Committee on Light Pollution, Radio Interference, and Space Debris (LPRISD)

From Sky Glow to Satellite Swarms: Challenges to Astronomy From the Ground and From Space

A Virtual Workshop - March 25, 2022
Welcome and Introduction
Jeffrey Hall, Lowell Observatory

Watershed moments for the source of our data: from LEDs to Satellites

AGENDA

● Updates in Critical Areas of the LPRISD Purview (45 min)
● Advocacy Regarding Ground- and Space-Based Threats to Astronomy (20 min)
● Q&A With Attendees (25 min)
Satellite Constellations in Low Earth Orbit: The State of Affairs
Pat Seitzer, University of Michigan

1. Existing Constellations under construction
   a. SpaceX Starlink
   b. OneWeb
2. A few planned Constellations
   a. Amazon Kuiper
   b. China
   c. e-Space
3. Solar power from space - recent developments
SpaceX Starlinks Generation 1 - goal 4408 satellites

- 2333 launched
- 221 reentered
- 2112 in orbit
- 2092 transmitting positions
- Almost 50% of constellation launched

SpaceX Starlinks Generation 2 - goal 29,988 satellites

- Awaiting FCC approval - major industry opposition.
- SpaceX proposes to operate both Gen 1 and Gen 2 simultaneously - 34396 satellites
MMT-9 observations of Visorsat at 550 km altitude - 15 passes

2020-08-23 to 2021-12-02

Goal - 7th mag

Number of 0.1 second observations

Magnitude (~V)

P. Seitzer - Univ of Michigan
OneWeb

428 launched

1 failed at 1200 km, possible Active Debris Removal Target (ADR) since natural decay time is many centuries

Initial goal of 648 satellites at 1200 km

Launches suspended from Russia.

Plan to resume later this year on SpaceX rockets.
Altitude distribution of 427 OneWeb satellites - 2022-Mar-24

P.Seltzer - Univ of Michigan

LPRISD Committee Virtual Workshop - March 25, 2022
Starlinks plus OneWeb are 45% of all active satellites!
Planned Constellations - a sample

Amazon/Kuiper - two experimental satellites to be launched later this year: requested Optical observations for comparison of apparent brightness.

China - planned 13,000 satellite constellation. 6 prototype satellites launched on March 5 - observations highly desirable.
NORAD IDs: 51946 - 51951

e-Space - planned 100,000 constellation of ‘small’ satellites in LEO. Three test satellites to be launched 2nd Quarter 2022. No further details this time.
Not just Internet constellations astronomers need to watch

Solar panel arrays useful only in daytime. But what if....
Mirrors in space are not a new idea - goes back 100 years.

Not a conventional solar power satellite, where power beamed to the ground via microwave.

Instead - reflect sunlight to existing solar farms on ground, they can then generate power as long as satellite is in sunlight.

At 800 km, well past astronomical twilight.

Recent study in *Acta Astronautica*:

*Enhancing terrestrial solar power using orbiting solar reflectors*

By Celik, et al. supported by Euro 2.5 million grant from European Research Council

*Acta Astronautica, Fig 2.*
Site conditions for solar farms very similar to astronomical observatories:

- Clear weather
- Low extinction

Chile - large solar farm that powers Santiago Metro on access road to two observatories:

- Las Campanas - GMT, Magellan, …
- ESO La Silla

Green power - electricity from solar farms well past sunset. Technically feasible. Prototype to be launched ….
Ground-Based Light Pollution
James Lowenthal, Smith College

Phoenix, AZ, 200 km away
Kitt Peak National Obs.

NASA
Zenith sky brightness info (2015)

- Coordinates: 32.06966, -111.76732
- SQM: 21.93 mag/arc sec²
- Brightness: 0.182 mcd/m²
- Artif. bright: 11.3 µcd/m²
- Ratio: 0.0662
- Bortle: class 2
- Elevation: 945 meters

lightpollutionmap.info
Light Pollution growing >2% per year world-wide (50-400% since 1992)

More area lit

Areas lit more brightly

Kyba+ 2017

Sanchez de Miguel+ 2021

Missed 4000K LEDs

Missed 3000K LEDs
Rapid move worldwide from HPS (MH, CFL, incandescent,...) to LED

Before: HPS, 2000K, well-shielded

After: LED, 3000K, poorly-shielded

Northampton, MA
D&QS2 Artificial Light at Night Working Group report to UN COPUOS

A. Policy Summary

B. Regulations, Laws, Rules, Policies, Models and Application Guidance

C. Technical Guidance

Recommendations to UN COPUOS:

1. Endorse overarching goal of reducing ALAN on decade timescale

2. Endorse policy framework for controlling ALAN – Regional lumen caps; IES/IDA Five Principles

3. Coordinate with related UN-level agencies (WHO, UNEP, UNDRIP, IUCN…)

LIGHT TO PROTECT THE NIGHT
Five Principles for Responsible Outdoor Lighting

USEFUL
All light should have a clear purpose.
Before installing or replacing a light, determine if light is needed. Consider how the use of light will impact the area, including wildlife and the environment. Consider using reflective painter’s or self-luminous markers for signs, curbs, and steps to reduce the need for permanently installed outdoor lighting.

TARGETED
Light should be directed only to where needed.
Use shielding and careful aiming to target the direction of the light beam so that it points downward and does not spill beyond where it is needed.

LOW LIGHT LEVELS
Light should be no brighter than necessary.
Use the lowest light level required. Be mindful of surface conditions as some surfaces may reflect more light into the night sky than intended.

CONTROLLED
Light should be used only when it is useful.
Use controls such as timers or motion detectors to ensure that light is available when it is needed, dimmed when possible, and turned off when not needed.

COLOR
Use warmer color lights where possible.
Limit the amount of shorter wavelength (blue-violet) light to the least amount needed.
What YOU can do

- Join International Dark-Sky Association
- Get internet-connected Sky Quality Meter, mount on Astro Dept. building rooftop
- Give talks to local environmental, neighborhood, public health groups: emphasize impact on human health, wildlife, economy, public safety (starry skies)
- Contact your colleagues in environmental studies, urban planning, architecture, geography…include LP in their classes, discuss with their colleagues/leadership
- Talk to your local, state and national representatives
- Get your town / city / community / university to adopt the IES/IDA Five Principles of Responsible Outdoor Lighting
The Spectrum Landscape for Radio Astronomy

Harvey Liszt
National Radio Astronomy Observatory &
North American ALMA Science Center
Charlottesville, VA
&
Chair, IUCAF (www.iucaf.org)
How stuff happens: First, WRC-19 AI 1.6

Allow non-GSO satellites to operate at 37.5 – 42.5 GHz and 47 – 51 GHz along with GSO?

<table>
<thead>
<tr>
<th>Topic</th>
<th>Responsible group</th>
<th>Action to be taken by the group</th>
<th>Concerned group</th>
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| Resolution 159 [COM6/18] [WRC-15] Studies of technical, operational issues and regulatory provisions for non-geostationary fixed-satellite services satellite systems in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) | WP 4A             | resolves to invite ITU-R to conduct, and complete in time for WRC-19:
1. studies of technical and operational issues and regulatory provisions for the operation of non-GSO FSS satellite systems in the frequency bands 37.5-42.5 GHz (space-to-Earth) and 47.2-48.9 GHz (limited to feeder links only), 48.9-50.2 GHz and 50.4-51.4 GHz (all Earth-to-space), while ensuring protection of GSO satellite networks in the FSS, MSS and BSS, without limiting or unduly constraining the future development of GSO networks across those bands, and without modifying the provisions of Article 21;
2. studies carried out under resolves to invite ITU-R 1 shall focus exclusively on the development of equivalent power flux-density limits produced at any point in the GSO by emissions from all the earth stations of a non-GSO system in the fixed-satellite service or into any geostationary FSS earth station, as appropriate;
3. studies and development of sharing conditions between non-GSO FSS systems operating in the frequency bands listed in resolves to invite ITU-R 1 above;
4. studies of possible necessary revisions to Resolution 750 (Rev.WRC-15) to ensure protection of the EESS (passive) in the frequency bands 36-37 GHz and 50.2-50.4 GHz from non-GSO FSS transmission, taking into account recognizing 1 above, including study of aggregate FSS interference effects from networks and systems operating or planned to operate in the frequency bands described in resolves to invite ITU-R 1 above;
5. studies towards ensuring protection of the radio astronomy frequency bands 42.5-43.5 GHz, 48.94-49.04 GHz and 51.4-54.25 GHz from non-GSO FSS transmissions, taking into account recognizing 1 above, including study of aggregate FSS interference effects from networks and systems operating or planned to operate in the frequency bands described in resolves to invite ITU-R 1 above, further resolves to invite WRC-19 to consider the results of the above studies and take appropriate action, | WP 5A<br>WP 5B<br>WP 5C<br>WP 5D<br>WP 6A<br>WP 7B<br>WP 7C<br>WP 7D<br>(WP 3M)<br>(WP 4B)
Then, an FCC Processing Round

Two years later, 40,000 new satellites

Astra files FCC application for 13,600-satellite constellation

by Jeff Foust — November 5, 2021

In race to provide internet from space, companies ask FCC for about 38,000 new broadband satellites

PUBLISHED FRI, NOV 5 2021 12:30 PM EDT

Rwanda submits ITU filing for constellation of 327,320 satellites
- 27 orbital shells at 550-640 km

https://spacenews.com/astra-files-fcc-application-for-13600-satellite-constellation/

https://www.cnbc.com/2021/11/05/space-companies-ask-fcc-to-approve-38000-broadband-satellites.html
And this, too

THE WALL STREET JOURNAL

The Fall and Rise of Iridium

A month after launch, the ballyhooed company had made more money selling mugs and T-shirts than handsets and services.

OneWeb exits bankruptcy and is ready to launch more broadband satellites

EXTREME TECH

Musk Warns SpaceX Possibly Facing Bankruptcy

Now arguing that only the 30,000+ satellite version of StarLink is viable
The WRC-23 Agenda

- AI 1.2 IMT (think cell phones)
- AI 1.4 IMT Base Stations on HAPS at 20 km
- AI 1.6 Communication for Sub-Orbital Vehicles
- AI 1.8 UAV in Segregated/Non-Segregated air
- AI 1.10 Non-safety aeronautical mobile comms
- AI 1.13 Data Relay Satellite links 14.8-15.35 GHz

Theme:

Flying frequencies whose potential interference we had coordinated away on the ground by regulation, quiet zone, remoteness, etc.
Further satellite reading

- Satellites talking directly to your cell phone
- 100 x proliferation of orbiting X-band radar
- $100,000,000 to CalTech for solar power satellites
- Good news, ESA-IUCAF MOU
  - Successor to CloudSat will mute over telescopes

https://iau.org/news/announcements/detail/ann22002/
http://www.iucaf.org/
Space Debris
Pat Seitzer, University of Michigan

Largest debris event since 2009.


Over 1500 fragments larger than 10 cm created.
Figure 7. The cumulative size distribution of the Cosmos 1408 fragments based on different measurement data. The black curve is the NASA SSBM model prediction.
Figure 4. Historical increase of the cataloged objects based on data available on 1 March 2022. The three upward jumps in fragmentation debris correspond to (1) the ASAT test conducted by China in 2007, (2) the accidental collision between Iridium 33 and Cosmos 2251 in 2009, and (3) the ASAT test conducted by the Russian Federation in November 2021. More Cosmos 1408 fragments are expected to be added to the catalog in the coming weeks and months.
Community Engagement
Aparna Venkatesan, University of San Francisco
Opportunity to Re-Imagine Scientific Exploration at the Existential Crossroads We Face

The skies and space belong to and impact all people
Broaderest constituency in near-Earth space is humanity
Duty to Consult (and all that entails)
Cultural and scientific practices worldwide with shared skies
The sky is part of the environment.
Ecosystems depend on the night sky and on each other.
WHAT HAVE WE BEEN DOING ABOUT THIS?

SATCON2 Community Engagement Working Group (25 members across the world, moving beyond industry, agencies and professional astronomers): amateur astronomers, members of sovereign Indigenous nations and tribal communities, dark-sky advocates, planetarians, and environmental/ecological organizations. Scores of interviews, surveys, conversations, outreach, meetings.

This has been amplified through the Dark and Quiet Skies conferences, many AAS-supported presentations to US and international agencies/branches of government, and the (brand!) new IAU Centre to address SatCon interference.

Premise: Industry, leadership, space actors and all constituencies must co-create a shared, ethical, sustainable approach to space.
THIS IS JUST THE BEGINNING of a long overdue conversation on our shared skies

- Preserving space and the night sky as a scientific, environmental and cultural commons for humanity.
- Duty to Consult
- Astronomers need to avoid binary thinking (science vs internet, science vs culture, Earth vs space as environments)
- Develop integrative approaches from ALL ways of knowing, e.g. we need to establish a NASA Office of Indigenous Affairs, or Office of Tribal Relations, with scientific progress rooted in cultural competency, relationships and sustainability
- Learn From the Past (highways/transportation, fossil fuels, telecommunications), and assess environmental, economic and infrastructure tradeoffs
- Better international regulation and globally coordinated oversight/enforcement
Initial Objectives

- Secure official AAS endorsement of the principles for protection of astronomical sites and dark and quiet skies from the SATCON 2 and D&QS 2 reports.
- Coordinate with and support AAS policy staff efforts for advocacy of dark and quiet skies protection.
- Develop and advocate for policy and regulatory changes at Federal Agencies and in statutory law to mitigate the impacts of satellite constellations, with full AAS endorsement
  - Make mitigation of impacts a condition of licensing for launch and operations
  - Encourage / require coordination agreements that include not only radio but also O/IR
  - Encourage filling open seats on the Council on Environmental Quality within the White House and advocate its establishment of environmental framework for orbital operations
  - Advocate for consideration of aggregate impacts, e.g., in FAA authorization
Policy Objectives - 2

- Coordinate with the IAU Centre to provide a posted collection of policy models from other countries available to advocates and interested Federal policymakers.

- Provide a posted collection of the recommended frameworks for control of ground-based light pollution from the D&QS 2 Report available to advocates and local/state policymakers.

- Post key cross-links to successful local policy efforts for light pollution control, e.g., IDA website.

- Provide a posted collection of up-to-date summaries of the scientific impact of satellite constellations on selected key investigations and descriptions of priorities of supporting agencies at both the technical and general audience level.

- Provide consensus definitions for the thresholds for OIR interference (as the basis for implementing coordination agreements) for noticeable, impacting, and harmful.
Participation in Policy WG

- All interested LPRISD members
- One or two CAPP members for policy crossover
- Need for some ‘research’ support and website curation - e.g., interested grad student junior members with guidance and effort from co-chairs and more senior members
- Outreach to general AAS membership - e.g., participants in Congressional visit day
Formation of the new IAU CPS or the *International Astronomical Union Center for the Protection of the Dark & Quiet Sky from Satellite Constellation Interference*

Connie Walker, NSF’s NOIRLab Scientist & IAU CPS Co-Director

**Mission**

- The Centre will **coordinate global efforts** to converge on mitigation solutions
- The Centre will bring together astronomers, industry, policy experts and the wider community and **act as a bridge between all stakeholders**
- The Centre will **produce and disseminate open source information and resources**
- In particular, the Center will **continue research** on the satellite constellation issues to arrive at feasible and implementable solutions in the areas of:
  - A hub for observations, software, etc. (SatHub)
  - Policy
  - Industry and Technology
  - Community Engagement
Organizational Chart for the IAU Centre
How to Participate in the New IAU CPS

- The Center **begins operation** on April 1st, 2022
- The Center will coordinate the involvement of **two groups of members**:  
  - Contributing members  
    - Opportunity to actively work on mitigation strategies  
    - Access to hubs and their resources  
    - Expected to commit resources and develop a work plan  
  - Affiliated members  
    - Interested in the work of the Centre  
    - Contributing on a best effort basis

If interested, contact Connie at connie.walker@noirlab.edu. By mid-April: cps.iau.org.
What You Can Do: Talking Points and Tools for Advocacy

Julie Davis, Bahcall Public Policy Fellow, AAS

**Talk to your congress members!** Tell them how the issues affect you & your science!

**Satcon Message**: “Mitigation of harm to astronomy needs to be a condition of licensing for launch and operations, and on-going financial support is needed to address harms to astronomical data.”

Advocate for expanding fiber internet as an alternative for broadband access

Comment on Regulatory and FCC filings (regulations.gov, fcc.gov/ecfs)

Include this issue in your outreach and course materials!
To find your congress members: [www.congress.gov/members/find-your-member](http://www.congress.gov/members/find-your-member)

- You should only contact *your* members of Congress.
- If your member is on a relevant committee, it is especially important to be in contact!
- Contact your member even if they disagree with you.
- Non-citizen experts can also contact their representatives (effectiveness may vary)

Visiting > Calling > Emailing, but all communication is important. The more they hear about the issue, the better.

- Keep your message **specific, brief, and timely**. Avoid jargon!

Visit [aas.org/advocacy/get-involved](http://aas.org/advocacy/get-involved) for advocacy resources!
Satellite Constellations and Space Debris: What LPRISD Is Doing

SATCON1, July 2020

https://aas.org/satellite-constellations-1-workshop-report
https://noirlab.edu/public/products/techdocs/techdoc031/

SATCON2, July 2021

D&QS1, October 2020

D&QS2, October 2021

https://noirlab.edu/public/media/archives/techdocs/pdf/techdoc051.pdf
Satellite Constellations and Space Debris: What LPRISD Is Doing

SATCON1 Key Findings

Achieve $V > 7.0$ (allows software removal of crosstalk trails in VRO images)

Orbits $\leq \sim 600$ km (limits optical visibility to $\sim 90$ min after sunrise/before sunset) (satellites are also somewhat defocused)

Fast orbit raise (minimize parking orbit time, use attitude adjustment to reduce brightness)

Improved sats data (higher precision than TLEs, include covariances)
## Satellite Constellations and Space Debris: What LPRISD Is Doing

**SATCON2 Key Findings**

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<th>Action</th>
<th>Details</th>
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<tbody>
<tr>
<td>Create SatHub</td>
<td>(comprehensive repository of data, software, community resources)</td>
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<tr>
<td>Develop software</td>
<td>(PassPredict, TrailFix, test suite of data)</td>
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<td></td>
<td>(Python libraries, data pipeline routines, Web interfaces)</td>
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<td>Engage broadly</td>
<td>(duty to consult; collaborate with industry; “Raise all voices.”)</td>
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<td>(“Science versus internet” is a false choice)</td>
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<tr>
<td>Update policy</td>
<td>(design sats from the outset with astronomy in mind)</td>
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<td>(need to consider aggregate impacts, not just individual operators)</td>
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<td>(obligation to reduce impacts should be a condition of licensing)</td>
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<tr>
<td>Urgency and $$$$</td>
<td>(the window of opportunity is fast closing)</td>
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<td>(proper funding [at least 8 figures] is urgently needed)</td>
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Satellite Constellations and Space Debris: What LPRISD Is Doing

KEY ACCOMPLISHMENTS:

Dark & Quiet Skies I (D&QS1), October 2020

- SatCon Working Group Report extended results from the groundwork laid by SATCON1
- Reported out to the UN Committee for the Peaceful Use of Outer Space’s Science and Technology SubCommittee

Dark & Quiet Skies II (D&QS2), October 2021

- SatCon Working Group Report extended results from the groundwork laid by SATCON2
- Had working groups on national policy, international policy, observatories and industry
- Did deep dive into national and international policy
- With the AAS’ and industry’s help, created best practices guidelines to mitigate impacts
- Reported out to the UN Committee for the Peaceful Use of Outer Space’s Science and Technology SubCommittee (STSC) - 25 UN Delegates from different countries signed on
- Invited to hold a symposium with industry and astronomers during the STSC meeting
- Invited back to report to STSC 2023 under a Dark & Quiet Skies agenda item

On the foundation of all four workshops, the IAU Center has been established.
Satellite Constellations and Space Debris: What You Can Do

Progress is most likely to come through legislation and policy. We must have ongoing communication with elected officials. **Every member of the AAS is an ambassador for our field.**

Your elected officials **want to talk with you**, regardless of your/their “side of the aisle.”

Engage with your **state** as well as your **federal** representatives.

Meet **in person** if at all possible. Ask for no more than 15 min.

Be straightforward, non-technical. **No** sarcasm or ultimatums.

These meetings are **regular conversations**, not any sort of “command performance.”

Acknowledge the **multi-faceted nature** of the issues.

**Thank them** for their service to the country and/or their state.
Q&A
Moderated by Meredith Rawls, University of Washington
Thank you for joining our workshop!

The IAU Centre will be a critical hub for addressing threats to astronomy from satellite constellations. Learn much more about it at our AAS 240 splinter session in Pasadena.

Committee on Light Pollution, Radio Interference, and Space Debris (LPRISD)