IAUS385 SYMPOSIUM

IN PERSON AND ONLINE MEETING

Astronomy & Satellite Constellations: Pathways Forward

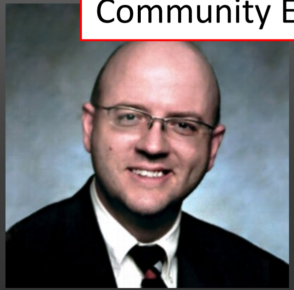
Connie Walker (SOC Chair) and the SOC Team

Agenda

- IAU Symposium 385 Overview
- Scientific Impacts of SatCons and Mitigation
- Industry’s Growing Involvement
- Policy Considerations
- Media Awareness
- Summary

IAUS385 SESSION CHAIRS

Community Engagement Hub



John Barentine
Dark Sky Consulting, LLC

Jessica Heim
U. Southern Queensland

SatHub (software, observations & more)

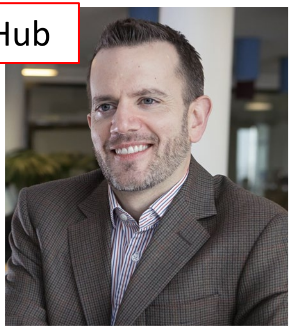
Meredith Rawls
U Washington & Rubin Obs

Siegfried Eggl
U. Illinois Urbana-Champaign

Mike Peel
Imperial College London

Policy Hub

Richard Green
Univ. of Arizona

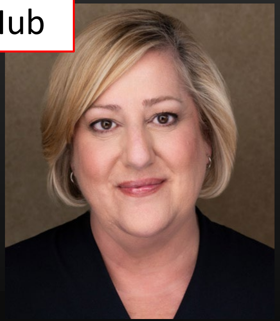


Andrew Williams
European Southern Obs.

Tim Stevenson
SKAO

Industry & Technology Hub

Chris Hofer
Amazon Kuiper Project



Patricia Cooper
Constellation Advisory, LLC

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IAU385 SYMPOSIUM

IN PERSON AND ONLINE MEETING

Astronomy & Satellite Constellations: Pathways Forward

CPS IAU NOIRLab SKAO CABILDO DE LA PALMA SANTA CRUZ DE LA PALMA La Palma

(In-person participants)

IAU Symposium 385 Overview

- 250 registrants; ***More than 46 countries represented***
- Program focussed on four themes that mirror the four Hubs of the IAU CPS
  - ➢ SatHub (on software and observations)
  - ➢ Policy Hub
  - ➢ Industry Hub
  - ➢ Community Engagement Hub.
  - ➢ This presentation will focus on the first three themes
- Half of the talks were contributed from a geographically diverse number of countries
  - ➢ Diverse groups are engaged and growing into a global community

Scientific Impacts of SatCons & Mitigation

Challenges (being addressed by SatHub & others)

Radio Astronomy: Ultra-bright beams of Starlinks passing over radio observatories; Unintended Electromagnetic Emission(UEME) from satellites; Limits on protection zones.

Optical Astronomy: "Whiteout" of entire detectors by satellites as bright as BlueWalker 3; Models of non-uniform distribution and brightness of satellites; Limits to active avoidance due to satellite maneuvers; Difficulties for adaptive optics / artificial guide stars.

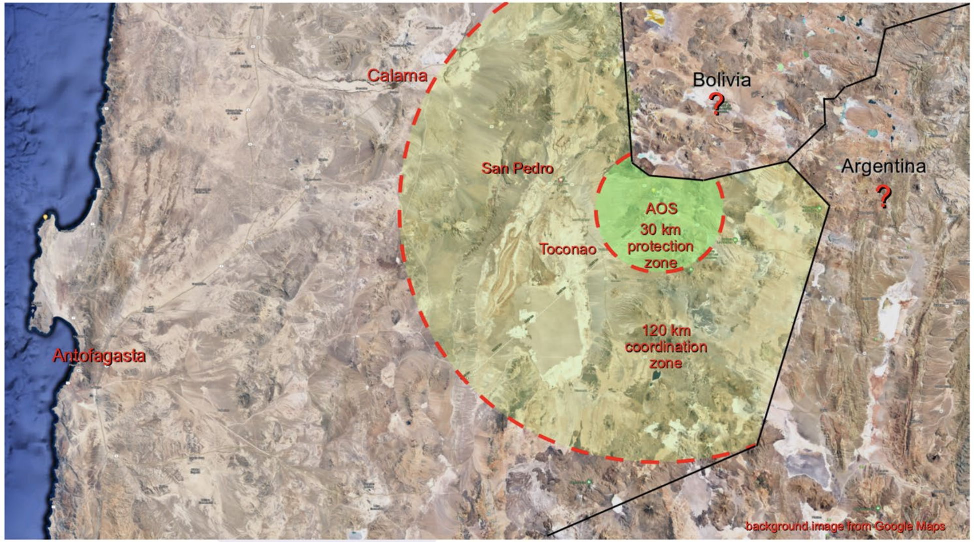
Spectroscopy: Most pronounced in "medium resolution" spectra; adds complexity to 4MOST/DESI

Space-based observatories: Growing number and density of satellites in LEO

Scientific Impacts of SatCons & Mitigation

The ALMA Site

National Borders Limit Protection Zones



G. Siringo: ALMA Spectrum & RFI * IAU Symposium #385 * October 3, 2023 * La Palma

In Search of our Cosmic Origins

Unintended Starlink Emissions at SKA - Low (D. Grigg)

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Scientific Impacts of SatCons & Mitigation

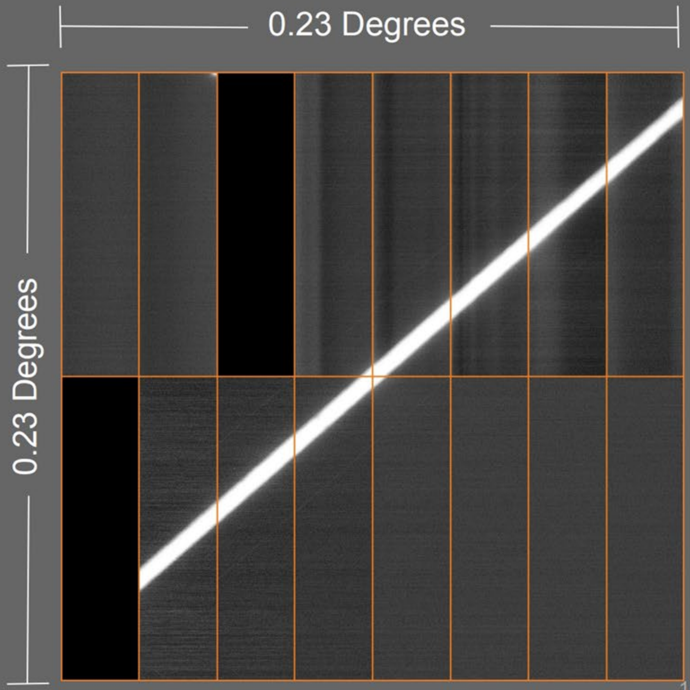
Brightness v Impact

- Crosstalk Correctable with <10% Error = 5,000 peak electron count = 7-8th magnitude*

  Faint brightness science affected

*Satellite magnitude calculations :

- Sat height: We assume 550km orbit. Higher is brighter due to slower orbit.
- Sat shape/Streak Profile: We use the profile shown to the right
- Filter used: We show r-band which is highly impacted.
- Viewing angle: We use 40 deg from zenith.
- We are using stationary sat magnitude.



Rubin Observatory CCDs

IAU CPS recommendation

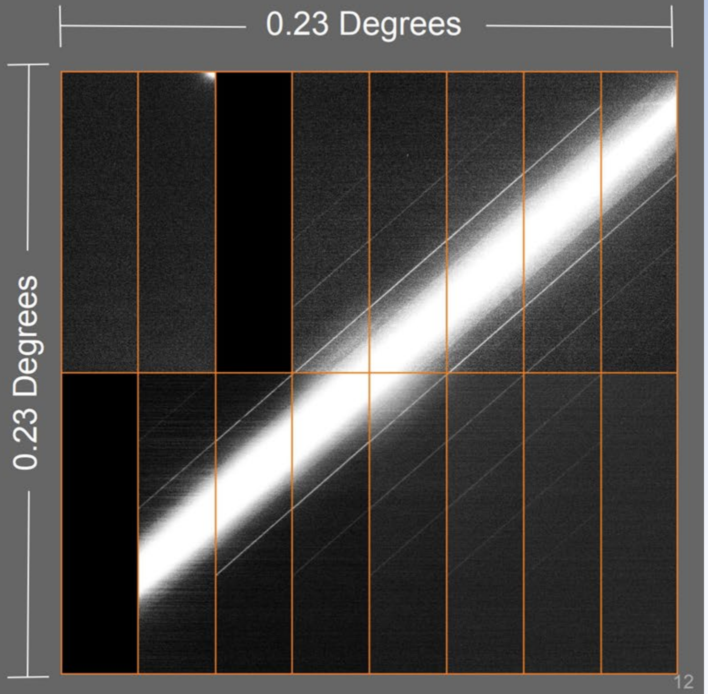
D. Polin /
T. Tyson (UC Davis)

Scientific Impacts of SatCons & Mitigation

Brightness v Impact

- Crosstalk Correctable with <10% Error = 5,000 peak electron count = 7-8th magnitude
- Correctable with <20% error = 10,000 peak electrons count = 6-7th mag
- Saturation/ “Correctible” with large Error = 100,000 electrons = 4th mag

  Most science programs affected



Rubin Observatory CCDs

Current Starlinks

D. Polin /
T. Tyson (UC Davis)

Scientific Impacts of SatCons & Mitigation

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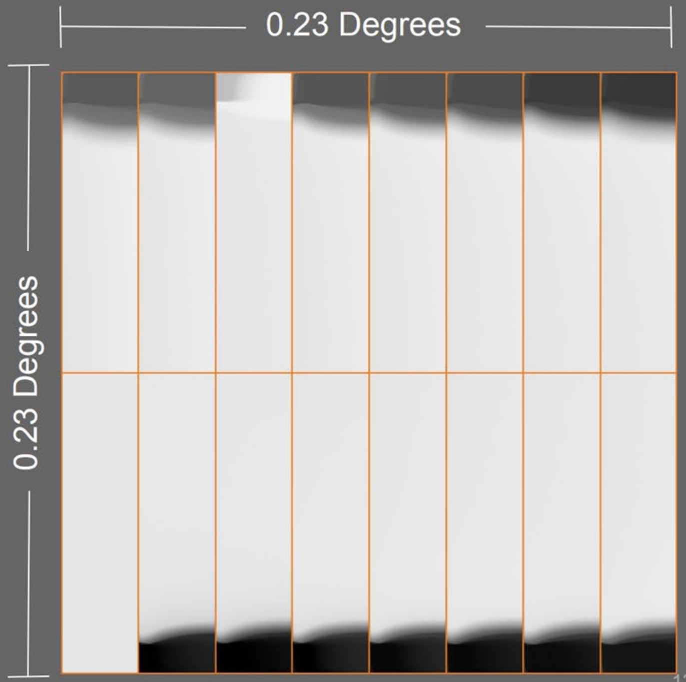
- Blooming/ Not Correctable = 1 Million electrons = 0-1 Mag



Rubin Observatory CCDs

BlueWalker 3

D. Polin /
T. Tyson (UC Davis)

Observing campaigns: BlueWalker3

Video: Marco Langbroek, Delft Technical University.

Starlink

BlueWalker

M. Tzukran

Scientific Impacts of SatCons & Mitigation

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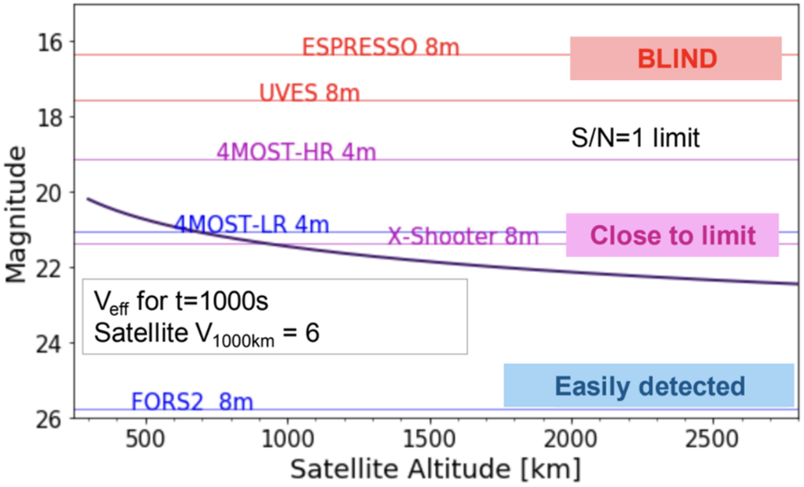
Space-based observatories: Growing number and density of satellites in LEO

Scientific Impacts of SatCons & Mitigation

Limiting Magnitude of the Spectrographs

Limiting magnitude: V with S/N=5 in 1h
- Size of the telescope
- Resolution of the spectrograph

- High-res (r~100 000) **blind**
  - UVES (8m): 17.0
  - ESPRESSO (8m): 15.8
- Mid-res (r~10 000) **some**
  - 4MOST-HR (4m): 18.6
  - X-shooter (8m): 20.8
- Low res (r~1 000)
  - 4MOST-LR (4m): 20.5 **some**
  - FORS (8m): 25.2 **affected**



Data Classification: ESO PUBLIC

High-res spectrographs are essentially blind to satellites, because of the long exposures that average out satellite contributions

In low-res spectrographs, pollution is easily detected, because satellites produce bright outliers.

The real issue lies with resolutions ”in between”.

SatCons and Laser Adaptive Optics

Laser Clearing House restrictions

“Deconflict” laser propagation and satellites

Dramatic increase in Gemini LGS observing window closures

Coordination agreements between NSF and Space-X/Starlink

- Starlink has “opted out” of the Laser Clearing House restrictions
- Discussions underway with OneWeb

Scientific Impacts of SatCons & Mitigation

Strategies for co-existence (being addressed by SatHub & others)

Radio astronomy: Satellite beam steering, conscious choices for constellation ground station placement, ITU regulation, Investigation of UEMEs.

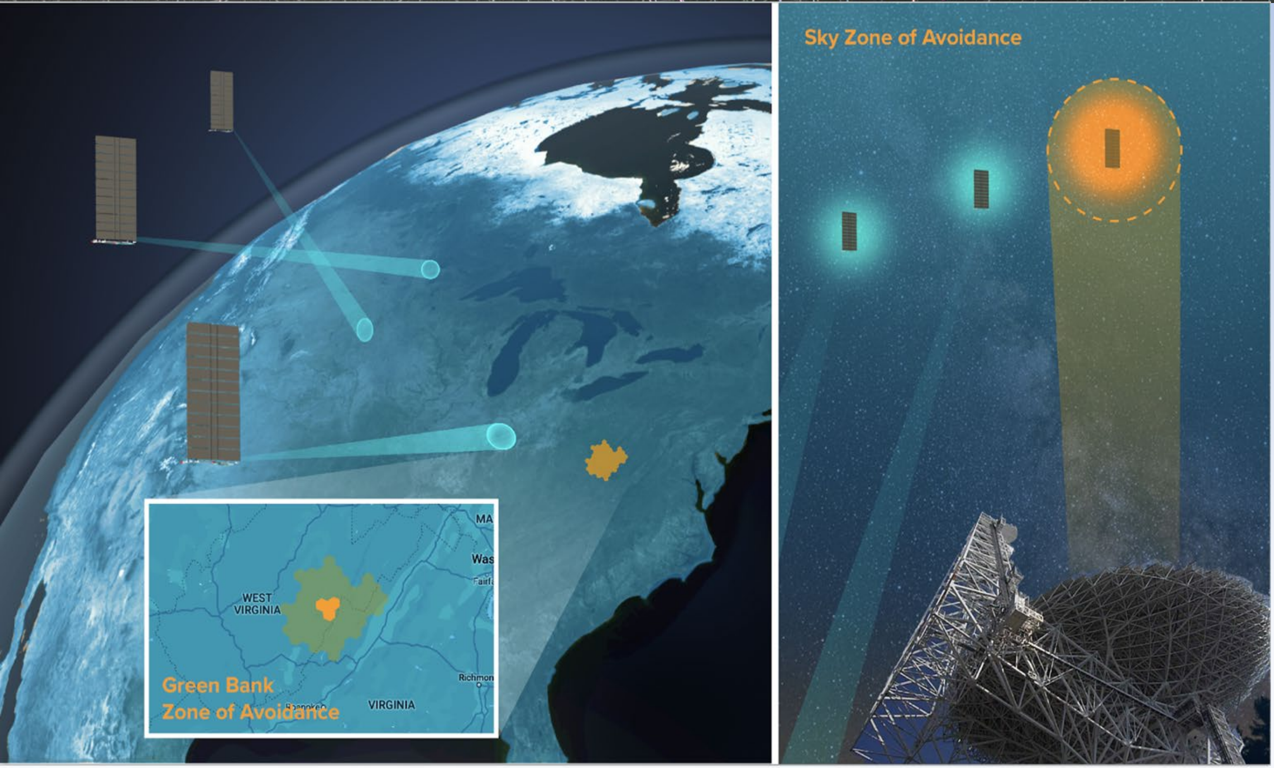
Optical astronomy: Better models for / data of satellite brightness (BRDF), coatings, ESA's sustainable space approach and monitoring capabilities

Spectroscopy: understanding satellite spectra, autonomous mitigation loops with imagers (4MOST)

Space based observatories: software solutions (Starunlink)

SatHub: bringing all stakeholders together to tackle the constellation challenge

Scientific Impacts of SatCons & Mitigation



Radio Astronomy / Constellation Co-existence example: Active Beam Steering (Ch. De Pree, NRAO)

Scientific Impacts of SatCons & Mitigation

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Space based observatories: software solutions (Starunlink)

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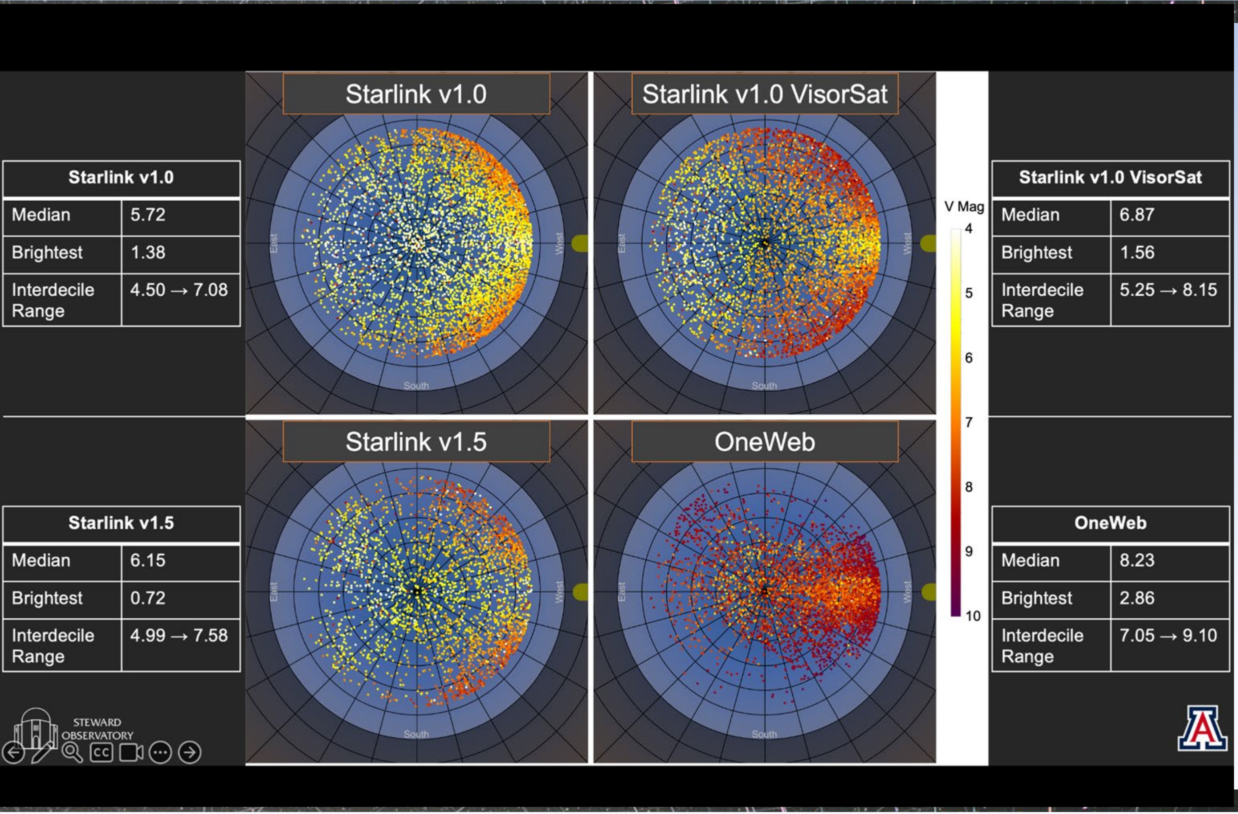
Scientific Impacts of SatCons & Mitigation



Measured brightness statistics of Starlink and OneWeb satellites (H. Krantz, UArizona)

Scientific Impacts of SatCons & Mitigation

Zero Debris: Technical Requirements

esa

Applicable orbits	Guarantee successful disposal	Improve orbital clearance	Avoid in-orbit collisions
Avoid internal break-ups	No intentional release of space debris	Limit on-ground casualty risk	Guarantee dark and quiet skies

Assessment and mitigate impacts on ground astronomy

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→ THE EUROPEAN SPACE AGENCY

The European Space Agency has added Dark and Quiet Skies protection to their technical requirements for missions (J. Siminksi, ESA)

Scientific Impacts of SatCons & Mitigation

Strategies for co-existence (being addressed by SatHub & others)

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SatHub: bringing all stakeholders together to tackle the constellation challenge

Industry & Technology Hub: Progress Report

- **ENLIST:** Ten active constellation operators committed to participate in Hub, with outreach to all key constellation proponents. Amplifying reach through leading satellite trade groups and manufacturers.

- **INFORM:** Created easily-accessible reference library and essential reading lists; consolidated best practices and latest recommendations. Regular presentations at astronomy and satellite events. Feedback is scoping the additional tools and resources companies need for predictive software, ground-based testing and calibrated observation.

- **EXCHANGE:** Early progress on creating a marketplace for solutions to make products, brightness models available to all.

- **PLAN:** 2023 Workplan shapes the Hub and its activities, along with an on-boarding plan to support companies as they join.

Industry & Technology Hub:

- **Upcoming Deliverables/Milestones:**
  - ➢ Further expand I&T Hub participants with constellation proponents that are commissioning spacecraft now and manufacturers
  - ➢ Onboard all participants fully, with a regular forum for discussion and “astronomer guides” where requested
  - ➢ Intensify focus on predictive and testing tools, informative observation inputs and broadened mitigation options that are affordable, accessible and effective

- **IT Hub’s Challenges:**
  - ➢ Building a trusted “safe space” internal community to advance solutions
  - ➢ Balancing industry successes with ongoing concerns

Policy Considerations

Purpose of IAU CPS Policy Activities

- Raise awareness of satcon issues at high level (EU Council, ESA Clean Space Charter, G7, UN COPUOS, etc.)
- Create a model regulatory framework for satellite constellations based on international treaty and national policy and law
- Create a basis and set of priorities for advocacy to establish such frameworks at international (UN) and national levels
- Support the development of incentives for the voluntary cooperation of industry
- Identify and track emerging threats in LEO, such as space solar power

Policy Considerations

Work Outputs Reported at the Meeting:

- CPS Policy Position Paper to be finalised with input from this Symposium
- Consolidated requirements document produced, harmonising the technical requirements from SATCON1, 2 and D&QS1, 2 conferences.
- Space policy and law research team is working on a detailed analysis of legal and policy questions and will issue a report to CPS
- Partnership ongoing with the Space Sustainability Rating and an initial framework for a module of dark and quiet skies (D&QS) built.

Policy Considerations

Key IAU CPS position relative to CAA purview

- CPS encourages States to take a whole-of-government approach to supporting and encouraging development of mitigations of the impact on astronomy:
  - ➢ Support astronomical observatories to develop, test, and operate required mitigation techniques to minimise the impact of large satellite constellations;
  - ➢ Implement incentive measures to industry to develop and implement technical and operational techniques to protect astronomy from the negative impacts of large satellite constellations.

Policy Considerations

Realization of our Goals within the US System

Progress to date has been enabled by the NSF's office of Electromagnetic Spectrum Management with programs like SWIFT-SAT.

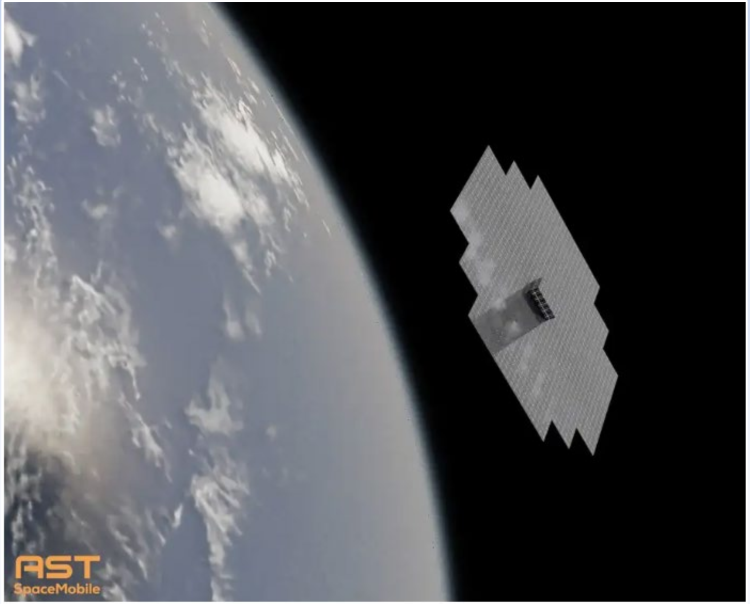
The Department of Commerce can play a role beyond the rapid expansion of space commerce, through support for the development and implementation of mitigations of the unintended consequences.

The Symposium & CPS in the News

- Plan to create an exec summary and organize a press conference to follow up on the meeting given high media interest.

- Have received high media pick up on the recent IAU CPS BlueWalker 3 publication in Nature (US-based media including Gizmodo, Space.com, Newsweek, The New York Times and The Washington Post)

The IAU CPS appeared in 120 media articles last week alone, with a total distribution of 240 million people, so there is great awareness and attention from media (and in particular US media) on the issue.



Artist's conception of BlueWalker 2 satellite. Image: AST SpaceMobile

Summary

- We are making good progress with respect to mitigation techniques, policy and industry cooperation.
- However there is a long way to go - this problem will be with us for a long time.
- There is a need to continue to move forward with efforts to mitigate brightness and radio interference as well as other concerns.
- We appreciate your active engagement.

Thank you for your kind attention.

Questions?

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