Dark & Quiet Skies

2023/2024 Updates

AAS Committee for the Protection of Astronomy and the Space Environment

Teznie Pugh - University of Texas at Austin, McDonald Observatory
Josh Reding - AAAS Science and Technology Policy Fellow

March 18th 2024 - NASEM - Committee on Astronomy and Astrophysics

Picture: Stephen Hummel
McDonald Observatory

The Charge of COMPASSE

COMPASSE represents the interests of AAS relating to the protection of dark and radio-quiet skies, the safe and sustainable use of outer space, and related issues, and empowers AAS members to be effective advocates for the protection of U.S. astronomy.

Primary Concerns: *Impacts on access to the night sky and impacts on astronomical science:*

1. ***Commercialization of orbital space (Satcons)***
2. ***Artificial light at night (ALAN)***
3. ***Preservation of the lunar and cislunar environments***

AAS Committee to Protect Astronomy and the Space Environment

Co-chair
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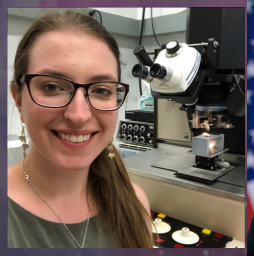
CE VCs
John Barentine
Jessica Heim

LP VC
James Lowenthal

Space Debris VCs
Jonathan McDowell
Patrick Seitzer



RFI/EMI
Sarah Marie Bruno
Joshua Reding

Policy VCs
Roohi Dalal
Richard Green
Yaswant Devarakonda


Artificial Light at Night

ALAN Issues

Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022 (Kyba et al. 2023)

The artificial glow of the night sky is a form of light pollution; its global change over time is not well known. Developments in lighting technology complicate any measurement because of changes in lighting practice and emission spectra. We investigated the change in global sky brightness from 2011 to 2022 using 51,351 citizen scientist observations of naked-eye stellar visibility. The number of visible stars decreased by an amount that can be explained by an increase in sky brightness of 7 to 10% per year in the human visible band. This increase is faster than emissions changes indicated by satellite observations. We ascribe this difference to spectral changes in light emission and to the average angle of light emissions.

ALAN Issues

Light pollution indicators for all the major astronomical observatories (Falchi et al. 2023)

Light pollution at astronomical observatories is one of the main factors to be taken into account to preserve their scientific productivity and their useful lifetime. Using the Garstang–Cinzano model applied to the Visible Infrared Imaging Radiometer Suite (VIIRS) 2021 satellite radiance data, we have compared 28 sites, all hosting telescopes with apertures larger than 3 m, plus some additional selected sites. We computed and analysed five indicators of light pollution: radiance at zenith; averaged at 60° zenith distance; averaged over all the sky; averaged in the first 10° above the horizon; and horizontal irradiance. We found large variations of the values of the indicators, with a factor greater than 600 for the zenith artificial radiance between the least and most polluted major observatories. The results show that two-thirds of all large observatories have already surpassed the critical 10 per cent increase in radiance over the assumed natural levels. The results presented and the method described here can help to plan countermeasures in order to lower the impact of light pollution on observatories. These same methods can be also used to protect the night environment from the impact of artificial light (e.g. on biodiversity, on animal behaviour and physiology, on human health).

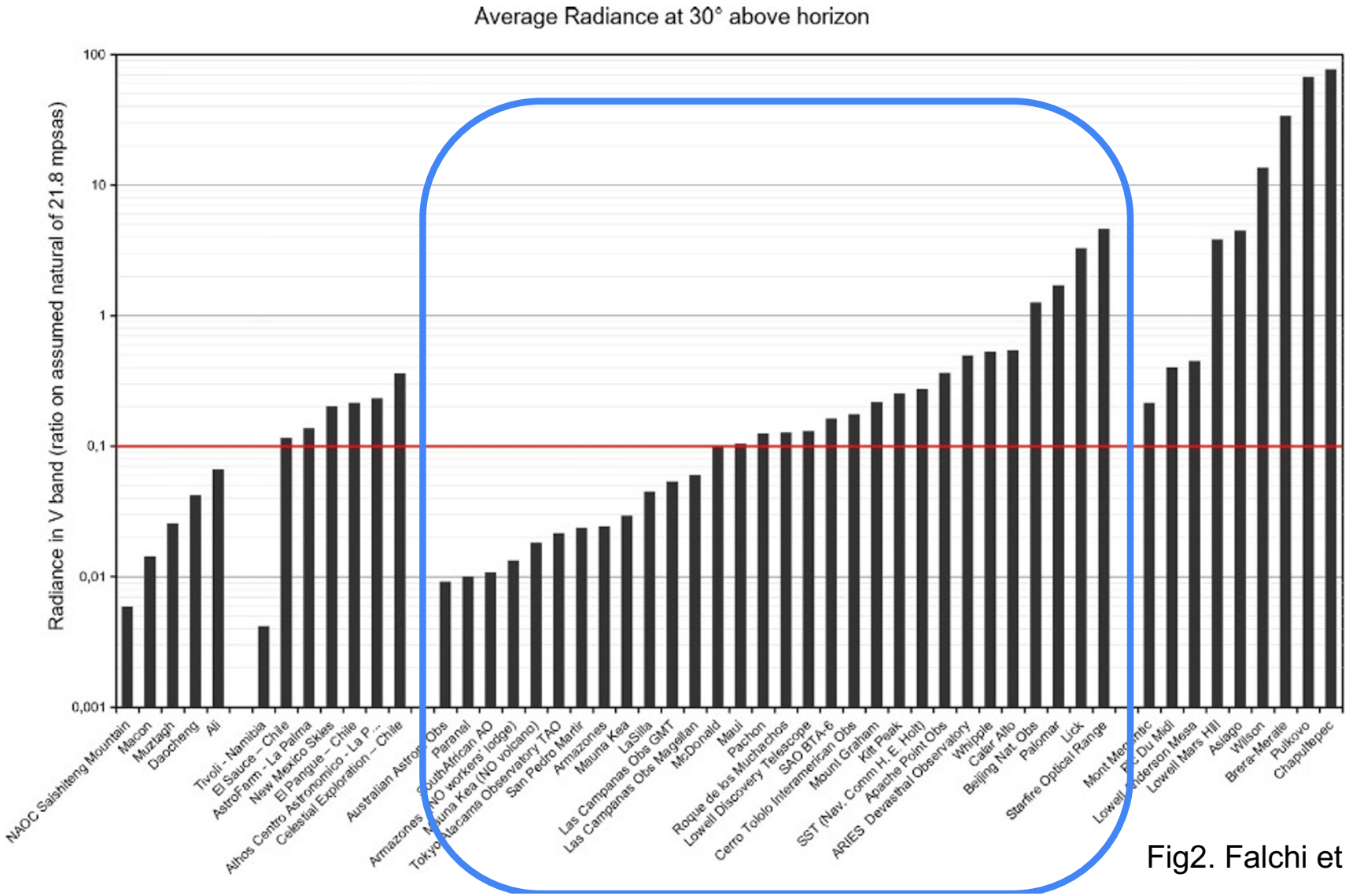
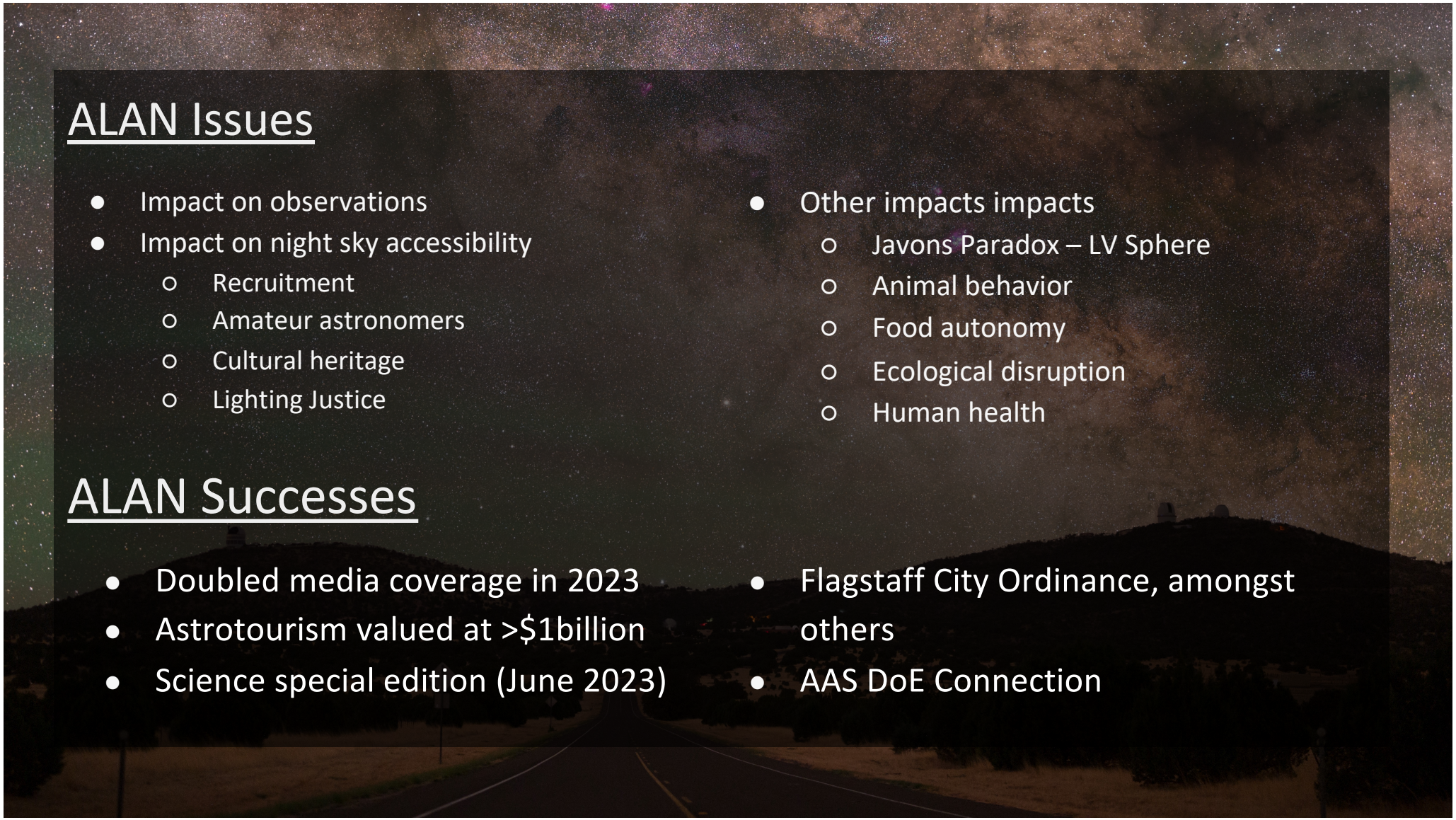


Fig2. Falchi et al 2023



ALAN Issues

- Impact on observations
- Impact on night sky accessibility
  - Recruitment
  - Amateur astronomers
  - Cultural heritage
  - Lighting Justice
- Other impacts impacts
  - Javons Paradox – LV Sphere
  - Animal behavior
  - Food autonomy
  - Ecological disruption
  - Human health

ALAN Successes

- Doubled media coverage in 2023
- Astrotourism valued at >$1billion
- Science special edition (June 2023)
- Flagstaff City Ordinance, amongst others
- AAS DoE Connection


SATCONS
Picture: A. H. Abolfath
NOIRLab/NSF/AURA

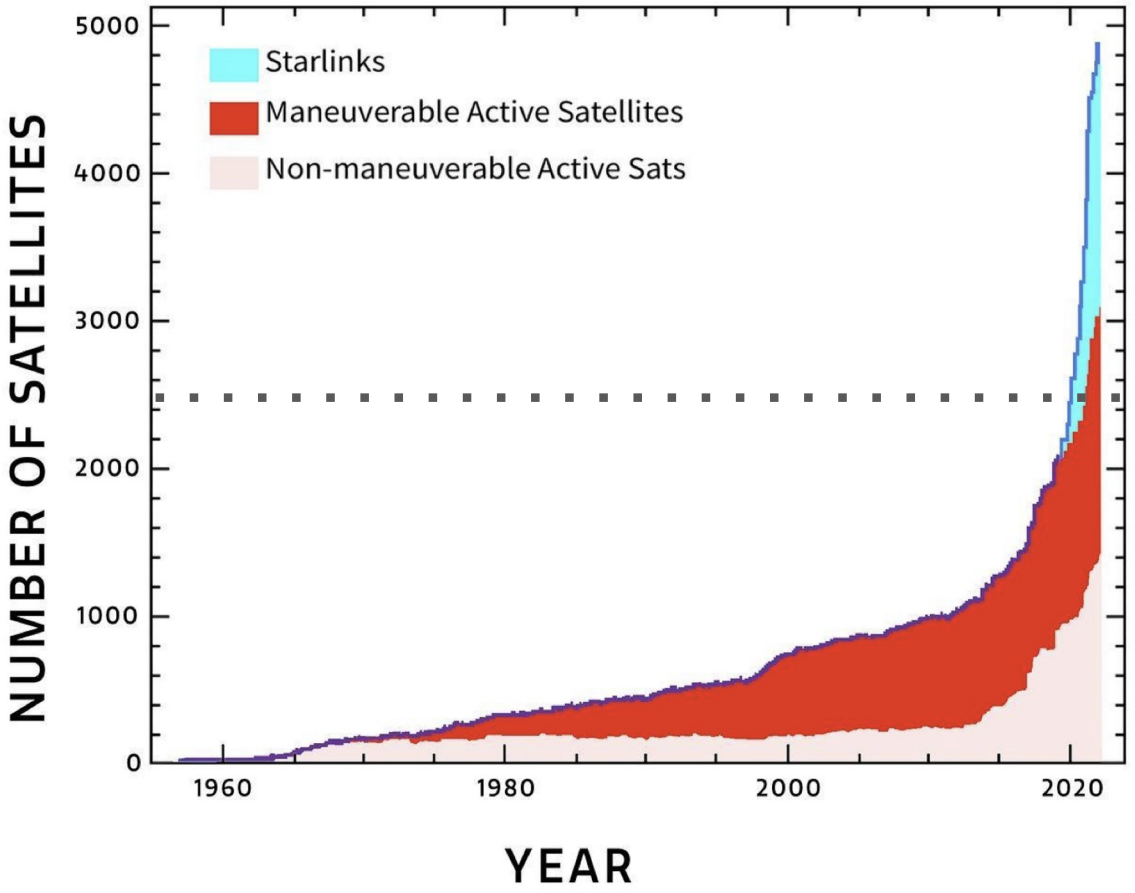
Satcons - 2023

427,171

ITU and FCC Applications

50% of all active sats launched in last four years

40% of all active sats are Starlinks



Credit: J. McDowell/CFA

Slide edited for accuracy: 03/28/2024

Satcons - 2024

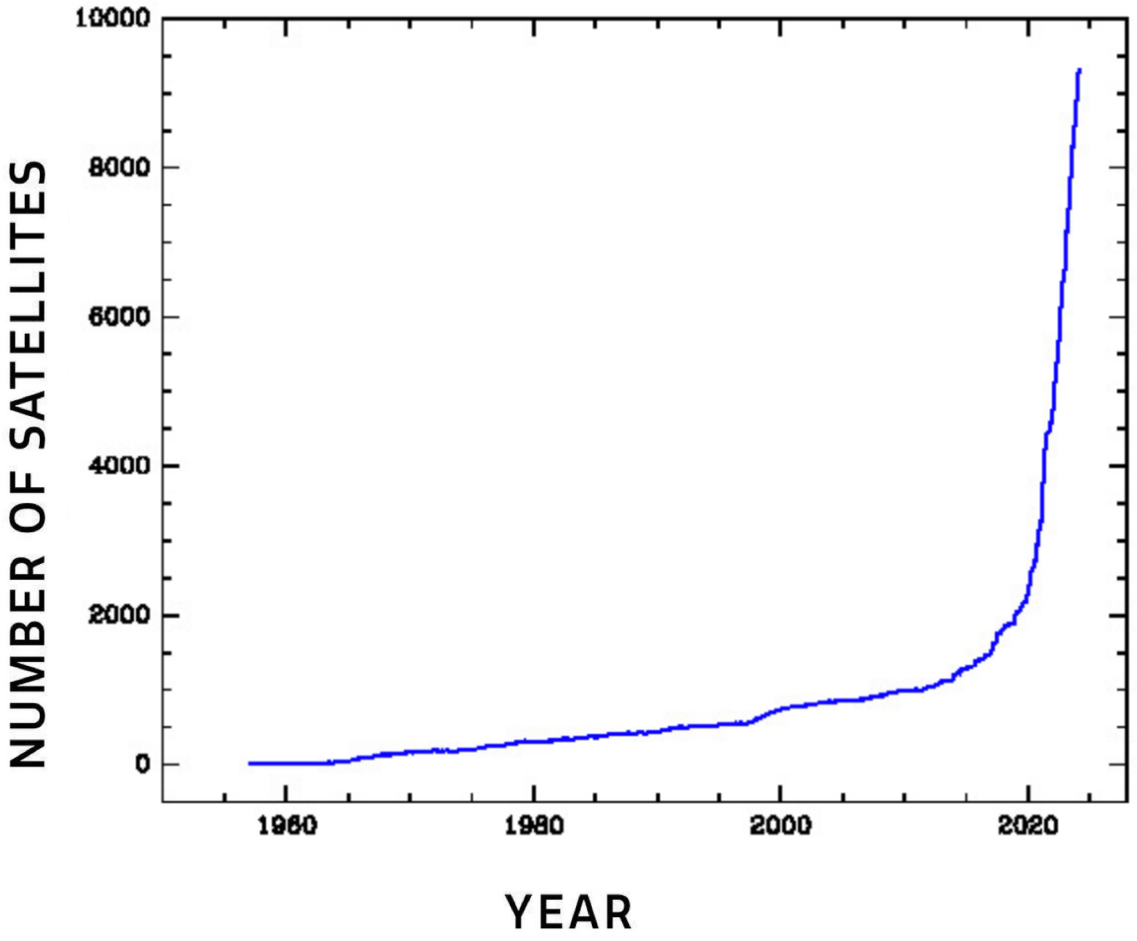
543,201

Applications

*as many as 1.1million planned**

81% of all active sats launched in last four years

~60% of all active sats are Starlinks



Credit: J. McDowell/CFA

* Includes numbers from governmental press announcements – unlikely to be realized

Satcon Issues

- Full cycle impact on observations
  - Streaks, occultations, diffuse sky brightening, extinction
  - Laser guide stars
  - Radio interference
- Impact on night sky accessibility
  - Recruitment
  - Amateur astronomers
  - Cultural heritage
- Long-term orbital sustainability
  - Space debris
  - Space-based observatories
  - EM spectrum traffic
  - Kessler
- Potential Environmental impacts
  - Launch
  - Deorbit – deposition rates
  - Animal behavior
- Cislunar/Shielded Zone of the Moon

New Challenges to Ground-Based Astronomy

Congested spectrum and new satellite operations

- *FCC unanimously approved regulatory framework for Supplemental Coverage from Space*

Space traffic management of satellite constellations

- *Department of Commerce now manages commercial space traffic*

Long-term sustainability of orbital environment

- *Priority issue both domestically (DOC, NASA) and internationally (UN COPUOS)*

Atmospheric impacts of satellite reentry

- *Metals from satellite burnup detected in stratosphere*

Optical wireless communications

- *NASA successfully tested first deep-space optical links*

International Developments

ITU-R WRC-27

Agenda Item 1.15: *"To consider studies on frequency-related matters…for future development of **communications on the lunar surface and between lunar orbit and the lunar surface.**"*

Agenda Item 1.16: *"To consider studies on the technical and regulatory provisions necessary to **protect radio astronomy operating in specific Radio Quiet Zones…from aggregate radio-frequency interference caused by non-geostationary-satellite orbit systems.**"*

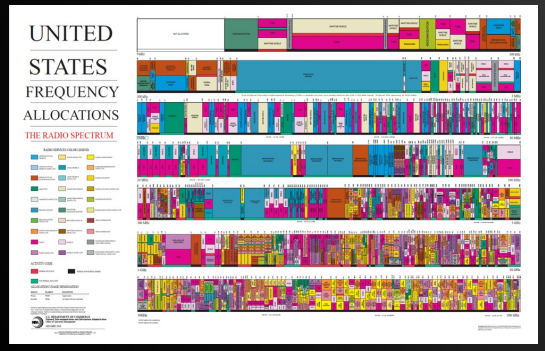
Agenda Item 1.17: *"To consider **regulatory provisions for receive-only space weather sensors and their protection** in the Radio Regulations…."*

Agenda Item 1.18: *"To consider…possible regulatory measures regarding the **protection of the Earth exploration-satellite service (passive) and the radio astronomy service in certain frequency bands above 76 GHz** from unwanted emissions of active services."*

UN COPUOS

5-year Agenda Item: *"**Dark and Quiet Skies, Astronomy and Large Constellations: Addressing Emerging Issues and Challenges**"*

Satellite-Astronomy Coordination – Radio



From SpaceX Coordination Agreement; other companies in similar discussions:

- Comply with Radio Regulations, U.S. and International Footnotes to the Table of Frequency Allocations
  - Geographic avoidance of National Radio Quiet Zone and Puerto Rico Coordination Zone
  - Transmissions near radio astronomy sites remain below thresholds defined in ITU-R Recommendations
- Avoid main-beam illumination of radio telescopes
- Develop data processing and technology solutions

Satellite-Astronomy Coordination – Optical

From SpaceX Coordination Agreement; other companies in similar discussions:

- Limit brightness to ~7th magnitude at 550 km orbit
- Limit orbits to ~700 km so satellites de-orbit on human timescales
- Orient satellites to not reflect sunlight directly at Earth
- Provide precise orbital telemetry to inform telescope observations
- Develop more robust telescope detector technology

https://cps.iau.org/industry-and-technology-hub/

Opportunities for Practical Solutions

Many companies cannot evaluate if their systems achieve IAU CPS Best Practices for optical brightness

- Collaborate with industry to develop standards for satellite brightness measurements and modeling
- Distributed observation effort for satellite brightnesses
- Inform space traffic management with astronomy observation needs
- Develop technological mitigations for satellites and telescopes

Spectrum and satellite-astronomy technology development is prioritized in the 2022 CHIPS and Science Act and 2023 National Spectrum Strategy!

Satcons - Updates

NSF sets up coordination agreements with SpaceX (Jan 2023) and OneWeb (April 2023, four more in process).

FCC is requiring this for all constellation operators : "to continue to coordinate and collaborate with NASA to promote a mutually beneficial space environment that would minimize impacts to NASA's science missions involving astronomy and to coordinate with NSF to achieve a mutually acceptable coordination agreement to mitigate the impact of its satellites on optical ground-based astronomy." The license also requires the constellation operator: "submit an annual report to the Commission, by January 1st each year, covering the preceding year and containing the following information: (1) whether it has reached a coordination agreement with NSF addressing optical astronomy; and (2) any steps . . . taken to reduce the impact of its satellites on optical astronomy, including but not limited to darkening, deflecting light away from the Earth, attitude maneuvering, and provision of orbital information to astronomers for scheduling observations around satellites' locations."

Satcons - Updates

AAS signs Zero Debris Charter, pens letter to NTIA supporting NRAO, and provides feedback on White House proposal for Space Mission Authorization.

IAUS-385: LSST numerical simulations

- *Survey Astronomy in particular is greatly impacted (Rubin Observatory is one large example)*
- *Fewer satellites the better (less than 10,000 is optimal, 400,000 is untenable)*
- *Fainter than visible to the naked eye in a dark site (fainter than 6-7 mag) is needed.*

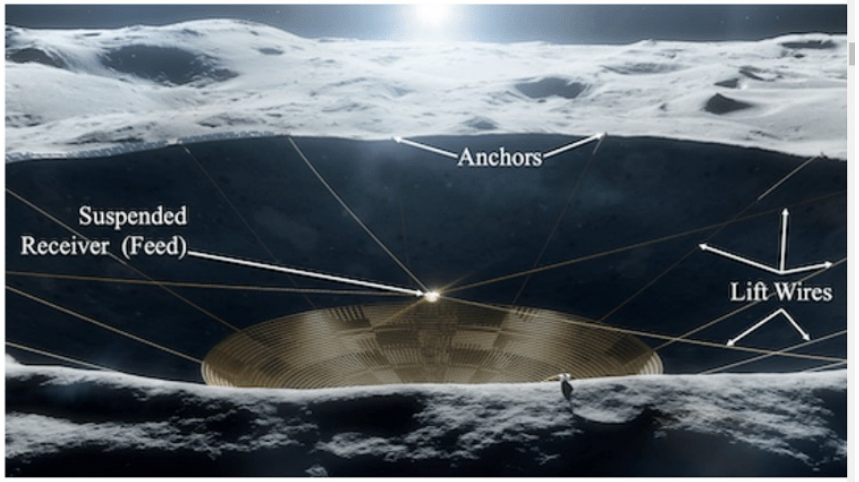
Lunar and cis-lunar Concerns

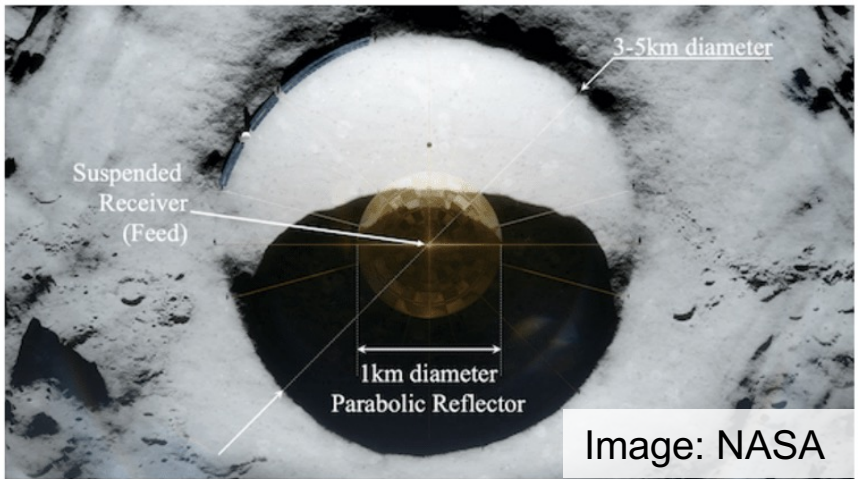
Lunar

- Astronomical interests in radio quiet sites
- Conflicting desires for cold crater use
- Electronic equipment radio noise

Cis-Lunar

- Impact of lunar orbit proliferation
- Impact of/on future orbital space stations



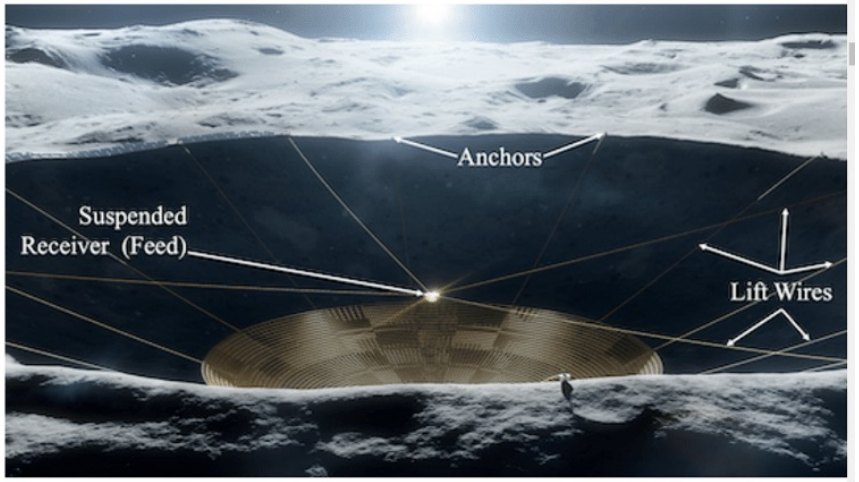


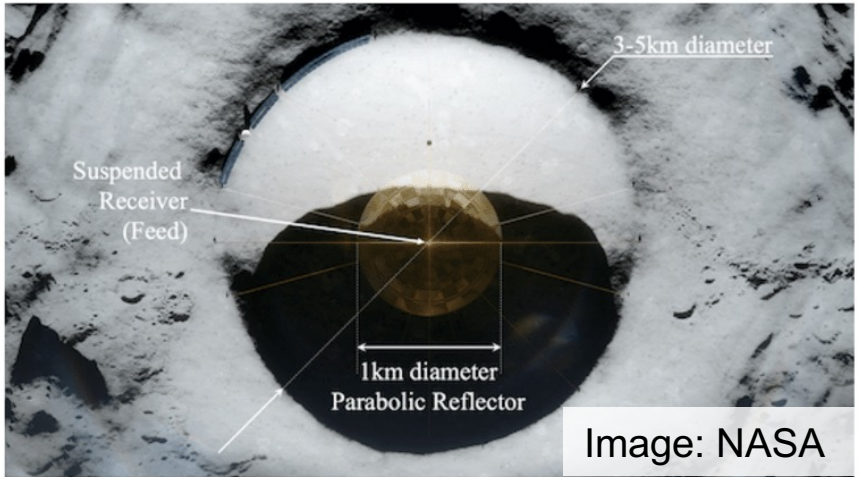
Lunar and cis-lunar Concerns

Building collaboration with the AAS Division on Planetary Science.

Building collaborations across planetary protection panels and committees.

Involved in letters to NASA regarding taking human remains to the Moon.





Key Goals for COMPASSE?

- *Raising Awareness*

  Amongst our constituents (in AAS), with policymakers, with federal agencies, and in the broader community

- *Coordinating Efforts*

  Maintain relationship with industry partners, federal agencies, policymakers, and other concerned/impacted groups

- *Policy Solutions (SATCON 3)*

  Defining impacts to our science, defining threshold for harm, working with policymakers on oversight of mitigation of impact on astronomy.

Last Year's Closing Questions

Questions

- How do we plan toward the impending rapid expansion of international operators not subject to FCC regulations? ***UN COPUOS, ITU, IAU CPS***
- What unknown effects need to be quantified? ***SATCON3***
- Can the NAS take a role in establishing a committee similar to CORF?
- Can the NAS take a role in establishing a group on Space Ethics?
- How can we navigate cislunar orbit and lunar surface regulation? ***ITU WC-27, IAU***

Closing Thoughts

"Space exploration, then, can be broken into three conclusive categories: astronomy, unmanned probes, and manned probes." – NASA 2009 http://adc.gsfc.nasa.gov/adc/education/space_ex/exploration.html

Our branch of space exploration is being inhibited by human activity on the ground and in orbit.

The Moon represents the next frontier of the conflict between commercial and scientific interests.