

Triennial Report for 2021-2024

Executive Committee Working Group for Dark & Quiet Sky Protection

Organizing Committee Members: Richard Green (Advisor), Solomon Tessema (EC Liaison), Constance Walker (Chair)

Other Working Group Members

Piero Benvenuti, Lina Canas, Laura Ferrarese, David Galadi-Enriquez, John Hearnshaw, Fatoumata Kebe (Junior Member), Harvey Liszt, José Rodriguez Espinosa, Ramotholo Sefako, R. Chris Smith, Diane Turnshek, Yongheng ZHAO

Working Group Associates

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Executive Committee Working Group for Dark & Quiet Sky Protection (EC WG for D&QS Protection) members have been active in representing the interests of IAU in several major areas:

2021

Conferences

- R. Green and C. Walker helped to organize a special session at the January 2021 AAS conference and half of an AAS town hall at the June 2021 AAS conference on the impact of satellite constellations on astronomy. Talks were also given at the European Astronomical Society (EAS), Royal Astronomical Society (RAS), SGAF's Space Generation Fusion Forum and IAU Symposium 367 (on Dark Skies).

UN COPUOS and the Science & Technology SubCommittee

- Both a "Conference Room Paper" (CRP) and a Technical Presentation were presented to the online meeting of the UN Committee on the Peaceful Use of Outer Space's (COPUOS) Science and Technology SubCommittee (STSC) on April 21, 2021. Six countries joined the authorship of the CRP before the meeting and delegates from another dozen countries supported the recommendations made within the CRP during the meeting. The outcome of the Dark & Quiet Skies Conference was presented to the Scientific and Technical subcommittee, notably recommending measures to mitigate the impact of satellite constellations on astronomy. As a result, we were invited to report at the full COPUOS meeting in

August. The CRP can be found here:

<https://noirlab.edu/public/products/techdocs/techdoc022/>.

- A presentation was made to the delegates of the hybrid UN COPUOS in August to request a single agenda item dedicated to the topic of satellite constellations' impact on astronomy and society. Consensus was not reached and the request was revisited at the in-person UN COPUOS Science and Technology Sub-Committee meeting in February 2022. (We also hosted a symposium on the topic at that time.)

SATCON2 conference

- Most of the Organizing Committee (OC) members of EC WG on Site Protection organized or were involved with the online SATCON2 workshop, held July 12-16, 2021 (and co-chaired by C. Walker). The focus of the workshop was to develop specific, implementable paths to carrying out the recommendations from SATCON1. Over 550 people registered for the SATCON2 workshop. The final combined report of all the chapters is available as of the last week of October 2021. The Executive Report can be found here: <https://noirlab.edu/public/products/techdocs/techdoc031/>. The combined report can be found here: <https://noirlab.edu/public/products/techdocs/techdoc033/>.

Briefings to Government

- Several briefings were provided in 2021 to the U.S. National Science Foundation, the U.S. Office of Science and Technology Policy, various committees at the National Academy of Sciences (the Board of Physics and Astronomy, the Committee on Astronomy and Astrophysics, the Space Studies Board and the US National Committee for the IAU), the Astronomy and Astrophysics Advisory Committee, the IAU Executive Committee, the Committee on Space Research (COSPAR), the U.S. Federal Communications Commission, the Satellite Industry Association, EAS, RAS, and the Commission Internationale de l'Eclairage (CIE).

IAU Center for the Protection of the Dary & Quiet Sky from Satellite Constellations

- In September 2021, NOIRLab and SKAO in partnership submitted a proposal in response to the IAU call for a Center for the protection of observatory sites from satellite constellation interference.

Dark and Quiet Skies II Conference

- Hosted in part by the IAU, several EC WG members organized and/or presented at the weeklong [Dark and Quiet Skies II conference](#) from October 3-7, 2021. (It was co-chaired by C. Walker.) It focused on the technical and political actions needed to implement the recommendations from D&QS I, in particular identifying

which stakeholders and partners would need to collaborate to implement a satisfactory solution for the preservation of dark and quiet skies. Specifically the topics concentrated on satellite constellations' impact on astronomy and society, artificial light at night and radio astronomy. An erupting volcano on the Canary Island of La Palma, caused the conference to be moved entirely online, to not use the resources needed on the island for its inhabitants. The conference program included invited talks as well as contributions selected through a call for abstracts. A total of 724 individuals, 32 percent of whom were women, registered to attend the conference; 77 countries were represented. On average 140 were attending at any one time.

2022

The Launch of the IAU CPS

- In early 2022, the IAU awarded NOIRLab and SKAO the IAU Center for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference ([IAU CPS](#)).

Conferences

- C. Walker was involved in the IAU CPS/AAS a [special session](#) at the AAS meeting, a [Department of Commerce symposium](#) (with R. Green), and the summit by the [Secure World Foundation](#), all presentations on the impact of satellite constellations on astronomy. With the policy leadership at the AAS, R. Green and C. Walker presented at least eight briefings related to committees on the Hill during FY22. C Walker presented a keynote presentation at the [IAU Communicating Astronomy with the Public conference](#).

Focus Meeting #2 at the IAU General Assembly 2022

- Several members of EC WG organized and/or presented at the two-day, hybrid IAU General Assembly [Focus Meeting #2 on Towards a World Standard for Dark & Quiet Sky](#). Held at the IAU GA on August 4, 2022 and August 9, 2022, there were ten topical sections that had 45 speakers for 49 oral presentations. After each section there was time for discussion. The SOC Chairperson of FM2 was Connie Walker (IAU C.B7 president; USA). Thanks go to SOC Co-chairs Richard Green (B7 advisor; USA) and Narae Hwang (South Korea) and to SOC Members James Lowenthal (C.B7 vice-president; USA), Sarah Pearce (Australia), Ramotholo Sefako (South Africa) and Diane Turnshek (USA), who along with David Galadi-Enriquez, is the editor for FM2. They also served as topical section chairs and Q&A moderators of FM2, besides presenting.

- The first day focused on ground-based light pollution and radio astronomy. Some of the main points that shone through from many talks were on new approaches to regional and zonal planning to control light pollution; the need to build relationships with colleagues in biology, ecology, human health, city planning etc, as essential in our efforts to bring decision-makers, regulators, and the general public on board; and to build mutually respectful partnerships with diverse communities and Indigenous nations.
- The second day of FM2 focused on the impact of satellite constellations on astronomy as well as related mitigations, both implemented and considered.
 - Highlights include key results from IAU CPS member, Jeremy Tregloan-Reed, that the new Starlink's using dielectric mirrors are 27% brighter than the visor design, and the OneWeb satellite's mean brightness while being in the safe zone ($V > 7.9$ for $r = 1200$ km), still has a significant number of satellites being too bright.
 - SpaceX removed the reflective visors from their satellites beginning in fall 2021. A new coating is being developed to reduce the amount of light directed towards Earth.
 - Increasingly sophisticated simulations (involving SKAO) predict what satellite beams will look like passing over a radio observatory.
 - A network of observers of satellite constellations is amassing images, especially using the eV-scopes.
 - Accomplishments of the four IAU CPS Hubs were also highlighted.

2023 to the present

Summary of the IAU CPS efforts from 2023 to the present

- Many members of EC WG are members of the IAU CPS. The four Hubs of the CPS have been very active. SatHub are working on developing and aggregating software and coordinating observing campaigns to model, predict, avoid, and otherwise mitigate reflections and emissions from low-Earth orbit commercial satellites. Accomplishments include internationally coordinated observations of the [Bluewalker3 satellite](#), as well as ground-based [detections of unintended low frequency radio emissions](#) from Starlink satellites. The Industry and Technology Hub is establishing relationships with the satellite industry to be able to exchange information on mitigation techniques between them and astronomers on techniques, organizing Astronomer Guides to assist. The Community Engagement Hub developed public engagement material like a [training series](#) of 8 video modules on topics involving satellite constellations. The Policy Hub has finished compiling its recommendations for the mitigation of satellite constellations' impact on astronomy. In summary, the CPS' four hubs were very

active, with policy successes like [securing statements from G7 ministers](#) on the need to protect dark and quiet skies. (See Addendum on p.12 for further details.)

IAU Symposium 385

- The [IAU Symposium 385](#) on Astronomy and Satellite Constellations: Pathways Forward was a huge success, bringing together some 250 experts in-person and online around an interdisciplinary programme covering the four thematic areas (or hubs) of the CPS (Community Engagement, Policy, Industry and SatHub), with a video summary [here](#). The IAU CPS Hub Leads and Management Team organized the IAU Symposium 385. (See Addendum on p.12 for further details.)

UN COPUOS Meeting and Science and Technology SubCommittee Meeting 2023 to the present

- The IAU CPS has been very active in international decision-making circles, being represented through the IAU, SKAO and ESO at the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), where the topic of the protection of dark and quiet skies was discussed at length. From 6 to 17 February 2023, a delegation from the IAU (who are also members of EC WG) attended the 60th Session of the Scientific and Technical Subcommittee ([STSC](#)) of the UN Committee on the Peaceful Uses of Outer Space ([COPUOS](#)) held in Vienna, Austria. A major topic of discussion during the meeting was the [Conference Room Paper on the Protection of Dark and Quiet Skies for Science and Society](#), which was prepared by the IAU CPS Management Team led by Piero Benvenuti, and presented by the delegations of the IAU, Chile, Spain, Slovakia, Bulgaria, Dominican Republic, Peru, South Africa, ESO and the SKAO. The CRP made two proposals for further action. First, it recommended that dark and quiet sky protection be kept on the agenda of the next three sessions of the STSC. Secondly, the paper proposed the creation of an Expert Group with the task of promoting awareness of and providing guidance on the impact of satellite constellations on astronomy, as well as enabling communication and cooperation between Member States and stakeholders. Both proposals obtained the support of more than 30 delegations. Several delegations also explicitly praised the work of the CPS and its cooperative approach to the issue. However, consensus was not gained by the delegates. This led to the creation of a Group of Friends, launched in the second half of 2023, supported by friendly delegations and spearheaded by Chile and Spain, and for which the CPS provides the secretariat.
- The request to establish an agenda item on the protection of dark and quiet skies from large satellite constellation interference featured prominently at the 66th meeting of the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) in Vienna in early June. Over three dozen member states

(countries) and many permanent observers (organizations) agreed, with the exception of one country. With no consensus, the request was tabled to the COPUOS Science and Technology Subcommittee meeting in February 2024.

- After days of heated debate in February 2024, the Scientific and Technical Subcommittee of the UN Committee on the Peaceful Use of Outer Space (UN COPUOS STSC) comprising 102 delegations (or countries) has approved for inclusion in its draft agenda an item titled “Dark and Quiet Skies, Astronomy and Large Constellations: Emerging Issues and Challenges”, which will progress for approval at the full UN COPUOS in June. This is a monumental opportunity to bring astronomy and the challenges presented by satellite constellations to the forefront of international attention. NOIRLab, through the IAU and by extension the IAU CPS, has been actively involved in the UN COPUOS STSC meetings over the last four years.

Members’ involvement in local, regional, national and international efforts

John Hearnshaw (EC WG on D&QS Protection and B7 member) submitted a petition to the New Zealand parliament to lobby for national legislation to protect dark skies. In January 2023, the members of the B7 Organizing Committee and the EC WG endorsed the petition put forward by Hearnshaw. EC WG members have been involved in the International Dark-Sky Association (IDA), renamed DarkSky International. **Connie Walker** (president, B7; chair of EC WG D&QS Protection) is on the board of DarkSky International, participating in many of their events on behalf of DarkSky and IAU. Walker is on the advisory council of the IAU NA-ROAD, as well as on the SOC for IAUS386 on Dark Skies and Astrotourism in 2023 and FM1 and FM5 for the IAU GA 2024 and chaired FM2 in 2022. She has been active with the AAS light pollution/radio interference/space environment group now called COMPASSE, especially in attending governmental meetings with staffers on “the Hill” on satellite constellation issues, which ties in with the IAU CPS Policy efforts. **Richard Green** (EC WG and B7 Advisor) has been especially involved in the COMPASSE Policy subcommittee and the CPS Policy Hub, as chair of both and now as interim CPS Director. In support of IAU, a sample of the presentations Walker gave were *The IAU Centre for the Protection of Dark and Quiet Sky from Satellite Constellations Interference* at the Forum for the Dark and Quiet Sky Protection hosted by the Xinglong Observatory, National Astronomical Observatories, CAS in April 2023 along with Richard Green, Ashley Vanderley (US NSF), and other notable individuals. Walker also gave the keynote presentation at CALCON2023 on *Satellite Constellations and Astronomy: The Challenges Ahead* as well as an invited speaker.

As a member of the EC WG on D&QS Protection, **Angel Otarola**, as well as other EC WG members, attended the various online meetings towards organizing the D&QS conferences. Otarola and others actively supported with inputs for drafting the proposal to have an FM session in the IAU GA held in South Africa.

Because in part of Angel Otarola's involvement in the EC WG and Organizing Committee of B7 – Inter-Division B-C Commission Protection of Existing and Potential Observatory Sites, in the period 2020-2022 he was invited to give inputs and views on the subject of ALAN and protection of astronomy sites, by the members of the committees that were advising the Chilean government on the discussion of a) the new norm for light pollution [1] and b) for the protection of sites holding astronomical observatories or with potential for the future development of astronomy projects in northern Chile ([2]).

[1]

<https://www.lightnowblog.com/2023/11/chile-adopts-new-national-dark-sky-regulations/>

[2] Publication in the Official Gazette of Chile on June 27, 2023, of decree No. 43,586 that creates areas with scientific and research value for astronomical observation or "astronomic areas", covering a total of 31 of the 34 communes present in the regions of Antofagasta, Atacama and Coquimbo

Antonia Varela (Director the Starlight Foundation) has also been a very active member of the EC WG on D&QS Protection and of the B7 Organizing Committee. Her main contributions in the last three years have been 1) a [science paper](#) on threats on light pollution with a [press release](#), 2) as the LOC chair of the successful [IAU Symposium 385](#) in 2023 and all the work that entails and 3) the protection of the sky as a new UN Sustainable Development Goal. Advocacy before the UN for *the quality of the sky and right to starlight* as a new sustainable development goal, [SDG18](#). "Sky quality" implies not only protection from light pollution but we have included the LEO satellite constellations, radio frequencies and space debris. Here are three articles on this effort:

- [Alliance Fundación Starlight and BPW Spain](#)
- [UN New York 2023](#)
- [UN New York 2022](#)

These examples only are the tip of the iceberg. There are many contributions to educational engagement as well. [Globe at Night](#) (Walker, director) is an international citizen science campaign on light pollution that got a boost during the IAU International Year of Astronomy and became a legacy project of that, as well as a foundational program of NOIRLab. Recently a *Science* journal article was published by [Christopher C. M. Kyba, Yiğit Öner Altıntaş, Constance E. Walker and Mark Newhouse \(2023\)](#), that used Globe at Night data. The paper concluded that the night sky brightness has increased worldwide by 10% a year on average over the last 12 years. Many

organizations, social media and news entities have used the results to bring awareness about light pollution issues to the public. This percentage is stated as a threshold by IAU.

Examples of Light Pollution Mitigation Efforts by a Major Observatory in Chile

NOIRLab is a major observatory in the world with whom some of the IAU members work. Its Office of Observatory Site Protection formed in 2022 to facilitate efforts within and between the NOIRLab sites in Chile and the USA, with these goals in common:

- Goal 1: To conduct regular uniform night sky brightness monitoring at each site with a common set of equipment.
- Goal 2: To conduct awareness campaigns around the observatories with our communities.
- Goal 3: To work with the local and national entities to support lighting modifications in accordance with regulations

Toward the first goal, the group is monitoring night sky brightness measurements on Cerro Tololo, Cerro Pachón, and soon Kitt Peak, as well as selected areas around the mountains, within major cities along the line of sight, at astro-tourism observatories and at nature areas.

Toward the second goal, the group is engaging the public to increase their awareness on the impact of light pollution on their lives and on astronomy. The group has supported many social and outreach programs, ranging from public talks like biodiversity and light pollution, to citizen science campaigns (e.g., Globe at Night), to a course on the norma luminica, to public telescope viewing, and to astronomical training on the protection of the night sky.

Toward the third goal, the [Oficina de Protección de la Calidad del Cielo del Norte de Chile](#) (whom the NOIRLab group works with) designs compliant outdoor lighting to produce energy savings and zero uplight. Then these solutions are used in working with local communities to modify non-compliant lighting. Now that the new light emissions standard is approved by the Chilean government, further approvals and implementation of lighting changes in the cities nearby our observatory centers will follow.

Cordially and respectfully submitted on behalf of Executive Committee Working Group on Dark and Quiet Sky Protection.

ADDENDUMS

IAU Center for the Protection of the Dark & Quiet Sky from Satellite Constellation Interference (IAU CPS)

- The IAU CPS SatHub Co-Leads answered reviewers' remarks for the Nature paper on optical observations of BlueWalker3. Started observations on Starlink Gen 2 minis.
- The IAU CPS SatHub Co-Leads (Rawls, Eggl and Peel), Tyson (UCDavis/Rubin) and IAU CPS Co-Director (Walker) submitted the NSF SWIFT-SAT proposal for software development (to avoid bright satellites over observatories) in partnership with Aerospace Corp.
- The IAU CPS Policy Hub has been instrumental in the development of
 - A draft position paper.
 - Streamlined recommendations made in the SATCON 1&2 Workshops and Dark & Quiet Skies I&II Conferences.
 - A comparative analysis of current national policies, international law, and other multi-national instruments, particularly for sustainability policies.
 - Expert panels to advise Swiss EPFL on astronomy issues. EPFL will also sponsor a Masters student to develop astronomy criteria for the Space Sustainability Ratings.
- The IAU CPS Community Engagement Hub created a set of accessible SatCon101 videos to communicate the situation with satellite constellations to a broad audience.
- IAU CPS Industry & Technology Hub
 - Coordinated with CE Hub on Astronomy 101 tutorial for satellite companies.
 - Reached out to 12 priority satellite companies; six show interest in participating in CPS.
 - Engaged 7 major satellite, space and manufacturing trade associations to enlist their help in raising awareness.
 - Conducted technical calls with IAU CPS with SpaceX, OneWeb and AST to discuss observed brightness and mitigations.
- Hired a full-stack software engineer to work with SatHub in creating software to avoid satellites in telescopes' Field of Views, especially over critical brightness thresholds.
- Many CPS Hub Leads and Management Team members gave talks at major conferences on various issues and solutions concerning the impact of satellite constellations on astronomy (e.g., Narae Hwang from KASI gave 2 talks; one was to COSPAR).

IAUS385 Summary

The symposium was a huge success, and the IAU-CPS was heavily involved with the preparation of the [sessions](#). The CPS Hubs who attended in person were [SatHub](#) co-leads Siegfried Eggli (University of Illinois Urbana-Champaign) and Mike Peel (Imperial College London); [Policy Hub](#) co-leads Richard Green (University of Arizona) and Andrew Williams (ESO); [Community Engagement Hub](#) co-lead Jessica Heim (University of Southern Queensland) and [Industry and Technology Hub](#) co-lead Tim Stevenson (SKAO). Connie Walker was SOC Chair and Antonia Varela was LOC chair.

The **Community Engagement Hub** sessions were fortunate to have presentations from Elder Wilfred Buck and other traditional knowledge keepers. The speakers shared perspectives on their relationship with the sky and cosmos, and discussed ways to co-create collaborative endeavors related to the night sky and space. We heard from speakers with a background in history and science and technology studies, who helped us to examine past and present space and astronomy issues from different lenses, and to explore environmental and cultural aspects of these topics.

The **SatHub** sessions concentrated on challenges to radio and optical astronomy, to X-ray astronomy, spectroscopy, space-based observations, and to amateur astronomy. They also addressed strategies for co-existence in all of these categories. In recent years, various strategies for co-existence in terms of optical astronomy have been developed. There are now better models and data for satellite brightness which are key to enabling any sort of mitigation, or for active avoidance, or for use in compliance checks. Future observations by the CPS SatHub observing network will determine whether some coatings and [Bragg mirrors](#) on reflective surfaces of Starlink satellites will help: and how well. For spectroscopy, better modeling and understanding of satellite spectra will enable the emission from satellites to be calibrated out of astronomical data. Autonomous imagers on large spectroscopic facilities can help identify when an exposure was contaminated. For space-based observatories there are software solutions (Starunlink) for streak detection and elimination that may help. Ultimately SatHub is bringing all stakeholders together to tackle the constellation challenge.

The **Policy Hub** sessions included awareness-raising and coordination. The Policy Hub is engaging a growing network of ~140 people in research and policy work and regular interactions with government affairs representatives from several national astronomical societies, observatories and spectrum managers. These sessions also included discussion on deliverables from the work packages the Policy Hub has undertaken (a position paper, Space Sustainability Rating, consolidating recommendations from the satcon-related workshops ([SATCON1](#), [SATCON2](#)), lunar policy, etc)).

Progress in policy-making in countries all around the world was also highlighted with the general message that steady interaction with policymakers and industry is required to raise awareness and promote the protection of dark and quiet skies. There are a

growing number of high-level recognitions of the topic of dark and quiet skies, including by the [European Council](#), ESA Clean Space Charter, [G7](#), [Earth Space Sustainability Initiative](#), and [UN COPUOS](#) among others.

The **Industry and Technology Hub** session consisted of a panel including a representative from SpaceX, who provided an update on Starlink satellites and their mitigation measures. The Q&A highlighted a number of concerns regarding relationships with regulators, the state of the market and limits to it, and the flow of information from operators to support independent researchers.