influenced by human factors and habitability considerations.

5.4 Design approach of the workshop

Within the design teams, all disciplines will work concurrently, decision-making has to happen by consensus, involving all the disciplinary perspectives from the earliest stage of the design process. Due to the complexity of the design task a broad design process – linking the concurrent engineering and the more process-oriented and iterative space architecture approach – will be required. Significant consideration of habitability and human factors will be crucial.

5.5 Facilitating interdisciplinary communication and collaboration

Interdisciplinary knowledge sharing, communication and collaboration skills are essential in designing all kinds of human habitats for extra-terrestrial environments. In addition to differing problem solving approaches, diverging terminology, culture, and professional practice between the disciplines can make knowledge exchange and communication in general very complex. Therefore, promoting clear articulation of concepts as well as careful examination through questions is essential [14]. Communication and relationship building will be encouraged also during non-working hours (e.g. during lunch-breaks and common activities in the evenings). Exchanging ideas and knowledge in a relaxed environment will complement the concentrated work being done during the days.

5.6 Facilitating creativity

Group creativity is becoming increasingly important, particularly for solving highly complex engineering and science problems. Such problems cannot be solved by a single person with a very specific disciplinary background. Often, the complexity of a problem demands diversity, because – to get a comprehensive understanding of a problem and a maximum range of possible solutions – it requires looking at it from many different angles. While teams with a high degree of diversity might be less socially cohesive than very homogenous ones [17], differences of opinion are an important promoter of creativity. Debate and dissent are crucial to producing innovative ideas and have shown to be much more effective in generating group creativity than brainstormings, where ideas are not to be judged or criticised [18]. An effort should be made to balance differences and similarities of team-members within the group: individuals in teams that perform very well regarding creative output tend to have different personalities, skills and backgrounds, while being similar in their values and goals [19].

Another important measure to promote group creativity during a workshop can be to provide opportunities for the working groups to meet in environments that support both concentrated work and relaxed discussions. This should be supportive of both convergent and divergent thinking in the group members [20]. Participants meeting in a relaxed environment with others that are working on the same or complementary design topics and discussing their ideas and design progress should also spur creativity and motivation. In addition, to promote innovation, intellectual challenges can be very motivating, particularly to people at early stages of their career [21].

6. Habitat Design and Interstellar Travel

6.2 Design drivers in interstellar travel

Careful consideration of habitability issues will be essential, especially for operational safety of long-duration spaceflight. In particular for the concept of interstellar arks – a vehicle that has to be completely autarkic – the significance of the interface between humans and their environment will shift from promotion of human productivity and health to critical parameter for long-term safety [22].

The main habitability issues that have to be addressed when designing for long duration human spaceflight, particularly for human interstellar travel, are:

1. closed-loop life support and food supply
2. human - machine interface
3. artificial gravity
4. micrometeoroid and space debris countermeasures
5. radiation protection
6. accommodation of societal development

As the design drivers to be considered here are manifold, it could be overwhelming for students to address all those topics at the same time. It might therefore be advisable that the challenges are split between groups to be more easily addressable. Particularly at a workshop with the limited duration of a few days, we cannot expect that all those issues would be sufficiently considered – even for a conceptual design stage – if they are not distributed well. To facilitate the conceptual design solutions going into a minimum depth, we split the issues that the designs should focus on most over the three groups:

1. human factors (including space medicine, human - machine interface, accommodation of societal development, etc…)
2. closed-loop life support and food supply, radiation and micrometeoroid protection
3. artificial gravity

7. Interdisciplinary Workshop Planning

The authors of this paper are convinced, that the experience of interdisciplinary collaboration is a highly beneficial asset for students and professionals of the future. Therefore, they are currently in the process of planning an intensive three-day interdisciplinary habitat design workshop in spring 2019. Taking place at the European Space Research and Technology Centre (ESTEC) in the Netherlands, the workshop will invite PhD- and master-students (aerospace engineering, space architecture, physics/energy systems, industrial design, biology, medicine, etc.) from European universities to come up with “Human Habitation Concepts for Interstellar Space Travel”. The aim of this three-day intensive workshop is – in interdisciplinary collaboration – the exploration of self-sufficient systems and technologies, which will be significant for the future of human spaceflight. At the same time, topics tackled in the workshop – conserving and recycling valuable resources, harnessing and using energy sustainably and high-density living – are of immediate interest to life on Earth as well.

7.1 Workshop overview

To facilitate successful achievement of the workshop objectives, the following parameters will be carefully considered.

7.1.1 Workshop location and length

Attending gatherings/meetings/workshops in new and inspiring locations can be a promoter of creativity and communication, as it requires people to step out of their comfort zone [23]. ESTEC should be a new and fascinating location for the participants, and particularly inspiring for people interested in space. Additionally, it provides access to valuable expertise on site – experts who will be available for lectures and feedback sessions.

A standard duration of three to five days is usually chosen for encounters that involve participants from a large geographical area (i.e. Europe) [14]. Time and financial constraints both on the side of the participants and the organizers need to be considered for defining the length of the workshop. The duration of three days for this specific workshop will be extended by workshop preparation on part of the students (i.e. exploring the preparation material, preparing a poster and short presentation within the assigned groups to present at the beginning of the workshop) and preparing the final report after the workshop.

7.1.2 Selection of participants

Open-mindedness and interest in working in an interdisciplinary team will be selection criteria. In addition, diversity in disciplines, but also in nationalities and gender need to be accommodated. While highly diverse working groups might require longer times to develop social cohesion [17], the challenge should make the experience for the participants even more useful.

7.1.3 Selection of design focus

Each of the mixed teams will have a specific design focus to work on. Selected experts will be invited to provide initial input for students. The three design foci are:

1. Space medicine and human factors:

The students will study physiological, psychological, sociological and cultural factors that affect humans in Outer Space. They will investigate ways in which the design and architecture of a habitat can alleviate physical and social stressors associated with living in an isolated, confined and extreme (ICE) environment. The students will suggest space habitat designs that could preserve, support and influence human life on an interstellar spaceship.

2. Next generation life support, radiation and micrometeoroid shielding and architecture:

Students will investigate advanced environmental control and life support technologies. They will come up with ideas on radiation mitigation, micrometeoroid protection, bio-regenerative closed-loop life support and significant food production for long-duration space flight. This includes ideas for ISRU and in-space manufacturing.

3. Artificial Gravity Design:

Students will study the implementation and complex mechanisms required by spin interfaces in the interstellar spaceship as a means to preserve the health of the interstellar travellers over generations from deconditioning in microgravity.

7.1.4 Students workshop preparation

Students will be assigned one of the three teams before the workshop and prepare on the specific topic their group has to work on. To start the workshop at a minimum standard of knowledge from all the involved disciplines, reading- and other preparation material will be provided. At the beginning of the workshop, participants will prepare a small introduction on what valuable contribution they think their discipline – and in particular they themselves – can bring to the workshop. In this introduction, the participants should make an effort to translate their disciplinary perspective into concepts that can be easily understood by students from other academic fields. To facilitate open communication and understanding between the disciplines right from the beginning, the students will be encouraged to scrutinise the meanings of those concepts through questions. Together in their assigned group, participants will also have to prepare a short poster-presentation on the assigned design focus.

7.1.5 Expert lectures and feedback

Besides the design sessions, lectures on workshop-relevant topics will be held by experts in the field, to improve interdisciplinary understanding and to acquaint students with important concepts from disciplines different to their own. Additionally, experts will be available for questions and provide design-feedback to the participants.

7.1.6 Working groups

When working on complex tasks in uncertain environments, a positive correlation between increasing team size and performance has been reported. This is most likely owing to the increased availability of resources (e.g. expertise) [24]. As the length of the workshop will be only three days, it was decided that the size of each group should not exceed ten people, to allow sufficient time for all group members to interact. The ten students of each group will be from diverse disciplinary backgrounds.

There will be three interdisciplinary teams, each with a different design focus. Students will be assigned a team (before they meet) and prepare for specific topics relevant to their design focus. During the workshop each student will work in one of the teams.

7.1.7 Definition of mission objectives

While the design focus of each group will be set, the individual groups will have to define the functional and mission requirements themselves. Providing a general design focus will give a general direction and facilitate getting started with the project, while still leaving plenty of room for creative development.

7.1.8 Review sessions

To ensure development of the projects, each evening the groups will compare their design development.

7.1.9 Presenting the final results

At the end of the workshop, the participants will present the outcome of their teams' work to external and ESA experts and workshop organisers. In addition, they will prepare a short final report on their workshop experience and project.

8. Conclusion

Students, not just from the traditional space-related engineering disciplines, but all the fields relevant to future human spaceflight need to be prepared for working in interdisciplinary project groups to tackle highly complex design tasks. Interdisciplinary workshops are a means to foster collaboration and communication skills between students from manifold disciplines and promote creativity and innovation. Academic workshops and courses increasingly acknowledge the importance of interdisciplinary approaches to future space exploration.

The authors of this paper are currently in the process of planning such an interdisciplinary workshop for masters and PhD students. The topic of "Human habitation concepts for interstellar space-travel" was chosen to provide a high-level broad research challenge that is interesting to and approachable from many different disciplines. It will challenge the participating students to come up with conceptual designs for truly closed, complex systems, as in the scenario of interstellar travel resupply is not an option. Efficient interdisciplinary collaboration and communication is crucial to adequately addressing such a challenge. At the same time, the topic poses a suitable framework to encourage the generation of creative ideas, new approaches and out-of-the-box thinking.

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