THE IMPORTANCE OF DARK AND QUIET SKIES IN SWISS ASTRONOMY AND THE DIALOG WITH THE SPACE INDUSTRY

E. David[(1)], S. Hellmich[(2)], and C. Crichton[(2)]

[(1)]*EPFL Space Center, EPFL, Station 13, 1015 Lausanne, Switzerland, Email: emmanuelle.david@epfl.ch*
[(2)]*EPFL, LASTRO, Versoix, Switzerland, Email: stephan.hellmich@epfl.ch*

ABSTRACT

Switzerland has a significant stake in preserving dark and quiet skies due to its active role in global astronomical research and its industrial contributions to space technology. Swiss astronomers actively contribute to multiple large-scale observatories and research initiatives, including SKAO, CTAO, MeerKAT, MWA,HIRAX, and ngEHT, which are negatively impacted by the RFI emitted from satellites. Additionally, Swiss astronomers utilize archival data from optical telescopes, such as the VLT Survey telescope (VST), the CHEOPS space telescope, NGTS, and the Swiss Euler Telescope, which are increasingly affected by satellite trails, especially from low Earth orbit (LEO) satellite constellations. Such interference is posing challenges in accuracy and can result in causes data loss, in particular for long exposures with wide-field telescopes and spectrographic observations.

Swiss industry's involvement in large satellite constellations also raises complex challenges, as increased satellite traffic not only threatens the pristine skies vital to radio and optical astronomical observations, but the increasing number of satellites could impact the satellite industry itself.

Recognizing this dual commitment to industry and science, EPFL is organizing dialogues among radio astronomers, space sustainability advocates, and industry leaders to balance these interests and convey Swiss perspectives at international regulatory forums, such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and the ITU (International Telecommunication Union). In addition, EPFL is involved in concrete initiatives such as the ESA Zero Debris Technical Booklet and the IAU Center for the protection of the Dark & Quiet Skies from Satellite Constellation Interference (CPS), proposing hands-on solutions with the large industry players.

The paper will present different Swiss stakeholder engagement initiatives. Then it will highlight Switzerland's position within these dialogues, focusing on the regulatory, scientific, and collaborative imperatives driving the push for preserving dark and quiet skies. Finally, it presents knowledge gaps and needs for research projects that are required to enhance a solution-driven dialogue.

Keywords: switzerland, dark and quiet skies, community dialogue.

1. INTRODUCTION

The exponential growth in the number of satellites in Low Earth Orbit (LEO) represents one of the most significant challenges to astronomical research in the 21st century. With more than 7,000 Starlink satellites already deployed and projections that suggest up to a million additional satellites from various operators within the next decades [6], the scientific community faces unprecedented interference with optical and radio observations. This rapidly evolving situation threatens substantial investments in next-generation astronomical infrastructure, including Switzerland's significant contribution to the Square Kilometre Array Observatory (SKAO).

The impacts are twofold: optical telescopes contend with satellite trails that compromise image quality and data integrity, while radio telescopes experience increasing radio frequency interference (RFI) from intended and unintended satellite emissions. Initial studies indicate that when proposed constellations are fully deployed, approximately 30 to 40% of exposures during twilight hours at facilities such as the Vera C. Rubin Observatory will be compromised [9]. Similarly, radio astronomers documented concerning levels of unintended electromagnetic radiation from satellites [4] that is not addressed in existing regulatory frameworks.

Switzerland occupies a unique position in this landscape, maintaining both significant astronomical research interests and a robust space technology sector. This dual engagement creates responsibilities and opportunities for Switzerland to contribute meaningfully to solutions that balance technological advancement with the preservation of scientific capabilities. The country's tradition of diplomatic neutrality and consensus-building further enhances its potential to facilitate productive dialogues between stakeholders with divergent interests. Swiss initiatives like the Space Sustainability Rating (SSR) [1] demon-

strate this capacity to bring together diverse stakeholders around shared sustainability objectives.

This paper examines the specific question: What technological and policy innovations from Switzerland could contribute to mitigating the impacts of the increasing number of satellites on astronomical observations?

This question is tackled through multiple dimensions: First, the paper establishes the current status of dark and quiet skies challenges and Switzerland's historical contributions to astronomy and space technology. Second, the mapping of the Swiss stakeholder landscape across the academic, governmental, and industrial sectors is depicted. Third, an analysis of ongoing Swiss dialogues that focus on regulatory, scientific, and collaborative imperatives is performed, including Switzerland's participation in international efforts such as the IAU CPS [15]. Finally, the paper proposes a strategic framework through which Switzerland can leverage its unique capabilities to advance practical solutions for protecting dark and quiet skies, based on ongoing initiatives such as ESA's Zero Debris approach [18].

Throughout this analysis, the paper emphasizes the importance of evidence-based approaches and multi-stakeholder engagement. By documenting current Swiss initiatives and proposing strategic enhancements, this paper aims to contribute to a solution-driven dialogue that preserves the astronomical commons while enabling sustainable development of space-based infrastructure. The perspectives presented reflect the authors' analysis and proposed directions rather than the official positions of the Swiss government or EPFL.

2. BACKGROUND

The following section will introduce the current status, mitigation efforts and challenges of astronomy, and the Swiss legacy in the space industry.

2.1. Current status, mitigation efforts and challenges for astronomy

The steeply increasing number of satellites in Earth's orbit is raising concerns among astronomers who are currently more or less defenseless against the impact of the growing activities in space. The implications caused by the large number of satellites from several proposed large constellations for optical observations were already studied when the first batches of Starlink satellites were launched [9]. It was realized that next-generation survey telescopes such as the Vera C. Rubin Observatory would be severely impacted: when the proposed constellations are fully deployed, about 30 to 40% of the exposures during the first and last hours of the night are compromised. These findings led to discussions with SpaceX and resulted in several experiments to reduce the brightness of their satellites that have been in turn evaluated by astronomers [10, 19, 11]. While special treatments to reduce reflectivity and visors to avoid the reflection of sunlight toward Earth appeared to be less efficient, better effects could be achieved by decreasing the operational altitude and orienting the satellites in a way that the solar panels, which represent the largest surface, expose only the dark sides to the observer [12]. Apart from the IAU recommendation of a maximum brightness corresponding to a minimum magnitude of 7 [3], there are currently no restrictions on the maximum optical brightness of satellites or regulations for mitigation measures to reduce brightness in satellite design or operation. This means that the efforts described above are based on goodwill of satellite operators, and it can not be expected that the operators of all constellations that are currently installed in orbit will be as cooperative as SpaceX currently is. Satellites from the AST direct-to-cell communication constellation BlueBird [13] or other proposed large-scale infrastructure in orbit such as space-based solar power [17] will never reach the magnitude 7 requirement of the IAU which means that interference with optical observations can only be avoided by dodging them, a solution that works as long as there are not too many bright objects. In addition to orbital data, this approach also requires knowledge of the shape and reflectance properties of the surface materials to estimate the brightness of a satellite, information that satellite operators usually do not provide. These characteristics are currently tediously obtained by astronomers who conduct observation campaigns coordinated by the IAU CPS in order to improve models to estimate the brightness of satellites [7].

Compared to observations in optical and infrared which are currently not protected, in radio astronomy, there exist regulations to avoid radio frequency interference (RFI) caused by emissions from ground- and space-based infrastructure. Radio observatories are usually protected by declaring the regions around the observatories as radio quiet zones, certain frequency bands are dedicated to radio astronomy to avoid interference with the observations, and satellite operators are required to use only the frequency bands that they have registered with the International Telecommunication Union (ITU). However, because certain observations are also made on wavelengths other than the protected bands, these observations are increasingly affected by the growing number of satellites [5, 21, 22]. In addition, interference caused by unintended emissions from Starlink satellites was recently detected [4]. While interference from intended emissions can be mitigated by turning off the transmitter while passing over a radio observatory or pointing the antenna away from it [14], the unintended emissions are currently raising major concerns in the radio astronomy community. These emissions are caused by low-frequency radio signals that leak from the onboard electronics and because they are unintended, they are not covered by any existing regulation.

Historically, RFI mitigation in radio astronomy involved the detection of interference and flagging the affected

data such that it can be excluded from further analysis. However, this approach can be used only as long as there are relatively few satellites and few data is lost. With the emerging large satellite constellations, new techniques are required to avoid excessive data loss. A promising but computationally expensive approach is to subtract RFI based on the trajectory of the satellite causing the interference and the characteristics of the emissions [8]. This technique requires precise orbital data and ideally a priori knowledge of the spectral characteristics for each source of interference. While orbital data is usually available, spectral properties, in particular for unintended emissions, are unknown because there are no tests foreseen to characterize such emissions before a satellite is launched. The signature and intensity of unintended emissions are very specific to the satellite design and was found to vary greatly between different versions of satellites in the same constellation [2]. Considering the large number of proposed satellites in large constellations, RFI removal techniques alone are not sufficient to mitigate interference in the future. Regulations are required to reduce unintended emissions by improving satellite design. To formulate such recommendations, a precise analysis of the implications of unintended emissions and effectiveness of RFI subtraction for next-generation radio experiments such as the SKAO is necessary. It was proposed to construct observatories in places that are free from RFI such as the far side of the Moon [16]. However, increasing activities on and around the Moon are endangering such endeavors if no regulations are implemented to protect astronomy and science on the Moon [20].

Astronomers around the world are raising awareness, collect data to quantify the problem, and advocate for the protection of the dark and quiet skies. The results of their work can provide the foundation for a dialogue with industry and policy makers to jointly develop evidence-based recommendations and requirements that can eventually be implemented in international regulations. However, a major challenge is the enormous pace in the satellite industry. In just five years, SpaceX has more than doubled the number of active satellites by placing more than 7000 Starlinks in LEO, and another 35000 satellites will follow over the next decade. And Starlink is not the only large constellation: Currently, there are more than a million satellites filed with the ITU [6]. This does not mean that all of these satellites will actually be sent into orbit, but it does give an impression of what to expect in the near future. In order to protect astronomy from interference caused by these satellites, astronomers and industry must work together to implement mitigation measures even before regulations exist. Otherwise, enormous investments in next-generation observatories such as the SKAO)or the Vera C. Rubin Observatory are at stake.

Finally, in 2007, the participants of the International Conference in Defense of the Quality of Night Sky and the right to observe stars, jointly with the representatives of UNESCO, UNWTO, IAU declared that "An unpolluted night sky that allows the enjoyment and contemplation of the firmament should be considered an inalienable right equivalent to all other socio-cultural and environmental rights. Hence the progressive degradation of the night sky must be regarded as a fundamental loss". It shows that the dark and quiet skies also have strong cultural roots that consolidate the argument to protect them.

2.2. Switzerland legacy in space swiss and technology

Switzerland has established a notable presence in space exploration despite its modest geographical footprint. As a founding member of the European Space Agency (ESA), established in 1975, Switzerland demonstrated an early commitment to cooperative space endeavors by ratifying all UN space treaties between 1969 and 1978, with the exception of the Moon Agreement.

Swiss scientific contributions began with the Apollo missions, where a Swiss solar experiment reached the lunar surface. The paper will not list all the contributions to space from the Swiss community, but it is noteworthy that Michel Mayor and Didier Queloz were awarded the Nobel Prize in 2019 for the discovery of the first exoplanet orbiting a main-sequence star in 1985. With CHEOPS, an ESA mission to study exoplanets, whose principal investigator is Prof. Willy Benz from the University of Bern, Switzerland remains in a leading position in the field of exoplanet research. In parallel, Switzerland joined the SKAO in 2019, one of the largest infrastructures under construction for radio astronomy.

This tradition of excellence continues through Switzerland's participation in the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), where it is contributing to global space governance discussions since 2008.

The Swiss flag has been carried into space by EPFL Professor Claude Nicollier and soon Marco Sieber, who was recently selected for ESA's newest astronaut cohort, ensuring Swiss representation in human spaceflight continues into the next generation. Today, Switzerland is making an active contribution to the International Space Station (ISS), the future outpost "Lunar Gateway" and the "ExoMars" and "Mars Sample Return" missions.

Switzerland also boasts a robust space industrial base, with companies like APCO and Beyond Gravity leading a diverse ecosystem of innovative enterprises. These organizations exemplify the precision engineering and technical excellence that Switzerland brings to international space endeavors, complemented by a strong network of emerging start-ups and scale-ups.

3. STAKEHOLDER MAPPING

In January 2025, the first Swiss space sustainability research days took place in Les Diablerets. The aim of the event was to strengthen the connections within the research community and to share the expertise to strengthen

the Swiss positioning. For the thematic of dark and quiet skies, governmental, academic actors as well as private individuals attended the event and actively contributed to the discussions.

3.1. EPFL Space Center's Established Role in Space Sustainability

The EPFL Space Center has established itself as a key contributor to international space sustainability initiatives through its technical expertise and multi-stakeholder engagement capabilities. The Center's recognized authority in this domain has led to numerous invitations to participate in high-level forums and working groups.

The Center's contributions to space sustainability span multiple dimensions across policy, methodology, regulation, and scientific domains. In the policy arena, EPFL Space Center actively participated in the co-development of the Zero Debris Charter and subsequent production of the Zero Debris Technical Booklet, while also becoming a signatory to the Statement for a Responsible Space Sector. Regarding methodological advancements, the Center has been a regular contributor to the Stuttgart Workshop on Life Cycle Assessment (LCA) of Space Transportation Systems since its inception in 2022.

The Center's influence extends to regulatory frameworks through its selection for the Technical Secretariat developing the Product Environmental Footprint Category Rule (PEFCR) for space, an initiative led by the European Commission (2024-2027) that will directly inform the EU Space Law and establish mandatory environmental standards for future European space systems. This regulatory expertise was further recognized when the European Parliament's Panel for the Future of Science and Technology (STOA) invited the Center to contribute to the consultations "The Future of Space - the Sustainable Path" for the European Space Law.

In the specific domain of protection of the dark and quiet skies, EPFL maintains an active membership in the IAU CPS, with formalization as an academic partner expected in 2025. This work is conducted within the framework of SKACH, Switzerland's contribution to the SKAO. Furthermore, Prof. Kneib, academic director of the EPFL Space Center was nominated together with Prof. Schildknecht from the University of Bern, to act as scientific experts in the Focus Group of the Group of Friends on dark and quiet skies for science and society, established in 2023 in the context of the UN COPUOS.

At the national level, the Center contributes to the development of the forthcoming Swiss Space Law while fostering inter-institutional collaborations with Swiss centers of excellence including the University of Bern, ETHZ, University of Geneva, Paul Scherrer Institute, University of Neuchatel, and University of Zurich. The successful organization of the Swiss Space Sustainability Research Days in January 2025, which convened 50 participants in Les Diablerets, exemplifies this commitment to national coordination. Additionally, the Center disseminates specialized knowledge through teaching at both EPFL and ETHZ, while offering continuing education for space professionals to advance sustainability principles within the space economy.

The demonstrated impact of these initiatives and the significant interest they have generated within both Swiss and international communities have created opportunities for expanded collaboration. This proposal aims to strengthen the EPFL Space Center's strategic positioning and enhance its engagement with the broader space community, particularly in addressing dark and quiet skies protection challenges.

3.2. Swiss Academic players

From an academic perspective, Switzerland hosts diverse expertise relevant for the protection of the dark and quiet skies. The University of Geneva has pioneered methods for mitigating interference in radio astronomy data caused by satellite transmissions. At EPFL, the Space Situational Awareness team conducts optical observations and monitoring of satellites and debris, while specialized research groups focus on physical characterization of space objects. The Space Sustainability Rating Association promotes responsible behavior among space actors and has conducted exploratory work to develop a module to evaluate the effects of a space mission on the dark and quiet skies. The Astronomical Institute of the University of Bern host (AIUB) is operating the Zimmerwald Observatory, previously led by Prof. Schildkneicht and from 2025 onward by Prof. Lucia Kleint, which also hosts the Swiss Optical Ground Station and the Geophysical Observatory. The University of Bern further hosts and operates the European Expert Centre for Space Safety. The Department of Evolutionary Biology and Environmental Studies at the University of Zurich is extending Earth-space system science to encompass the dynamic space environment, including reentry pollution and light pollution impacts. The ethical dimensions of planetary sustainability are being examined at both the University of Zurich and the University of Bern, where researchers are formulating critical questions for the field. Although not exhaustive, this overview demonstrates how Switzerland's academic landscape enables multidisciplinary approaches to challenge for protecting the dark and quiet skies.

3.3. Swiss administration

On the administrative side, Switzerland is represented at the ITU and the UN COPUOS. The entity representing Switzerland in the ITU is the Federal Office of Communication (OFCOM or BAKOM)[1]. The Federal Office of Communications can rely on the technical ex-

[1] https://www.bakom.admin.ch/bakom/en/homepage.html

pertise of the Committee on Radio Astronomy Frequencies (CRAF) of the European Science Foundation. The Department of Foreign Affairs (FDFA) which represents Switzerland in the UN COPUOS is supported by several academic experts and all Federal departments work collaboratively to represent Swiss interests in these forums.

Finally, the Swiss armed forces are currently validating the new budget for a space domain. The key competence that is developed is Space Domain Awareness. For intelligence purposes, it is important to establish the ability to monitor the activities of all actors in this operational domain. The technologies developed for such purposes are also relevant for the protection of dark and quiet skies. In this matter, the spillover will be positive for the scientific community.

3.4. Swiss industry

Despite Switzerland's modest size, several companies are developing significant expertise in Space Situational Awareness (SSA) and Space Traffic Management (STM) that directly impacts or supports dark and quiet skies initiatives. s2a-Systems provides comprehensive optical observation capabilities spanning from LEO to cislunar space. Their observations provide precise positions of space objects, which represents critical data for flight dynamics teams to determine the state of their spacecraft. Their capabilities extend to monitoring the status and behavior of individual Resident Space Objects (RSOs), which involves regularly observing the vicinity of objects and identifying nearby objects. Spacetalk facilitates the global exchange of high-quality data among space actors without providing collision analysis directly. Their platform supports the sharing of SSA data products and contact details, enabling each stakeholder to conduct independent assessments and establish contact with other actors when needed. This solution could also serve as a valuable platform for scientific and industrial communities to exchange data, particularly in providing astronomers with the information necessary to schedule their observations and space debris researchers with important data to assess the debris environment. Additionally, larger industry players such as Beyond Gravity are developing complementary solutions in this domain, further enriching Switzerland's industrial ecosystem for space sustainability.

3.5. Swiss NGOs Supporting Dark and Quiet Skies Initiatives

Several Swiss-based organizations offer potential support mechanisms for dark and quiet skies initiatives through complementary approaches and expertise. Geneva Science and Diplomacy Anticipator (GESDA)'s Science Breakthrough Radar (`https://radar.gesda.global/`) identifies untapped space resources, including Earth observation capabilities, solar power, vacuum, and microgravity. This radar framework presents an opportunity for integration with dark and quiet skies initiatives, enhancing both scientific observations and resource utilization considerations. The Geneva Science-Policy Interface (GSPI) (`https://www.gspi.ch/`), based at the University of Geneva, serves as an independent platform that promotes science-informed solutions to complex global challenges. Their focus on connecting scientists with policy actors from Geneva-based international organizations ideally positions them to advocate for the protection of the dark and quiet skies through evidence-based policy recommendations. The Geneva Centre for Security Policy (GCSP) advances peace, security, and international cooperation through knowledge sharing, skill development, and network building. Their Prize for Transformative Futures in Peace and Security, which attracted 171 submissions in 2023, awarded the third place to the Space Sustainability Rating in that year.

The complex interplay between scientific advancement, policy development, and security concerns creates multiple entry points for dark and quiet skies advocacy. The Space Sustainability Rating ([1]) incentivizes private actors to adopt sustainable behaviors in space. Although dark and quiet skies considerations are not yet formally incorporated into the SSR methodology, preliminary efforts to extend the rating system have begun. This represents a promising avenue for integrating the protection of astronomical observation into broader space sustainability frameworks. In a context of increasing geopolitical tensions, these organizations collectively offer support through scientific anticipation (GESDA), science-policy translation (GSPI), international cooperation frameworks (GCSP), and sustainability metrics (SSR). The fine boundary between sustainability and security concerns provides a strategic opportunity to position dark and quiet skies preservation within multiple policy frameworks, potentially increasing support from diverse stakeholders.

4. SWISS DIALOGUES FOCUSING ON REGULATORY, SCIENTIFIC AND COLLABORATIVE IMPERATIVES

Switzerland is actively involved at both national and international levels, driving efforts to protect Dark and Quiet Skies. Our contributions focus on three key areas: shaping regulatory policies to mitigate satellite interference, advancing scientific research to develop data-driven mitigation strategies, and strengthening international partnerships to foster coordinated solutions across borders. Through direct engagement with policymakers, research institutions, and industry leaders, Switzerland is committed to ensuring that space activities progress while safeguarding the needs of astronomy and broader sustainability in space.

4.1. Regulatory & Policy Engagement

Switzerland is actively shaping international discussions on dark and quiet skies through its involvement in key regulatory forums. At the UN COPUOS, Switzerland supports enhanced governance to limit radio and optical interferences from satellites with astronomical observations. Switzerland also helped secure the protection of dark and quiet skies as a formal agenda item at the UN COPUOS Scientific and Technical Subcommittee.

As part of this effort, Switzerland is a committed member of the Group of Friends (GoF) on Dark and Quiet Skies at UN COPUOS, a diplomatic initiative focused on policy recommendations for mitigating satellite impacts. Professor Thomas Schildknecht (University of Bern) and Professor Jean-Paul Kneib (EPFL) were nominated as expert in the focus group of the GoF, contributing to the Conference Room Paper (CRP) that outlines practical steps for reducing satellite brightness, controlling unintended electromagnetic emissions, and improving data-sharing between satellite operators and the scientific community. Their work ensures that regulatory and policy discussions remain informed by scientific expertise.

Switzerland is also actively involved in the Committee on Radio Astronomy Frequencies (CRAF), which advises European regulators on protecting radio astronomy from interference. Through CRAF, Swiss experts contribute to policies that address unintended emissions from satellites, spectrum management strategies, and the long-term protection of radio-quiet zones.

At the national level, Switzerland has called for systematic monitoring of satellite radio emissions to support evidence-based policymaking. The Federal Office of Communication (BAKOM) continues to engage with European partners to align regulatory approaches. By participating in these international and national efforts, Switzerland is helping to shape policies that balance technological progress with the need to preserve the night sky for future generations.

4.2. Scientific Contributions

Swiss research institutions, particularly EPFL, the University of Geneva and the University of Bern, are at the forefront of developing mitigation strategies to protect dark and quiet skies. This includes optical calibration techniques to model satellite reflections, RFI monitoring, and advancements in data processing to correct for satellite contamination in astronomical observations.

Recent efforts have focused on mitigating unintended electromagnetic radiation (UEMR), a growing challenge for radio astronomy. TABASCAL, a Bayesian inference framework, is being used to identify and subtract RFI caused by satellite emissions, improving data clarity in radio astronomy. Tests on real observational data, including EDA2 telescope data, have demonstrated its ability to distinguish and remove UEMR from Starlink satellites, improving radio interferometric imaging. These advances are critical for protecting the SKAO, which relies on clear frequency bands in the 50-350 MHz range, many of which remain vulnerable to interference.

4.3. International Collabration

Switzerland's dialogue with industry stakeholders is critical to balance scientific priorities with commercial interests. The Swiss Space Sustainability Research Days convene experts from academia, industry, and government to identify practical solutions for satellite design and operations that reduce sky pollution. Discussions with satellite operators emphasize the need for voluntary brightness mitigation measures, improved orbital data sharing, and industry participation in scientific impact assessments. Furthermore, a potential formalization of the partnership with the IAU CPS would strengthen global efforts to promote sustainable space practices.

By integrating regulatory, scientific, and collaborative approaches, Switzerland is positioning itself as a leader in advancing policies and technical solutions that protect the night sky while enabling responsible space development. The ongoing dialogues ensure that astronomical research, policy frameworks, and industry practices evolve in a manner that supports both scientific discovery and technological innovation.

5. SWITZERLAND'S ROLE IN PROTECTING DARK AND QUIET SKIES: A STRATEGIC FRAMEWORK PROPOSED BY THE EPFL SPACE CENTER

Switzerland has a distinguished legacy of diplomatic leadership and scientific excellence that positions it uniquely to address emerging challenges in space sustainability. This paper outlines a comprehensive framework through which Switzerland, with EPFL as a key institutional partner, could contribute significantly to the protection of dark and quiet skies for scientific research and the preservation of cultural heritage.

EPFL Space Center's engagement in dark and quiet skies protection is structured around three fundamental pillars:

1. **Public Information and Engagement**: Developing targeted campaigns to increase public awareness about the scientific, cultural, and environmental importance of preserving dark and quiet skies.
2. **Cross-sectoral Collaboration**: Facilitating dialogue and cooperation among diverse stakeholders, including astronomers, satellite operators, policymakers, and civil society.

3. **Research Support and Funding Development**: Identifying funding opportunities and supporting proposal development for initiatives that address technical and policy challenges in this domain.

Switzerland is strategically positioned to make substantial contributions through several complementary roles:

1. **Science Diplomacy** Building on the Genevcience and Diplomacy Anticipator (GESDA) model, Switzerland can serve as a neutral facilitator for science-policy interfaces addressing space sustainability. This approach leverages Switzerland's diplomatic tradition while addressing the inherently technical nature of the challenges.
2. **Stakeholder Engagement** EPFL and the Swiss Committee on Astronomy (SKACH) will lead coordinated stakeholder engagement efforts within Switzerland, ensuring a coherent national position that represents academic, industry, and public interests.
3. **International Collaboration** The framework establishes formal collaboration with advocacy organizations, particularly the International Astronomical Union Center for the Protection of Dark and Quiet Skies (IAU CPS). Swiss institutions will provide evidence-based research support drawing on both national and international expertise.
4. **Technical Innovation and Scientific Advancement** Switzerland's unique ecosystem—hosting major international organizations like CERN, research facilities such as the Swiss National Supercomputing Centre, and participation in the Square Kilometre Array project—enables the development of user-inspired technologies addressing specific challenges in space sustainability.

This framework supports the development of position papers and recommendations aligned with international initiatives, similar to the "Call to Protect the Dark and Quiet Sky from Harmful Interference by Satellite Constellations" [**Bassa2024**], which received endorsement from the European Science Council, Space Sustainability Rating, and SKACH.

The first action items lays on knowledge transfers to the community and the public. EPFL will systematically translate outcomes from international forums to the Swiss community through:

- Targeted summary reports and web conferences
- Position papers disseminating knowledge and collecting feedback
- Facilitated expert connections when specific technical needs are identified
- Annual position papers addressing the four key working streams of space sustainability

A second step is the community building. Building on the successful Swiss Space Sustainability Research Days (January 2025), this framework establishes an annual Swiss Space Sustainability event to disseminate state-of-the-art knowledge and foster community development.

Finally, an institutional committent is recommended. The EPFL Space Center will formalize its contribution to dark and quiet skies protection through:

- Official institutional participation in the IAU CPS
- Support for observation campaigns
- Development of tools for astronomers
- Representation at international forums including focus group of the Group of Friends of the Dark and Quiet Sky for Science and Society in the context of UNCOUOS
- Presentations at key conferences including AMOS, IOC, ESA Space Debris, SKACH, and SKAO

With this framework, we expect the following outcomes

- New research initiatives at EPFL supporting dark and quiet sky protection
- Annual position papers tracking developments across working streams
- Enhanced national coordination on space sustainability topics
- Strengthened international recognition of Switzerland's leadership in this domain

Switzerland's unique combination of diplomatic tradition, scientific excellence, and institutional capabilities positions it as a potentially influential contributor to global efforts preserving dark and quiet skies. Through structured engagement across policy, research, and community domains, Switzerland can help develop solutions balancing innovation in space with preservation of scientific and cultural heritage.

6. CONCLUSION AND NEXT STEPS

In conclusion, Switzerland is at a critical juncture where its scientific expertise, diplomatic tradition, and industrial capabilities converge to address the growing challenge of satellite constellation interference with astronomical observations. This paper has outlined how Switzerland can leverage its unique position to play a pivotal role in the protection of dark and quiet skies through coordinated

regulatory engagement, scientific innovation, and multi-stakeholder collaboration.

The Swiss approach balances multiple interests: protecting significant investments in astronomical infrastructure like SKAO, maintaining its leadership in space technology development, and upholding its commitment to sustainable development of outer space activities. This balanced perspective enables Switzerland to serve as an effective mediator between scientific and industrial interests, fostering dialogue that leads to practical solutions.

The proposed three-pillar strategy—enhancing public awareness, facilitating cross-sectoral collaboration, and supporting targeted research—provides a comprehensive framework to address this complex challenge. By formalizing participation in international forums like the IAU CPS and the Group of Friends at UN COPUOS, Switzerland can amplify its influence while contributing evidence-based solutions to global policy discussions.

Moving forward, Switzerland must take concrete steps to advance this important work. This includes establishing a Swiss Dark and Quiet Skies Coordination Platform that brings together academic institutions, industry representatives, and government agencies to develop a coherent national position. Targeted funding mechanisms must be developed to study critical knowledge gaps, particularly in satellite design improvements, interference mitigation techniques, and evaluations of policy effectiveness. A Swiss technical assistance program could support smaller astronomical facilities and developing nations in implementing mitigation strategies for satellite interference. Industry engagement should be expanded through incentive programs such as in the Space Sustainability Rating that recognize and reward satellite operators implementing best practices in reducing the impact on astronomy. Finally, Switzerland's diplomatic initiatives must be strengthened by providing technical expertise to Swiss representatives in international forums and developing position papers that can inform multilateral negotiations.

The protection of dark and quiet skies represents not merely a technical challenge but a governance opportunity where Switzerland's tradition of consensus-building and evidence-based policy can make a significant contribution. By proactively engaging with this issue, Switzerland can help to ensure that the rapid development of space technology proceeds in harmony with scientific advancement and the preservation of our shared cosmic heritage for future generations.

REFERENCES

[1] ADRIEN SAADA et al. "Promoting responsible space practices: A primer on the Space Sustainability Rating". In: *Aerospace Europe Conference - EUCASS - CEAS - 2023*. 2023. DOI: 10.13009/EUCASS2023-432.

[2] C. G. Bassa et al. "Bright unintended electromagnetic radiation from second-generation Starlink satellites". In: *Astronomy & Astrophysics* (2024). DOI: 10.1051/0004-6361/202451856.

[3] Chile et al. *Recommendations to Keep Dark and Quiet Skies for Science and Society*. Committee on the Peaceful Uses of Outer Space, Vienna. 2021.

[4] F. Di Vruno et al. "Unintended electromagnetic radiation from Starlink satellites detected with LOFAR between 110 and 188 MHz". In: *Astronomy & Astrophysics* (2023). DOI: 10.1051/0004-6361/202346374.

[5] Brandon N Engelbrecht et al. "Radio frequency interference from radio navigation satellite systems: simulations and comparison to MeerKAT single-dish data". In: *Monthly Notices of the Royal Astronomical Society* (2024). DOI: 10.1093/mnras/stae2649.

[6] Andrew Falle, Ewan Wright, Aaron Boley, and Michael Byers. "One million (paper) satellites". In: *Science* (Oct. 2023). DOI: 10.1126/science.adi4639.

[7] Forrest Fankhauser, J. Anthony Tyson, and Jacob Askari. "Satellite Optical Brightness". In: *The Astronomical Journal* (2023). DOI: 10.3847/1538-3881/ace047.

[8] Chris Finlay, Bruce A Bassett, Martin Kunz, and Nadeem Oozeer. "Trajectory-based RFI subtraction and calibration for radio interferometry". In: *Monthly Notices of the Royal Astronomical Society* (2023). DOI: 10.1093/mnras/stad1979.

[9] Olivier R. Hainaut and Andrew P. Williams. "Impact of satellite constellations on astronomical observations with ESO telescopes in the visible and infrared domains". In: *Astronomy & Astrophysics* (2020). DOI: 10.1051/0004-6361/202037501.

[10] Takashi Horiuchi, Hidekazu Hanayama, and Masatoshi Ohishi. "Simultaneous Multicolor Observations of Starlink's Darksat by the Murikabushi Telescope with MITSuME". In: *The Astrophysical Journal* (2020). DOI: 10.3847/1538-4357/abc695.

[11] Takashi Horiuchi et al. "Multicolor and multi-spot observations of Starlink's Visorsat". In: *Publications of the Astronomical Society of Japan* (2023). DOI: 10.1093/pasj/psad021.

[12] Anthony Mallama et al. "Starlink Generation 2 Mini Satellites: Photometric Characterization". In: *arXiv e-prints* (2023). DOI: 10.48550/arXiv.2306.06657.

[13] Sangeetha Nandakumar et al. "The high optical brightness of the BlueWalker 3 satellite". In: *Nature* (2023). DOI: 10.1038/s41586-023-06672-7.

[14] Bang D. Nhan et al. “Toward Spectrum Coexistence: First Demonstration of the Effectiveness of Boresight Avoidance between the NRAO Green Bank Telescope and Starlink Satellites”. In: *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad6b24.

[15] Mike W. Peel et al. *Summary of SatHub, and the current observational status of satellite constellations*. arXiv:2404.18742 [astro-ph]. 2024. DOI: 10.48550/arXiv.2404.18742.

[16] Dario Pisanti et al. “Modelling science return from the lunar crater radio telescope on the far side of the moon”. In: *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* (2024). DOI: 10.1098/rsta.2023.0073.

[17] Erica Rodgers et al. “Space Based Solar Power”. In: *AIAA AVIATION FORUM AND ASCEND 2024*. American Institute of Aeronautics and Astronautics, 2024. DOI: 10.2514/6.2024-4944.

[18] T. Soares, S. Morales Serrano, B. M. Cattani, and S. -A. de Courson. “ESA’s Zero Debris Approach: a Responsible Path to Mitigate Space Debris in Valuable Orbits”. In: *2nd International Orbital Debris Conference*. Vol. 2852. LPI Contributions. 2023.

[19] J. Tregloan-Reed et al. “Optical-to-NIR magnitude measurements of the Starlink LEO Darksat satellite and effectiveness of the darkening treatment”. In: *Astronomy & Astrophysics* (2021). DOI: 10.1051/0004-6361/202039364.

[20] International Astronomical Union, International Academy of Astronautics, Secure World oundation, and For All Moonkind. *Protection of Astronomy and Science on the Moon*. Committee on the Peaceful Uses of Outer Space, Vienna. 2024.

[21] Yu Wang et al. “Satellite RFI mitigation on FAST”. In: *Research in Astronomy and Astrophysics* (2021). DOI: 10.1088/1674-4527/21/1/18.

[22] Mustafa Harun Yilmaz. “Aggregate Interference Analysis of a LEO Satellite Constellation into the Radio Astronomy Observatory”. In: *2025 United States National Committee of URSI National Radio Science Meeting (USNC-URSI NRSM)*. 2025. DOI: 10.23919/USNC-URSINRSM66067.2025.10907102.