

#PLASUS21 Workshop Report

PLANetary SUSTainability 21: Challenges, Opportunities and Necessities

Thursday 29/4/21 9-17 CET online

Abstract

Humans are setting out for the stars. Our space environment is being used more and more intensively, mega constellations are beginning to light up the night sky and disrupt science. Junk is accumulating in the more heavily used Earth orbits. Several countries now want to go to the Moon, and this time plan to use its resources.

As time on Earth is limited, we need to move. But we need ethical guidelines in the area of outer space, which is an international domain, especially because the law remains open to interpretation. Moreover, we need to link the issues of sustainable space use with the environmental debate here on Earth: we should discuss an 18th Sustainable Development Goal for our space environment.

Do we really need to grow into space? How can we do it in a sustainable way? It is high time for an integrated discussion of space matters with planetary concerns. The workshop PLASUS21 – „Planetary Sustainability 21: Challenges, Opportunities and Necessities” connects space & global sustainability, key space actors and sustainability thinkers.

Sponsors

We want to express our gratitude to the generous sponsors who made the event and associated research possible: the individual donors through crowdfunding on *wemakeit* (21.000 CHF), the *UZH Space Hub* (5.000 CHF), the *Reformed Churches Bern Jura Solothurn [RefBeJuSo]* (5.000 CHF), the *Federal Department of Foreign Affairs [FDFA] of Switzerland* (4.000 CHF), and the *International Space Science Institute [ISSI] Bern* (1.000 CHF). We also thank our Media Partner *SpaceWatch.global*, and our platform provider *Space4Impact* for their highly professional handling of the event.

Schedule

09:00-9:05 Opening: Natália Archinard (Federal Department of Foreign Affairs of Switzerland)

09:05-9:30 Planetary Sustainability: the concept (Andreas Losch with André Galli, University of Bern & Xiao-Shan Yap, EAWAG/University of Utrecht)

09:30-10:00 Planetary Boundaries and Limits to Growth (Christian Berg, Club of Rome)

10:00-10:25 Earth-Space Sustainability (Xiao-Shan Yap, EAWAG/University of Utrecht)

10:25-10:40 Break

10:40-11:25 Environmental challenges: Space Debris, Megaconstellations, and the Preservation of our Night Sky (Thomas Schildknecht, University of Bern)

11:25-11:45 Active Space Debris removal (Luc Piguet, ClearSpace SA)

11:45-12:05 Space Sustainability Rating (Nikolai Khlystov, World Economic Forum)

12:05-12:10 Words of welcome from our host (Mathias Wirth, University of Bern)

12:10-13:30 Lunch Break (with the option for 1:1 sessions)*

13:30-14:30 Challenges and Opportunities I

- Space can do more for Earth (Gaetan Petit, Space4Impact)
- Space Resources & Innovation (Dovilė Matuleviciute, Luxembourg Space Agency)

14:30-14:45 Break

14:45-16:15 Challenges and Opportunities II

- Forward to the Moon: Europe's exploration program Terrae Novae and Artemis (Stefaan De Mey, European Space Agency)
- Sustainable Space Logistics (Emmanuelle David, EPFL)
- Biological Challenges in Space (Oliver Ullrich, University of Zurich)

16:15-16:30 Break

16:30-17:00 Planetary Sustainability: Moving Forward (Panel with Christian Berg, Stefaan de Mey, Nikolai Khlystov, Dovilė Matuleviciute and Thomas Schildknecht, moderated by Xiao-Shan Yap and Andreas Losch)

17:00-18:00 Free (Option for 1:1 sessions*)

*The platform offered the option to schedule 1:1 meetings with other registered participants on the platform. 2 persons used this function.

The talk "Sustainable Embeddedness of Space Activities" by Traugott Jähnichen unfortunately had to be canceled. His views you can [read here](#).

Executive Summary

The workshop took place Thursday 29/4 9:00-17:00 CET online, and was hosted by the Ethics Division of the Department of Systematic Theology, Faculty of Theology at the University of Bern. There have been a total of **14 speakers**, and **94 participants** registered who watched the videos as follows:

Video	Views	Watch hours	Average View Duration
PLASUS21 Morning	138	100.5	43:41:00
PLASUS21 Afternoon	85	89.3	01:03:04

The recordings are now listed on youtube and can hence attract a wider audience:

<https://youtube.com/playlist?list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc> UR

In Natália Archinard's (Swiss Federal Department of Foreign Affairs) opening statement, Planetary Sustainability was identified as a very up to date topic. It is also discussed in a similar fashion within the COSPAR community these days, as André Galli (University of Bern) pointed out. In this workshop's context, sustainability is understood according to the classic Brundtland report's definition of sustainability, while adding two recognitions: 1) it essential to respect the boundaries of the Earth system including limits to growth, 2) it is nevertheless necessary to discuss an expansion into space.

The first talk by Christian Berg (Club of Rome) and the introductions by organizer Andreas Losch¹ and André Galli reflected on these two recognitions. Xiao-Shan Yap (EAWAG) tracked the developments of such an Earth-Space Sustainability through a discourse network analysis. Sustainability in space is a huge challenge because of space debris, but also if we want to preserve the pristine night sky, as the keynote by Thomas Schildknecht (University of Bern) made clear. Several approaches try to tackle the space debris issue, either through active debris removal (ADR) – as presented by Luc Piguët (Clear Space SA) –, or through a Space Sustainability Rating (SSR), brought forward by WEF's Nikolai Khlystov. Greetings by Mathias Wirth on behalf of the host concluded the morning session.

The afternoon session focussed on challenges and opportunities within this framework: space (businesses) can do more for Earth, as platform provider Gaetan Petit (Space4Impact) framed it; the strategic space resources initiative was presented by Dovilė Matuleviciute (Luxembourg Space Agency). Stefaan de May laid out ESA'S Terrae Novae and the ARTEMIS plans for space exploration, while Emmanuelle David (EPFL Space) emphasized the need for a sustainable space Logistics (SSL) in this context. Biological challenges in space, including some theological reflections, were discussed by Oliver Ullrich (UZH Space Hub).

In a concluding discussion the most pressing issues were identified. A systemic approach to sustainability is needed, including advancements in international practices and rules regarding space. The next technical challenge would be a sustainable life support system in space. The most pressing problem are the emerging megaconstellations, but one may not underestimate the potential of space resources to transform human civilization and life on Earth. The question how to share the benefits remains. There is conceptual convergence regarding the need of something like an SDG18 Space environment, but it would need to be worked out in detail. Also it could be helpful, if the concept of planetary boundaries would include something like «orbital boundaries» in the near future.

MORNING SESSION

Opening remarks

Natália Archinard (Swiss Federal Department of Foreign Affairs, current Chair of the Scientific and Technical Subcommittee of the UN Committee of Peaceful Uses of Outer Space (UNCOPUOS))²

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=1&t=0s

SUMMARY: The Planetary Sustainability project brings a comprehensive approach and an ethical/philosophical reflection into the sustainable use of outer space. Looking at how humanity has been using the Earth, ethical and philosophical thinking is welcome to accompany further developments in outer space activities, especially with respect to human exploration of the Cosmos.. The Scientific and Technical Subcommittee of UNCOPUOS is addressing issues in relation with this workshop's topics. It is for instance looking at the use of low-Earth orbits and the impact of large constellations on astronomical observations from the Earth. Further, it should soon kick-start the work of the new Working Group on long-term sustainability of outer space activities. As we can see, the workshop topics are very actual and very relevant.

¹ Due to technical difficulties, the introduction by Andreas Losch was moved to the beginning of the afternoon session

² Complete speaker bios in the Appendix.

Planetary Sustainability: the concept (a)

André Galli (University of Bern)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PLI1mUkD-LLdWKcT7p8ADNCw09v-4Lc_UR&index=1&t=407s

SUMMARY: The talk presents where the space science community stands with regards to planetary sustainability and the questions pertaining to ethical questions policy about the exploration research and usage of outer space. The place to discuss these questions is the Committee on Space Research (COSPAR), which has been maintaining the guidelines for planetary protection to avoid organic constituent and biological contamination in space since the beginning of the space age. COSPAR also has a new panel or framework for environmental stewardship on Celestial Bodies, where two researchers from the planetary sustainability project participated in this year's assembly. A majority of the attendants of the COSPAR 2018 scientific assembly was in favor of „Space Environment“ as an autonomous 18th SDG.

The talk also defined PLA.SUS. as understood in the context of this workshop: The definition follows the Brundtland report's definition, adding two recognitions: we must respect the boundaries of the Earth system, plus without expansion of our instruments and people into space, humanity could conceivably perish.

Current developments (satellite networks, planned return to the Moon) show a high urgency to address the issues. At the next COSPAR assembly in 2022, several events related to „planetary sustainability“ in a broader sense of the term are planned.

Planetary Boundaries and Limits to Growth

Christian Berg (Club of Rome)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PLI1mUkD-LLdWKcT7p8ADNCw09v-4Lc_UR&index=1&t=1160s

SUMMARY: Humanity lives in a finite environment, and is proceeding on a path which is anything but sustainable. „We are the first generation that can end poverty, and the last that can end climate change.“ (Ban Ki moon, UN General Secretary) Unlimited Growth does not exist in nature – the Club of Rome's „Limits to Growth“ report got that right. Its predictions for 1970-2000 matched the developments. The term „Anthropocene“ was coined by Paul Crutzen. While in the Holocene we had a largely constant temperature, we are now at full speed to irritate the delicate balance in our climate system (CO₂ +50% vs preindustrial times). Atmosphere is a very thin coat covering the earth. The troposphere (the first 11km of the atmosphere) extends to just 0,1% of the Earth's diameter.

We are exceeding planetary boundaries where the likelihood for irreversible devastating developments increases. Scientists say that the issues of biodiversity loss and the biogeochemical flows of nitrogen and phosphorus might be even more harmful to our ecosystems. We are pushing away wildlife (from 99% of Earth's biomass 10.000 years ago to 1% today). The current pandemic can partly be seen as a consequence of this.

Colonizing space to escape ecocide? No resolution to our messy situation on Earth. We should not leave the impression to the public that it is already too late to save the Earth. The distance to possible target exoplanets is just too large.

By 2050, humanity would need 3 earths if we continue like we do. Astronaut Alexander Gerst related to our „blue dot“: We better not destroy the only space ship that we have.

Q&A

What do you think about the Donut Modell that also includes societal aspects to planetary boundaries?

It's critical to include societal aspects. We have missed that sustainability can only be reached in an integrated way. We have listened to the climate scientists, but not studied the social conditions of protecting the climate.

I am curious how we can societally translate outer space sustainability ... as many of these metaphors and examples that really impressively illustrate planetary limits may not work for seemingly "limitless" outer space. How can we break the myth of unlimited cosmic scales?

Even if we could one day travel with 90% of light speed, it would take 80 years to get to an interesting exoplanet like Trapist-1. This is a physical boundary which we will probably never move beyond. It's insane to think that we can colonize the universe and get back to Earth.

If we think to use the resources of other space objects for Earth, that's like thinking if we only switch to Electric vehicles all would be fine, which is naive. Our consumerism is not just the problem, but the symptom of our desire to ever more consumption, cf. Erich Fromm's and Victor Frankl's analyses. It's the quest for meaning humans are driven by, we need to address this to address consumerism.

The same mechanisms that are driving humanity to transgress planetary boundaries and leading us to reach limits to growth (overconsumption, maximization of profits, etc.) are also more and more powering space activities: raise of commercial space, industrialization, democratization,...

As a result, the space sector might contribute more and more to environmental impacts on Earth, and also reach its own "environmental limits", such as space debris.

How can we avoid that?

Cf the previous answer, and maybe we can use the image of phase transition of water. You can heat it up – or lower the surrounding pressure, both achieves a phase transition. If we only do pressure on one action and ignore all others, your transition might not succeed. But we see many actors, Fridays For Future, the European Commission's green deal and Blackrock urging sustainable developments, which is a promising sign. Large transformations historically never have been monocausal.

Earth-Space Sustainability

Xiao-Shan Yap (EAWAG/University of Utrecht)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=1&t=3377s

SUMMARY: The talk discussed the opportunities and challenges of building a sustainable and functioning Earth-space system into the future. It points to three main sustainability challenges: 1) Social-technical complexities in using space, 2) Space as a new tragedy of the commons, 3) The next era of Space governance.

The talk went on to present an in-depth case study of Active Debris removal (ADR) through a discourse network analysis. Values, interests and concerns discussed among different Space actors were mapped by analyzing 289 articles. Search string protocols and coding scheme were utilized to derive concepts and actor networks. As a result, the development of space debris challenge was characterized by four phases, the current phase (2018-) marked by the launch of Megaconstellations. The analysis can be used to identify divergent policy scenarios which could help us better prepare for a sustainable and functioning earth-space system.

Q&A

Are there any detailed projections?

This is ongoing research, but we have different scenarios.

You are wondering how institutions and governments could address the situation in space, and how to model impacts/consequences of the current situation in space. It just sounds like CO2 (i.e. Atmosphere indeed) or Oceans (i.e. water and livestock). Part of the solution might be found through those terrestrial matters that are addressed through the 'common goods economics' developed by Nobel Prize Jean Tirole... Have you investigated that path?

Interesting approach, but not yet examined. [Written response] For this, we tried to draw clearer distinctions since NASA and Jaxa represent single nations compared to ESA. But we will see how to best present the networks in the end. Thanks for the point!

In spite of numerous climate summits, we are still using more fossil fuels each year, and CO2 emissions have been steadily rising. In a similar fashion, in spite of space debris guidelines, we are launching more and more satellites (especially with incoming Megaconstellations), and the number of debris is steadily rising. Isn't current governance too "weak"?

Definitely, former governance is quite weak, there is an ongoing discussion whether a voluntary based structure can really be sustainable.

ESA gained strength after Jan Wörner became its director. What role do individual persons and their interests play?

Individual actors with strong leadership are indeed taken into account, they are coded into the views of the respective institutions.

In terms of more developing countries participating in space development, do you consider equitable access to space as a part of the space sustainability framework?

Opening the space sector «for all» provides opportunities and is important, especially when developing countries are already less privileged. However, how to ensure equal participation while not exhausting orbital resources is more difficult. This is a common challenge that we should work together and look into.

Environmental challenges: Space Debris, Megaconstellations, and the Preservation of our Night Sky

Thomas Schildknecht (University of Bern)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=1&t=5312s

SUMMARY: After a look at the Historical Evolution of objects in near Earth space (LEO and GEO), we face a lot of space debris now: >10 cm ~35'000, >5cm ~60,000, >1cm ~900,000 (Still energy of hand grenade in a collision). The ISS is already peppered with impacts. On 10.2.2009 an inactive and an active satellite (Cosmos and Iridium) collided which created thousands of thousands of space debris objects which create a shell around Earth. Likewise, so-called breakups frequently happen.

Why we should care depends on your interest in space. Be aware that space is still mainly a military area, so information is not available for all objects. Open questions include those about the population of space debris, its physics and mechanisms. What approach do we choose? Zimmerwald observatory in Switzerland has a couple of primary optical sensors, further stations in South Africa and Australia

are in similar use. If you want to avoid collisions you need to use lasers. What do we know in 2019? Space debris is a serious issue and we need to make sure that we have no unlimited proliferation of the distribution of objects. Statistics show an increase of the number of objects and a steep increase in the mass of the objects (payload) since 2017 due to commercial Megaconstellations. For a long time, we had mostly maneuvers to avoid payload or rocket related conjunctions, due to Megaconstellations this shifted to satellites. What can we do to protect the space environment? We need to prevent explosions, limit orbital lifetime, care for Post Mission Disposal (PMD), and avoid collisions. Clean-up is in many aspects very challenging. Even when disregarding constellations, we need 90% PMD to mitigate the impact of space debris. The planned megaconstellations have together at least 13000 additional satellites scheduled. If we take that into account, even with 90%PMD and no explosions the population of space objects is much higher. International Guidelines have evolved, lastly the COPUOS ones, but they are all non-binding.

Satellite Constellations and Society: strings of pearls may be fascinating, but do we want to see them all the time, more than 100 moving satellites visible by naked eye. The pristine night sky is a human heritage which needs to be preserved. Satellite streaks are already expected on every exposure from large telescopes, besides the diffuse background brightness from artificial objects, and the radio noise from satellites. Outer space «Light pollution» may cut us from accessing the sky accessing knowledge about our universe. There is currently ZERO regulation in these regards. Technical means to preserve night sky are to darken the satellites, and to orient them differently. IAU recommendations to UNCOPUOS are hence to preserve a pristine, starry night sky; establish dark sky oases; limit optical and radio brightness of satellites; take into account in licensing process; darken satellites; no high-altitude constellations; provide orbit data.

We need to ensure long-term sustainable use of outer space / ensure protection of dark and quiet skies for science and society / Stringent international rules & mechanisms to ensure enforcement. Take Home message: Our societies, not private companies, need to decide on tradeoffs between the benefits of megaconstellations and protecting the space environment and dark and quiet skies as resources shared by all humankind.

Q&A

For the planet, we have the concept of the planetary boundaries, would it make sense to have an orbital boundaries concept as well?

There is already related work going on about the capacities of space. The question is which risk/pollution limit we do accept.

[Further Q&A at the end of the morning session.]

Active Space Debris removal

Luc Piguet (ClearSpace SA)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PL1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=1&t=8018s

SUMMARY: Making Earth Orbits sustainable: how can we build a commercial case to make sustainable operations a viable option? Today space is like a motorway network without tow truck services. There are more non-functional than functional objects in space. Prevention of incidents is much cheaper than recovery of debris. The technically feasible smaller design of satellites nowadays is what drives a fundamental transformation: the launch of megaconstellations. Should we stop this?

We are in a situation where our mode of life depends increasingly on space infrastructure. It is not going to stop because space infrastructure is in total much cheaper than a ground based one.

Space Safety and sustainability requires a balanced multi-dimensional response; collision avoidance, debris prevention and servicing and Active Debris Removal resulting in Space Situational Awareness. ClearSpace addresses the challenge of autonomously capturing and removing non-cooperative satellites in space. ClearSpace-1 is the first mission to remove a debris from low earth orbit to fly by 2025. Both the chaser and the object will return to the atmosphere. The objective is, however, to go to reusable services. On-orbit services are a market that is already active and projected to grow to 4.5B by 2028. Removing man-made space debris is the responsibility of today's generation to ensure tomorrow's generations can continue to benefit from space technology and exploration.

Q&A

[After the next talk.]

Space Sustainability Rating

Nikolai Khlystov (World Economic Forum)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PL11mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=1&t=9407s

SUMMARY: The WEF'S Global Future Council on Space Technologies initiated a conversation on potential ratings for space missions. A call for proposals to find partners for the SSR was launched at IAC 2019, a consortium of ESA+MIT/UT/Bryce won in 2019. Sustainability in space will ensure that we continue to use and maintain the resources of the space environment for generations to come, and refers to the long term capability to avoid loss, disruption, or degradation of space services and activities. The SSR Team builds on existing concepts (like the UNCOUOS guidelines) and considers specific decisions about design, operations and post mission disposal that reduce risk of collisions, shorten orbital time for debris and increase Space Situational Awareness. Awareness of the project has been spread on several conferences and events. Main objective of the concept is to create an incentive to a) design missions compatible with sustainable operations and b) operate missions considering not only mission objectives & service quality, but also the potential harm to the orbital environment and the impact on other operators. It's less a new set of guidelines, but a system to recognize compliance and better than required behaviors. Four tiers currently exist, «certified», «silver», «gold», and «platinum». A step indicator signals extra commitment beyond current practices. All stages are rated individually: 1) feasibility, 2) design, 3) in-orbit and 4) disposal, resulting in a final rating. The current scope could one day be extended to planetary, lunar, asteroid missions etc. Parameters in the rating right now are based on 6+1 modules, selected according to relevance, access and verifiability. Normalization and weightings of the composite indicators are required to combine the modules into a single score. First valuable beta tester feedback is in, and it is now time to select a future operator or host organization which shall be finalized in 2021.

Update: EPFL'S eSpace Center has just been selected as host for the SSR.

Shared Q&A

If we know that there is an issue with debris around Earth, why we are still launching satellites since there is no clear solution how to solve the problem?

I read about the accelerated rhythm of launching thousands of satellites in the next years, especially with the developed of more companies who can do that with cheaper prices.

If these two processes are not synchronized and clear procedures and laws created I think it will happen as in the case of pollution of Earth. So we never learn from our mistakes...

Thomas Schildknecht: This is really the main issue right now, we are entering a completely new area in

using space. Just imagine you have one launcher with 110 small satellites, and this happens. Each of these satellites would in principle need to be registered and have a license from the so-called launching state. This licensing process takes in account right now some of these mitigation guidelines and requirements. But we have no restrictions on the amount of objects launching and who is allowed to launch something. The only restrictions we have and what is regulated in particular in geostationary orbit is the ITU, via the frequencies you need for each satellite. Each and every operator in space needs a frequency to communicate with its satellite. Otherwise we would have a full mess. This is done on an international level right now. But this is not the case in any other orbital region, though. We could face the issue that in certain areas in space we can't do safe operations. How do we manage the capacity of space up there, for example? If one company decides to use a certain shell, they are allowed to do that, both on international level and on national level as well. By the end of the day we have to face the facts up there. It's like the challenges we have with pollution on Earth. We need to decide if certain types of missions are of a benefit for society or if we finally say no, we don't think the benefit is outweighing the negative impact of a certain mission. How? I don't know. We have to look at other communities like the climate community how they deal with these issues.

I like to know about the cleanup mechanism. You showed us an example that could work for larger objects, but the largest threat actually comes from the smaller ones. How could we ever get rid of these small objects, is there a chance?

Thomas Schildknecht: Taking out the large objects does not have an immediate impact on missions, but have a huge impact on the long-term sustainability. Small size objects you have to care about as an operator. Many of them, depending on their altitude, are going to be cleaned up because they fall down to Earth (and dissolve in the atmosphere), smaller faster than big ones. We need something else than a «vacuum» cleaner, we are thinking of using lasers to nudge them a little bit. The idea is a part of ADR, we need an auto mechanism what we call just in time collision avoidance. We need to have means to nudge two colliding objects to prohibit it. Even large ones.

Luc Piguet: Every small object comes out of a large one. If you want to address the issue you need to take care about the bigger ones first, because this is something which can be done. Below 10 cm we don't really see them. Every single collision that happens creates more small debris.

Do you advocate for the idea of weak sustainability where operators can potentially pay a fee to "pollute" space (similar to a carbon tax), or the opposite idea of strong sustainability where fiscal cannot replace the environmental or social dimension of sustainability?

Nikolai Khlystov: I am not sure we have a clear position on this right now. We first need a proper multi stakeholder discussion to agree on what makes sense. Promoting that discussion is going to be critical. Financing is a big issue that needs to be addressed.

The 86.2m you got for the project is just for one mission, right? You of course sketched out how you envision reusing the removal devices in the future, how do you imagine to finance the future?

Luc Piguet: The budget is mostly no-recurring engineering costs, much can then be replicated on a much lower costs. This is really the key that you can bring the cost of a single removal down to a prize at a level where the cost cannot be an excuse anymore to do nothing. Ideally below 10m per removal. The first mission cannot be used as a benchmark. There will be more expensive missions like removing ENVISAT, a massive 8t object, which is tumbling. But the whole mission did already cost around 2.3 billion total cost so far, then a mission of 80m might actually make sense. Still the object is to bring the costs substantially down.

If the SSR is in place there would be new opportunities to refinance your services. Until then, you could deal with insurances offering removal as an option, eventually?

Luc Piguet: The space industry have a very strong multiplying factor, the number of assets in space and the number of uses on the ground. The uses of the service should support the effort, like with the carbon offsets. That kind of models should be explored, which really fits into the rating approach.

Nikolai Khlystov: It is taking a number of years to get the ball actually rolling. We are far away from closing climate gaps, for instance, compared to the 2030 targets, it has been closed by 12-14%. Space debris can eventually be addressed in a quicker fashion. The rating could help motivate and incentivize and really showcase the responsible actors. Not everybody will get a perfect rating in the beginning, only a few actors will be very good, which pulls the whole sector in the more sustainable territory.

With space being regarded as a “warfighting domain”, can space collisions be seen as a threat to “national security”? Do you sense a higher degree of responsibility shown by the owners to control their debris?

Thomas Schildknecht: In a nutshell I would say yes. A major driver for the US to help others by having bilateral agreements and providing operators «conjunction messages» was the military concern of the defense community to protect their own space assets. But this is only addressing a very narrow part of the whole picture, we cannot rely on the military to put enough pressure onto states.

CC carbon offset: These pricing mechanism policies usually have to be progressive and are characterized by an important time lag before being effective. For instance, the price of carbon cannot be raised to abruptly so that actors can have the time to adapt. But regarding space debris, since thousands of constellations satellites are already planned to be launched in the following years, isn't it too late for this kind of policy?

Luc Piguet: It's not too late, because this a way for paying for a cleanup.

Thomas Schildknecht: It's not too late. But cleaning up is the last thing in the chain, we need traffic management and collision avoidance before. None of the commercial operators is fully capable of doing this part alone. We need ways incentives to finance that part as well.

Nikolai Khlystov: We have to start doing things on all these aspects, from all different angles.

Words of welcome from our host

Mathias Wirth (University of Bern)

LINK: https://www.youtube.com/watch?v=5CBZuEfUBo8&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=1&t=12657s

SUMMARY: Thank you all dear participants of the PLASUS 21 workshop. It is my pleasure and honor to welcome you on behalf of the Faculty of Theology and of the Ethics Division of the Department of Systematic Theology (at the University of Bern). I am glad that despite this pandemics situation you are keeping your sides not only on urgent matters but also on important issues, accepting the call and Dr. Andreas Losch's invitation, whom I thank for his excellent work.

The question of sustainability and ethics is always a question of responsibility and a sense of a beyond, it is about responsibility for the things that do not pose an immediate concern, but are not less relevant, such as future generations, generations in social precarious situations etc. In today's

workshop you will be able to reflect on yet unaddressed planetary responsibilities that are not as distant as they might first appear. I am incredibly grateful for your thoughts on the technical, normative, political and economic questions in this workshop, and for your far sidedness, and I wish you all great success.

AFTERNOON SESSION

Planetary Sustainability: the concept (b)

Andreas Losch (University of Bern)

LINK: https://www.youtube.com/watch?v=IQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=0s

SUMMARY: These days we go into space 4.0, as ESA calls it, an era marked by cooperation of space agencies and commercial entities. For instance, there is Blue Origins, the company of Jeff Bezos, which aims at reusable launch vehicles. More ahead is SpaceX, similar somehow which wants to go multi-planetary to mitigate the consequences of an eventual doomsday event on Earth. There is a third big company, Virgin Galactic which wants to develop space tourism. You can criticize these approaches, but they all also have some positive impact. Because of spacefaring we know that we live on a blue marble, preciousness of our planet was underlined by our spacefaring. We have all the satellites enabling our current civilization. The early plans to go back to the moon developed into the lunar gateway idea, and there are space mining plans which started with asteroid mining ideas which are now more focused on water mining on the moon.

There are also problems. How can we do this in a sustainable matter? The first tourist or the first satellite is not a problem, but if you have lots of them you can have a problem. The space debris issue we discussed. When we harvest resources in space as an international domain what about the sharing of the benefits, and can space mining actually be sustainable?

The idea of sustainability is a long term point of view: Sustainable development is a «development that meets the needs of the present without compromising the ability of future generations to meet their own needs.» Essential for it is cooperation and peace on the planet, because else we can perish. But there might be other events (than an atomic war), that's why we need to take care of our expansion into space. Later generations should be able to meet their own needs without perishing due to events in our solar system. We need to keep up all dimension of sustainability, but we need to take care of a technological imperative, as our time on Earth is limited. Planetary Protection und Defense are essential. We are responsible for our future on this planet, which is the essence of the imperative of responsibility (Hans Jonas): «Act so that the effects of your action are compatible with the permanence of genuine human life.» But we also need to look into space. The SDG's cover almost all aspects of life on this planet, but we are missing our space environment.

Q&A

It's a fantastic idea of pushing forward the idea an SDG18 for space sustainability. How long have you been pushing this idea for and what were the major challenges?

I had the idea early in 2018, and wrote about it in a blog, but I am not the only one who pushes the idea so we could join causes. It is important for whatever comes out after SDG's in 2030, it is high time to integrate space.

What about the relationship between individual human beings and humanity?

It think it is important but it is also part of a global discussion. Individual freedom has an end where we are all effected, but the dignity of the individual is also very important. The individuals need to be convinced to act globally.

«Planetary» sometimes refers to our Earth and sometimes to other planets and worlds as well. Is that right?

The term is ambiguous indeed. I started with sorts of an «interplanetary» approach in the field of astrobiology, but then I realized that already on Earth we have a lot of challenges with space debris and space mining evolving, but ideally it should be an integrated discussion, bridging the far reaching Sci-Fi thoughts and the pressing reality we have regarding space debris and planetary concerns we have as well. Maybe the planetary boundaries concepts need to include some orbital boundaries, so the concept needs to extended to include our orbits.

Challenges and Opportunities I

Space can do more for Earth

Gaetan Petit (Space4Impact)

LINK: https://www.youtube.com/watch?v=lQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=910s

SUMMARY: Space4impact believes that «Space can do more for Earth». It is a tech translator whose value proposition is to connect non-Space actors with Space startups through their platform to create disruptive innovation and sustainable impact. On the platform where this event took place you can browse space startups which all have a clear impact for Earth. Space4impact provides open innovation competitions for space startups to help them gain new customers outside of the space field. Examples of space applications are Snow monitoring in the mountains(SDG 7+13), remote infrastructure monitoring (SDG 9+11), urban planning (SDG 3+11), and precision farming (SDG 2+8). Space4Impact is also working on a free online lecture @EPFL to raise awareness about what space technology can do outside the space field.

Q&A

Earth observation brings a lot of opportunities. One of the major challenges is translating the raw data into application services. Have you come across any resistance of actors who are favoring more ground-based inspections?

We talk to different industries and each have different processes. As an example of an easy to use solution, a Swiss company offers their customers to upload their own images and help them analyze them.

You showed how the initiatives on your platform relate to the SDG'S. Is it possible to filter companies according to SDG'S?

That is in the making, we can already select startups according their applications in non-space industries. Similar to what the WEF is doing for space sustainability, we want to build our own label for space technology impact on Earth.

What about the responses from developing country context. Do they lack certain capabilities in ground based inspections, so these Earth observations are a window of opportunity for them. They for sure also face challenges, what is your insight on that?

Using space data is indeed a great opportunity where there is a lack of ground based infrastructure. We have met a lot of very interesting startups who are able to bridge this lack of information for other nations as well. We want to help as we can.

Space Resources & Innovation

Dovilė Matulevičiūtė (Luxembourg Space Agency)

LINK: https://www.youtube.com/watch?v=lQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=2429s

SUMMARY: There are huge benefits and opportunities which will be enabled by space resources utilization (SRU), which vary in terms of applications, types of resources and mission profiles. The SRU value chain consists of the steps: prospect – establish – mine – transport – refine – manufacture – supply. SRU are recognized by space agencies and integrated into their future plans for lunar development. The International Space Exploration Coordination Group published a global exploration roadmap. Objective is to demonstrate in-situ resource production and utilization capability sufficient for crew transportation between lunar surface and Gateway and lunar surface utilization needs. Rationale is to expedite sustainability for future moon and mars exploration and to identify future commercial markets on lunar surface.

H₂ O₂, and H₂O on the Moon will be the first priorities, for rocket fueling and life support. The importance of In situ SRU has been recognized by many countries, in particular in the US and in Europe by ESA. The challenge of a sustained and sustainable human presence in space comes with the vision of a human presence at the Moon, sustained by local resources, by 2040. With the spaceresources.lu initiative, Luxembourg aims to contribute to the peaceful exploration and sustainable utilization of space resources for the benefit of humankind. It has five strategic pillars, consisting of political support, a legal framework, research & education, innovation R&D and funding instruments. Luxembourg was a first mover and is now one of the world leaders in this domain. Global awareness has rapidly increased and Luxembourg has stepped up its international engagement. It has contributed to rapid progress on further clarifying the legal and regulatory framework. The latest major step was the creation of ESRIC (European Space Resources Innovation Centre), which will develop activities in 4 main pillars: Research, Business, Knowledge and Community.

Q&A

How do you understand «sustainable» there, in the utilization of space resources?

We do not have an intention to support activities which go against international law and space treaties. Those activities need to be authorized and we need to know which is actually happening in space. It is also important that we think about some kind of «benefit sharing» and an ethical consideration as well. Space should be explored for the benefit of everyone, for the benefit of all countries and humankind. the question is what benefits and how we can share them – science, technology, application. Another question would be how we develop our international cooperation to avoid conflicts and what would be the basic rules that we all need to respect.

You joined the ARTEMIS accords, have you ever thought of joining the Moon Agreement?

You know you ask me a controversial question. Just recently we ratified the Convention of Registration of Space Objects, We are also planning to ratify the Rescue Agreement in the future. However, we do not have plans to ratify the Moon Agreement – for the moment. But amongst the signatories of the ARTEMIS Accords, there also was Australia which signed the Moon Agreement before.

Activities on the Moon are increasingly performed by private actors. How do you see moving forward the participation and governance arrangements between national agencies/governments and private actors when it comes to utilize these resources in space?

We are currently discussing with NASA about our involvement in the ARTEMIS program, it is clear for us it will mainly be through private companies. We also promote public-private partnership, private companies will be more and more be involved, and certain capabilities rely on the private industry as well.

Which kind of companies do we see involved? Smaller or larger, more famous ones?

For smaller companies it is maybe a bit more complicated, at the same time there are also initiatives and domains where they can be very active.

How do you expect about international governance regarding space based objects resources while Trump decided that should the US be the first to land on, the object hence resources are theirs? You can share your perspective on this.

It is a national priority of the US, and for us it was very important that all issues regarding space resources are also addressed on international level, like UNCOPUOS. US were maybe more explicit about their plans, while China and Russia also plan similar missions. We shall not forget UNCOPUOS, especially its legal subcommittee. There is a real need to talk about questions related to the space resources activities and find a common ground and basic rules.

You want to make use of space resources first in space and it is water on the Moon at first and asteroids later, is this correct? If there is ever a use of resources of space like platinum metals, won't that tip the price balance in a way that it is not worth it anymore?

We want to focus on in situ resource utilization. It is not our plan to return anything to the Earth in a short term. In situ resource utilization would also involve other issues like planetary protection etc.

When are expected missions that would bring back resources on Earth by an amount sufficiently high that it would make a difference? Or at a rate comparable to the depletion rate? Are we talking 2050 or after ?

It will happen in the next 20,30,50 years. It also depends on the needs on the Earth. Even if we look at other governments plans, there is no real idea to return the materials to the Earth. The missions with plans to bring back space resources to Earth won't happen before 2050.

How would you see the opportunities of the space resources program and relate it to the sustainability challenge of planet Earth?

We saw in recent examples like the COVID crisis or environmental issues, that space applications in general contributed a lot to addressing those challenges. Regarding space resources, we also think it will support tackling some Earth challenges. We try to involve the terrestrial mining industry in our initiative and investigate how we could use their technologies in the space domain. Space resources activities can also contribute to economic growth and wellbeing. We promote the peaceful exploration of space.

Might there be a place for sustainability in the sense of environmental sustainability in your considerations after all? For example including recycling concepts?

From the environmental perspective there are challenges, such as contamination of space environment. These aspects are considered in our national strategy. We do not want to change space environment in an extend that would be detrimental We try to achieve the right balance between research, public and private interests and needs.

Andreas Losch: Maybe one can connect the space economy to the idea of a circular economy.

Challenges and Opportunities II

Forward to the Moon. Europe's exploration program Terrae Novae and Artemis

Stefaan De Mey (European Space Agency)

LINK: https://www.youtube.com/watch?v=lQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=4410s

SUMMARY: ESA'S Terra Novae program has three destinations, which are linked: LEO with the ISS, the Moon with the Lunar Gateway, and Mars. Space Care is important for ESA, what Space can do for Earth. The experience gained by the astronauts in LEO is an important capital, the overview effect is one of the things, they are symbols of our society, and role models. The current astronaut's „alpha“ mission is embedded into the SDG's. For instance, equipped gas re-liquefiers save thousands of t of CO₂.

Mars: for the sake of science and planetary protection, a rover needs to be prepared in the cleanroom. It will launch 2022. Also, a sample return mission is in the planning, ESA is building the Earth return orbiter, that will catch in Mars orbit the sample, bring it to Earth, and be reorientated to a graveyard orbit.

Moon: There are many institutional and commercial missions planned. Lunar Surface Exploration Objectives are provided by ISECG's Global Exploration Roadmap. China and Russia plan a lunar resource station, the US are planning the Artemis (and related) missions until ~2024. ESA provides the Orion module, for the first time the US allow some other country/institution to take part in critical components of their mission. Actually, 50% of the lunar gateway comes from Europe. Elon Musk's starship has just been selected as human landing module, much bigger than previous and competitor's modules. It can transport more resources but eventually also creates more dust on the surface of the Moon. ISECG'S publication „The Moon as a spaceport to the Universe“ is highly recommended. There is a carbon free process to turn regolith (simulant) into metal, extracting oxygen. Solid rocket boosters are using metals and burn metals, maybe a new carbon free type of fuel of the future. ESA's agenda 2025 includes the ambitions to set foot on the Moon in 2029, three Europeans by 2035, and 2035 also setting foot on Phobos. „Exploration is not a choice, really, it's an imperative.“ (Michael Collins)

Q&A

You mentioned the competition for the lunar module, the decision for SpaceX was juridically challenged, what delay follows?

From a legal perspective this will delay the process by 100 days, assuming the appeal is found not correct. In any case, SpaceX has been selected for the first landing only, not for all future landings.

Will the one who will visit Phobos come back to Earth?

As an agency, we will never send astronauts on one-way missions (so yes).

Will an acceleration of the mentioned activities of humans in space be possible?

Typically, an institution like ESA needs to take into account the mandates of all our member states. Sometimes, we can't be as sharp as commercial companies, which can have very long-term visions. If we as ESA say something, however, it is more carefully thought through, while what commercials say usually takes more time than originally announced. For instance, Elon Musk has not spent any thoughts on a life support system for going to Mars, which he thinks he can just buy.

Are most of the exploration plans centered around anthropogenic benefits? Are there plans to conserve some parts of Moon/Mars the way they are; similar to conservation/national parks here on Earth?

There are initiatives (for all Moonkind, e.g.) who want to preserve the Apollo landing sites, but I am not an expert on this.

Sustainable Space Logistics (SSL)

Emmanuelle David (EPFL)

LINK: https://www.youtube.com/watch?v=lQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=6466s

SUMMARY: Small Satellite launches via dispensers are one building block of SSL. There is a growing space infrastructure, regarding human space settlements, SR exploitation, and Very Large Space Infrastructure development. There is a need to put all this into space in a sustainable way. Already now, there are too many objects in space (cf. the debris problem). UNCOPUOS defines the long-term sustainability of outer space as the ability to maintain the conduct of space activities indefinitely into the future in a manner that realized the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of present generations while preserving the outer space environment for future generations.

In 2019, EPFL introduced an initiative on SSL. Logistics is the management of the flow of things between the point of origin and the point of consumption. Space logistics, is the theory & practice of driving space system design for operability, managing the flow of materials, services and information needed throughout the life cycle. We do not want repeat in space the mistakes we made on Earth, hence we want to do it in a sustainable way. Objectives of the initiative are to create and support research initiatives, build communities and develop talents in these regards. eSpace research flow follows both a top-down and a bottom-up approach. In February, we hosted the first digital SSL symposium, all videos are available on EPFL's YouTube channel³. Key outcomes are the shared urgency to act around space sustainability, there are many top-down initiatives, but there is also the need for more transparency cc space sustainability and better communication around the topic. On the second day it became clear that also non-space actors look into sustainable space logistics. Day 3 emphasized the need for a legal framework, and there is a huge challenge for the dual use of technologies. A discussion full of hope concluded the symposium. The speaker endorses the idea of an SDG18 Space environment.

Q&A

How would you balance the two pillars of sustainability, the economic and ecological one?

I wouldn't see them as separate pillars, they belong together.

What is the ambition of DHL to be part of this endeavor?

I cannot answer on their behalf, but I recommend watching their video.

³ LINK: <https://www.youtube.com/watch?v=3AyLU2w6k5c>

ClearSpace was a very successful spin-off of EPFL, what do you expect for the future?

The initiative is still young, but we expect significant research outcome, and the development key technologies out of the EPFL labs.

Biological Challenges in Space and the dialogue between theology and natural science

Oliver Ullrich (University of Zurich)

LINK: https://www.youtube.com/watch?v=IQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=8067s

SUMMARY: Biological challenges in space mean 1) effects on the space environment on humans, 2) human's efforts to overcome these challenges, 3) enabling manned space exploration. It is not only a question of possibilities, but also one of purpose and necessity. Aim and reason of human space exploration involve aspects which the experimental-empirical method cannot answer, for instance is the presence of humankind limited to Earth? There are major hazards and biological risks of space flight. Space Medicine involves proactive and reactive care of humans to optimize physical, physiological and mental well-being, within the unique constraints of an extreme environment. Most long-duration missions have been 4-7 months, a Mars mission may last up to 30 months or longer, though, it would be a mission into the unknown. Gravitational force has been constant for billions of years of evolution on Earth. The NASA Human research program defined high priority «red» risks for crew health, like space radiation, neuro-ocular syndrome, adverse cognitive and behavioral conditions, psychiatric disorders, inadequate food and nutrition. One has to consider the combined impact of all these hazards. The effects of microgravity on the musculoskeletal system can only be countered by constant exercise currently. For several reasons, infection control is difficult. For long term exploration missions we need completely new medical procedures, in particular in surgery. Good news is that the human organism, especially our cells, can adapt over time to microgravity, except bones, muscles and radiation effects. Humans can therefore conditionally exist in an environment outside Earth.

Theology provides an answer why we have to go to space: God enables and requires humankind to acquire knowledge. There is a broad biblical mandate to explore, where we have a mandate to cooperate humbly where the journey of discovery may span generations. Human exploration of space may hence generate interdisciplinary bridges and trigger a long-term learning process that is necessary for sustainable development on and beyond Earth.

Q&A

Are there any bio-robots with human tissue on board to test some effects after 6 months, is something like that planned?

That would be the next step. We have a lack of sufficient data from astronauts. Tiny organs could be a decent test subject, but their „life“ needs to be sustained as well. The first flight to Mars will hence be a high-risk mission.

Given the difficulties of long-distance manned flight, what is the rationale not to do this with robots only?

I do not see robots and humans in conflicts, both are the only ones that can do specific missions. Robots will fly first, humans will follow, as robots never will fully substitute humans.

For long-term space mission wouldn't one use a centrifuge for 1g gravitation?

This was originally planned for the ISS, but then withdrawn for technical and financial reasons. For long-term missions this could, however, be really a solution for many problems.

Do people from divergent theological backgrounds approach space exploration differently?

I do not see so many differences in accepting the human limits and there is the common sense that there is something greater than us humans, which makes a lot of dialogue possible.

Wrap up & Closing Panel

Christian Berg, Nikolai Khlystov, Dovilė Matulevičiute, Stefaan de Mey, Thomas Schildknecht

Moderation: Xiao-Shan Yap, Andreas Losch

LINK: https://www.youtube.com/watch?v=lQDIBuEiLcQ&list=PLI1mUkD-LLdWKct7p8ADNCw09v-4Lc_UR&index=2&t=10132s

What will be the most pressing issue or biggest challenge to be addressed, is there any obvious action which should be taken immediately?

Christian Berg: Everyone has his or her perspective on things. I am dedicate to the – still 17 – SDG's. There is no one root cause to the problems and there is no one size fits all answer. We have a systemic problem and need a systemic solution. We need to work towards a common understanding, a common goal, but from different angels.

Stefaan de Mey: I look from a practical perspective. A life support system is much needed for long term space missions, although we don't need it right away. The MELISSA project is on it. Almost every aspect of such a system has a relevance for Earth. It is an exemplification of a circular economy.

Christian Berg: I fully agree, as I use to take the water supply in the ISS as an example for a circular systems in lectures. Basically, we have the same issue for the globe.

Xiao-Shan Yap: Being based at EAWAG I have to add to this. We have both scientists working for developing countries and on the MELISSA project, there is often cross-fertilization in the discussions.

Dovilė Matulevičiute: From my legal perspective, we need to address international practices and rules, minimum standards which will have to be respected by all countries going to Moon, Mars or anywhere else.

Thomas Schildknecht: The issues with sustainability in outer space are very similar to those in other areas (on Earth). Most urgent is a short term issue, how to deal with the upcoming mega-constellations in near Earth space. It is a factor of 10 or 100 more than previously, and discussions in COPUOS and such need to speed up. In long term regards, it is like climate change. We have to agree on a limit.

Nikolai Khlystov: From a technical angle I agree with Thomas about the urgency cc debris, that's critical. That doesn't prevent us from having experts on focusing other elements, maybe not as urgent, but not less important. We need to start talking about how we approach the resources issue. People underestimate the significance of this development for the 100-200 years, and its potential to transform human civilization and life on Earth. The question how to share the benefits remains. Probably we will even have not one approach, but two camps on the Moon.

How do you see balancing the opportunities from space based infrastructures to promote sustainable development on Earth?

Christian Berg: I am skeptical about the involvement of the private sector in space flight, as they want ROI, but there are legal issues which need to be sorted out. I am afraid that we continue the growth paradigm to space, which will not work anymore, we need to think of more sustainable patterns of living and doing business. We should explore the opportunities that are there, but I also see the legal and geopolitical issues we need to address before we really make these current projects real.

What will be the kind of governance structure which will be more promising?

Dovilė Matulevičiute: For many years, e.g. in UNCOPUOS, we have worked on non-binding soft law instruments. However, with the space debris there is the need for some kind of a basic set of rules, which will be respected by everyone. Some kind of common ground, maybe at international level of like-minded countries, maybe at UNCOPUOS level. Governance is important especially with regard to the private sector, we have to supervise those activities and to assure responsible and sustainable operations in space.

What is your perspective on the role of ESA in space sustainability?

Stefaan de Mey: At ESA, we try to be responsible, not only regarding space debris. The only thing we can do is try to be a role model for example.

What can research on (planetary) sustainability help the discussion and political decisions?

Christian Berg: Ellen McArthur foundation for circular economy was established because of the founder's experience of a very limited and confined environment when sailing self-handedly around the world. We as humanity need to understand we live in a finite environment. Political leader soften know what needs to be done, but have no majority to do so. Science needs to speak up to create pressure on the politicians.

What could faith leaders contribute to enable the discussion on sustainability?

Thomas Schildknecht: SpaceX is a big business case, nevertheless Musk invested a lot into improving the sustainability of Starlink – Because of public and stakeholder pressure and stakeholder to be „the nice guy“. We need to try all these instruments, already known in other domains.

Would an SDG 18 help discussing the integrated dimension of sustainability topic of this workshop?

Nikolai Khlystov: *CC governance first*, which Christian and Dovilė referenced: there is no going back, it is a governmental AND private sector now. We need stakeholders to participate and also achieve some results. Without private investments and innovations we wouldn't be where we are today.

CC SDG 18: is a very interesting concept to make challenges more publicly known.

Stefaan de Mey: Planetary Sustainability as an 18th goal is more like an overarching thing compared to the other goals which might be confusing, concrete targets for this 18th SDG would help clarifying where you want to go.

Thomas Schildknecht: I was in favor of such an 18th SDG for a long time. I am not sure if „planetary sustainability“ as a term would be good, though. What is missing in the sustainability discussion is that people are not aware there is something above the atmosphere which is closely connected to the sustainability discussion on Earth. The data we use for climate models, they come from space, for instance. There is very little awareness of this.

Christian Berg: There is little awareness of the 17 SDG's already. It is also an odd number, because it was outcome of a political process. It is pie in the sky if it is possible at all to achieve them all at once. Sustainability understood in this way is a problem of optimization, with 169 targets. On the other

hand, we do need more awareness of the leveraging capacity and aspect of space science also to be more sustainable on Earth, but you understand now why am a bit hesitant.

Dovilė Matulevičiute: I think as soon as we start talking about SDG's we also need to think about knowledge and an education effort.

Oliver Ullrich: We should careful not to separate Earth from space too much, I would be in favor of an SDG18 solution which unites the goals on and beyond Earth. The first goal should be to enhance the awareness, there an SDG18 could help.

Gaetan Petit: I would focus on the first step, raising awareness, following with a more sustainable space utilization.

Xiao-Shan Yap: Governance through goals often did not lead to concrete results, although there are benefits if we include space sustainability in the SDG discussion. Half of the current SDG's can only be measured by space based technologies, so space should be integrated into the perspective.

Andreas Losch: *my motivation is that we have the planetary boundaries, but space is not part of this concept yet, sorts of „orbital boundaries“ would help; it is, however, clear that even if we achieve all the SDG's, this could transgress the planetary boundaries already, there is research on that, so we need to be cautious about what we are doing. Maybe an SDG 18 can help. Thanks to all speakers and all who participated!*

Responses

- Many thanks to the organizers!
Great ideas, excellent speakers! Very well organized! Cheers!
- I really thank you for the organization of this very precious workshop full of insights!
Again thank you very much!
- Thank you very much for the event, it was awesome. So many insightful, inspiring presentations and conversations!
- thanks to the organizers
- A fabulous event - thank you to all involved!
- Many thanks for these most excellent sessions. My question ... would be - what, from your perspective, do you think Space Agencies should be doing now (and in the near future) to support and progress more rapidly mitigations in areas such as space debris - is it investment / funding, awareness raising, applying to change legislation / regulation, or other things?

Appendix: Speakers bios

Dr. Natália Archinard holds the space portfolio at the Federal Department of Foreign Affairs of Switzerland. She has been leading the Swiss delegation to the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) for more than a decade and serves as the Chair of the Scientific and Technical Subcommittee of COPUOS for the period 2020-2021. Ms Archinard has been representing the Swiss government in multilateral negotiations on space security and sustainability-related initiatives, including the development of the Guidelines on

the Long-term Sustainability of Outer Space Activities within COPUOS and the draft International Code of Conduct proposed by the European Union in 2012-2015. She is member of the Swiss delegations to the European Space Agency (ESA), including at ministerial level, and to the United Nations General Assembly 1st and 4th Committees. At national level, she is involved in the design and the implementation of the Swiss space policy. Dr Archinard was educated in mathematics at the University of Geneva and obtained her PhD from the Swiss Federal Institute of Technology (ETH) Zurich.

Dr. Andreas Losch, MBA is an award-winning theologian, specializing in the dialog with the sciences and with philosophy. He was managing editor of the Martin Buber edition, coordinated the project “Life beyond our planet?” at the Center for Space and Habitability (CSH) Bern and works as researcher affiliated with the Theological Faculty of the University of Bern on „Ethics of Planetary Sustainability“. As such he was active participant of the UNISPACE+50 preparatory event. Losch is a member of the Center of Theological Inquiry (CTI), Princeton, New Jersey, and he serves on the council of the European Society for the Study of Science and Theology (ESSSAT) and on the board of trustees of the Karl Heim Society. He is also editor-in-chief of the theology & science website www.theonat.info.

PD Dr. André Galli

received a Ph.D. in Physics from the University of Bern in 2008. After a period as an engineer and technology consultant and his post-doctoral period at the Netherlands Institute for Space Research, he rejoined in 2012 the University of Bern as a scientist. His research topics cover a broad range from laboratory experiments in the context of icy surfaces in the solar system, data analysis for space missions (Mars Express, Venus Express, IBEX, Rosetta), to project science and management for upcoming space missions (JUICE and IMAP in particular).

Prof. Dr. Christian Berg has extensive professional experience as sustainability lecturer and keynote speaker for (corporate) sustainability. Among others, he worked as Chief Sustainability Architect at SAP and led the task for Sustainable economic activity and growth within German Chancellor Merkel’s future dialogue. His book “Sustainable Action. Overcoming the Barriers” was accepted as the new report to the Club of Rome. Therein he gives a comprehensive account of barriers to sustainability and suggests action principles for sustainability which support actors in contributing to the realization of the SDGs. He holds degrees in physics, philosophy, theology and engineering. For more information, please see www.christianberg.net or visit his profile on [LinkedIn](#).

Dr. Xiao-Shan Yap is a research scientist at the Environmental Social Sciences department at Eawag in Switzerland and a guest Assistant Professor at Copernicus Institute of Sustainable Development, Utrecht University. Although trained as a Development Economist, Xiao-Shan has worked across different social sciences disciplines with her primary focus on development and sustainability issues. In the past, she has run empirical fieldwork on sectors ranging from semiconductors and integrated circuits to solar photovoltaic energy integration, as well as water recycling and sanitation, across different countries including Taiwan, China, India and South Africa. In 2020, she founded the [Earth-Space Sustainability](#) research initiative, with the aim of using evidence-based social science research to inform forward-looking policy scenarios concerning Space governance.

Prof. Dr. Thomas Schildknecht is a leading expert on space debris, space safety and space sustainability. Under his leadership for more than 25 years, his research group has acquired a World-class expertise in the observation and the characterization of space debris. He is the Director of the Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald and the Vice-Director of the Astronomical Institute of the University of Berne (AIUB), Switzerland. At both, national and global level, he has served and continues to serve in numerous technical and policy-making committees. He is a member of the Swiss delegation at UNCOPUOS and substantially contributed to the work of its working group on long-term sustainability of outer space activities. At ESA he is currently the Chair of the ESA Space Safety Advisory Group advising the ESA Director responsible for the space safety programme.

Luc Piguet is the CEO and co-Founder of ClearSpace, a ground-breaking initiative based in Lausanne to clear up Space debris. In November 2020 ClearSpace SA signed a service contract with the European Space Agency (ESA) worth 86.2 million euros to remove orbital debris. This mission, named ClearSpace-1, will see the first debris removed by 2025. Luc studied at EPFL, with a degree in Electrical Engineering and an Executive Program at Stanford GSB.

Nikolai Khlystov is the Lead for Future of Mobility Platform and Space at the World Economic Forum, in Geneva. Nikolai leads the various efforts on space like the Global Future Council on Space and the Space Sustainability Rating. He has supported the Socio-Economic Panel of the Hague International Space Resources Governance Working Group and has appeared on a number of space related panels. Nikolai is a Russian Canadian and first became interested in space in his last year of university's bachelor degree.

Dr. Gaetan Petit is the co-founder of [Space4Impact](#), an initiative that aims at fostering the economic growth of space activities in line with the UN SDGs for a sustainable future. Gaetan worked as a technology transfer officer at the Swiss Space Center and as a scientist at the European Space Agency's Advanced Concepts Team. Gaetan holds an engineering degree from EPFL Lausanne and a PhD in Neuroscience from ETH Zurich.

Ms. Dovilė Matuleviciute currently holds the position of policy officer responsible for legal affairs at the Luxembourg Space Agency (LSA). At the LSA, her fields of expertise are international affairs and relations as well as legal and regulatory issues. Ms. Matuleviciute is a delegate of Luxembourg to the International Relations Committee of ESA, the United Nations COPUOS Scientific & Technical Subcommittee and Legal Subcommittee. Before joining the Ministry of the Economy and the Luxembourg Space Agency in 2016, Ms. Matuleviciute worked at a private space company where she was managing legal and contractual matters. She gained her first experience in various fields, such as business law, markets regulation & competition law, intellectual property law, international public law and European Union law, at multiple internationally recognized law firms based in Vilnius, Berlin, Paris and Brussels.

Dr. Stefaan De Mey is a senior strategy officer in the Directorate of Human Spaceflight and Robotic Exploration Programmes of the European Space Agency (ESA) where he coordinates the strategy area for human and robotic exploration. In this role he is also representing the Directorate in relevant European and international strategic networks, such as e.g. the International Space Exploration Coordination Group. From 2011 to 2016 he has been Secretary General of Eurisy, an international association of Space Agencies, with a mission to

bridge space and society by promoting uptake of satellite data and services, and policy and operational research. In this function he has also been acting as Eurisy's GEO principal alternate and Eurisy delegate to the UN Committee for the Peaceful Use of Outer Space. Prior to this position at Eurisy, Dr. De Mey has acquired extensive experience in Exploration programmes, providing the integration management function for ESA payloads/experiments selected for the International Space Station (ISS), and system engineering functions e.g. for biomedical research in microgravity, the EXPERT re-entry vehicle and launcher services, and the ASIM Earth Observation system for high altitude lightning. He started his career as a researcher in the field of cardiovascular fluid dynamics and the non-invasive diagnosis of heart failure using ultrasound. Dr. De Mey holds a PhD from Ghent University, a Master degree in Civil Engineering, and a Bachelor degree in Law.

Ms. Emmanuelle David is the executive manager of the EPFL Space Center. The EPFL Space Center (eSpace) is an interdisciplinary unit responsible for the federation of space activities at the school and co-lead a research initiative on sustainable space logistics. Emmanuelle has 10 years' experience in space transportation in academia, agency and industry from pre-development projects up to launch operations. She holds Space Engineering degrees both from the University of Technology of Compiègne, France, and the Technical University of Braunschweig, Germany.

Prof. Dr. Dr. Oliver Ullrich is Full Professor of Anatomy / Gravitational Biology and Cell Biomechanics, University of Zurich (UZH) and Director of the UZH Innovation Cluster Space and Aviation (UZH Space Hub), Professor of Space Medicine, EAH Jena and Professor of Space Biotechnology, Otto-von-Guericke-University Magdeburg, Germany, and Adjunct Professor, Beijing Institute of Technology (BIT). He is an elected Academician of the International Academy of Astronautics, President of the Swiss SkyLab Foundation, Vice President of the German Society for Aerospace Medicine, member and chair of different advisory boards for aerospace agencies and companies, and recipient of several research and teaching awards. He is experienced as scientific leader of more than 35 parabolic flight, suborbital and orbital research missions, including the International Space Station (ISS), and is working for the US (NASA-UZH Space Act Agreement) and the European (ESA) space program in the field of gravitational biology and space medicine. He is a physician and biochemist, habilitated in anatomy and cell biology and specialized in molecular immunology and aerospace medicine. He also graduated in "Teologia del Popolo di Dio" at the Pontifical Lateran University, Vatican.