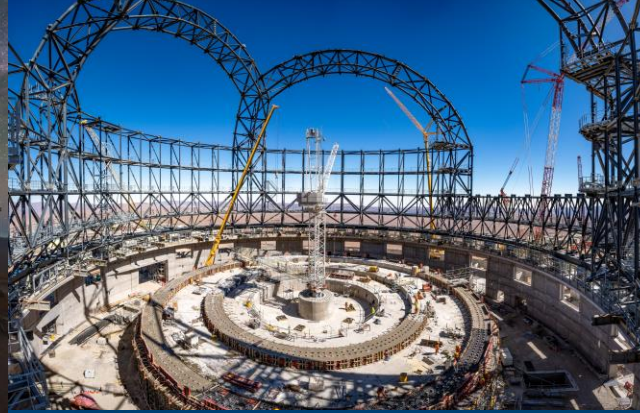
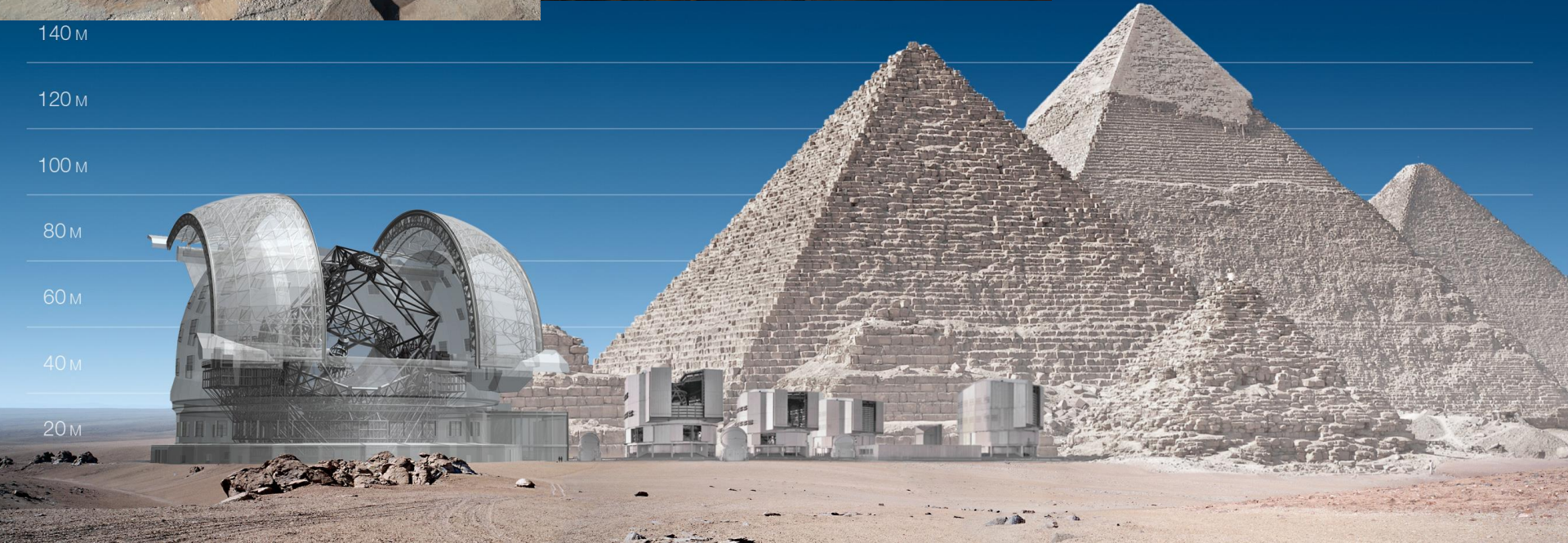
# Dark and Quiet Skies

**Dr Andrew Williams**
European Southern Observatory
International Astronomical Union CPS

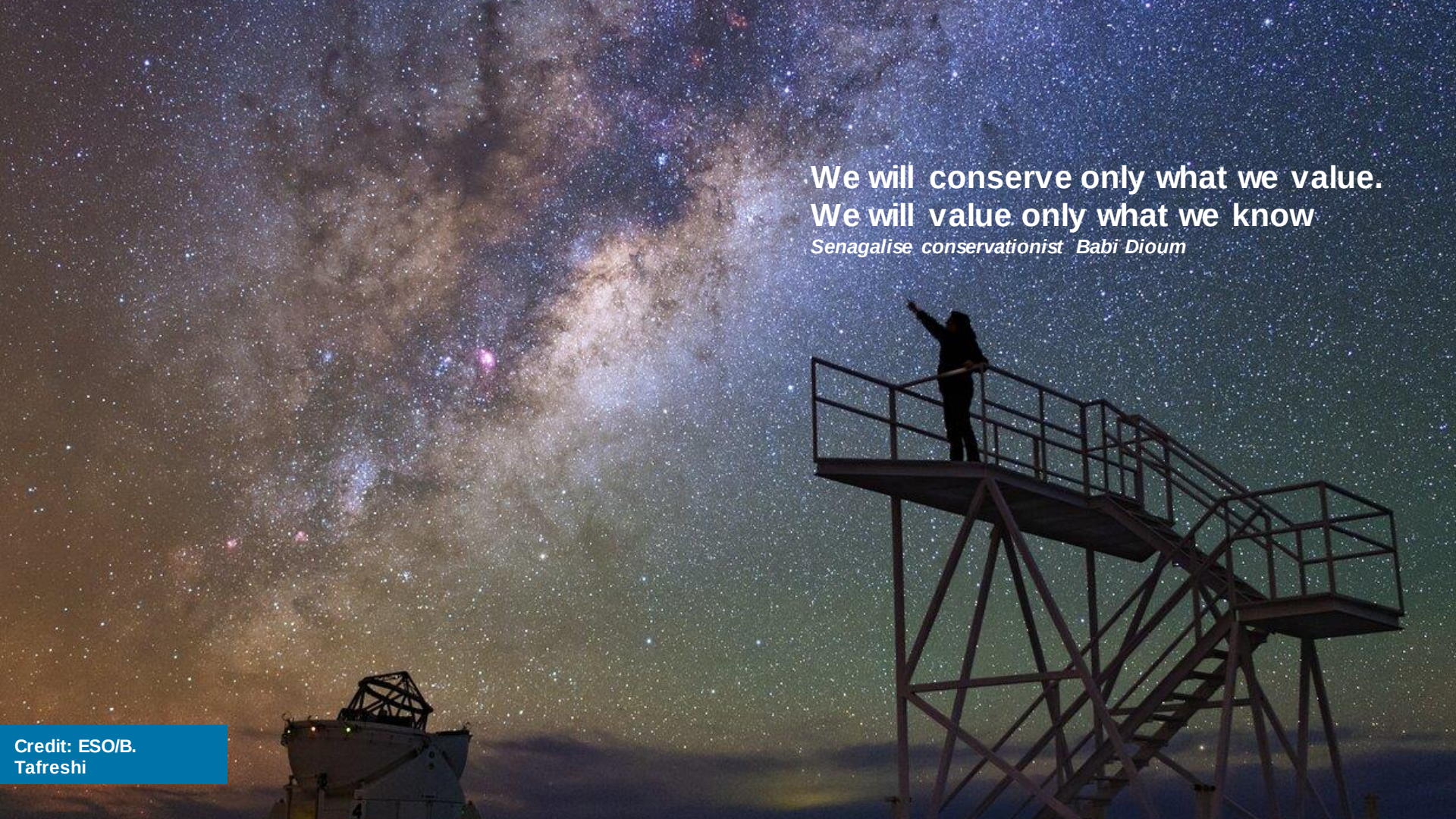
Andrew.Williams@eso.org




140 м
120 м
100 м
80 м
60 м
40 м
20 м


Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference
CPS
IAU
NOIR Lab
SKAO

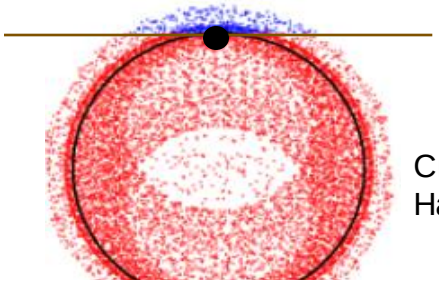

Join the IAU CPS!
https://cps.iau.org/



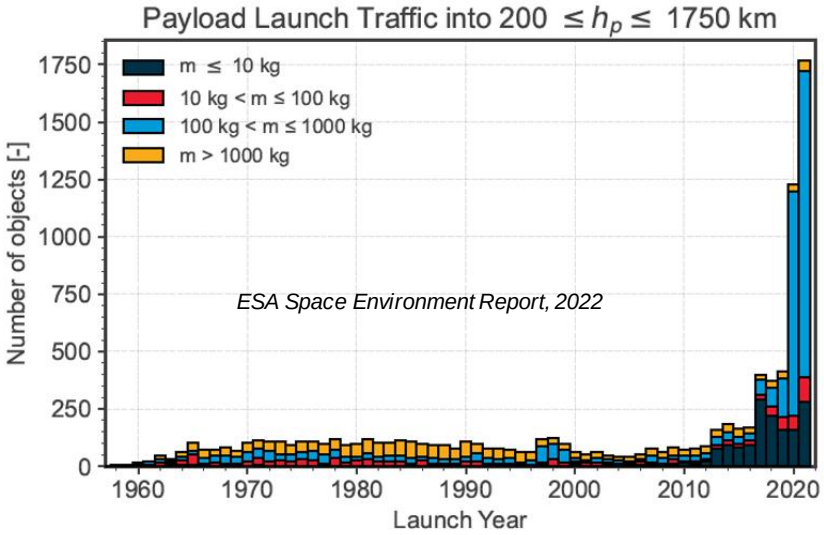

Credit: ESO/B. Tafreshi

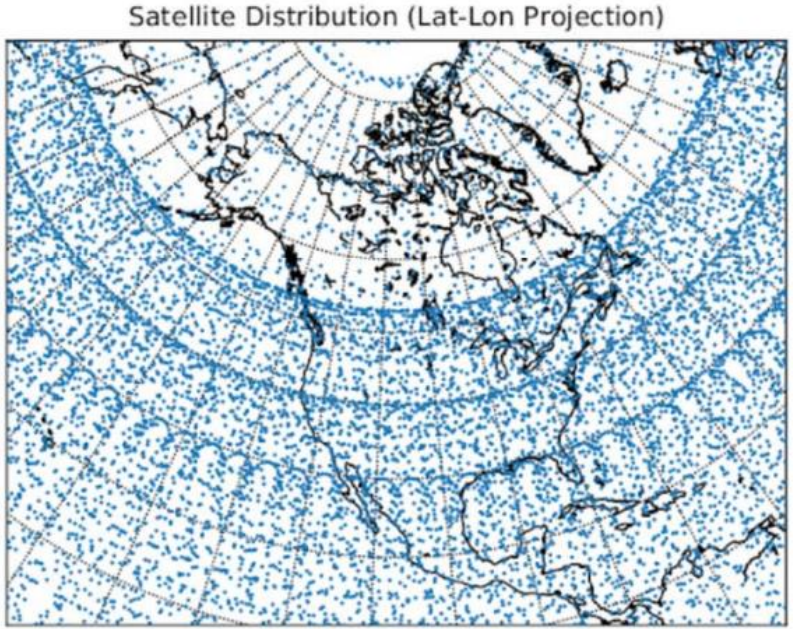
# Many more satellites in Low Earth Orbit

Side view:



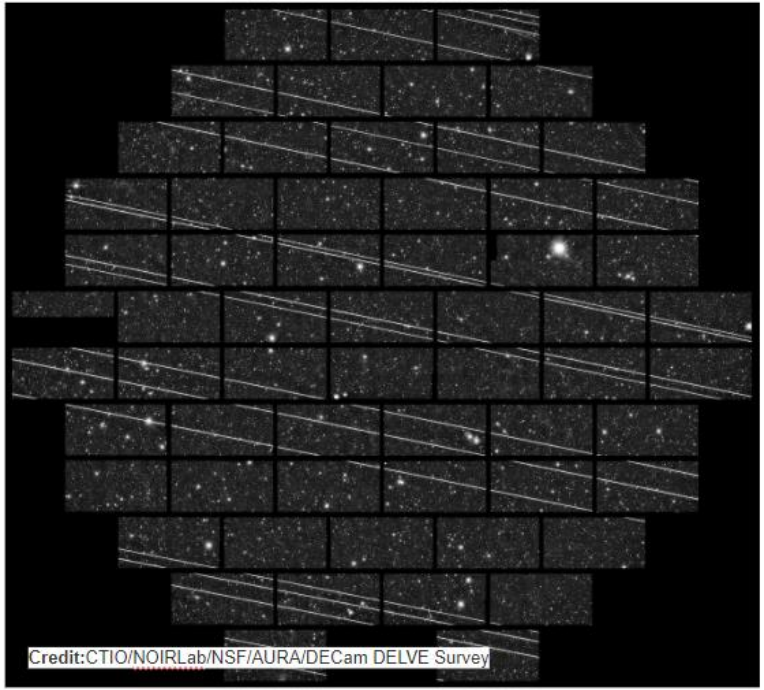
Credit: O. Hainaut, ESO

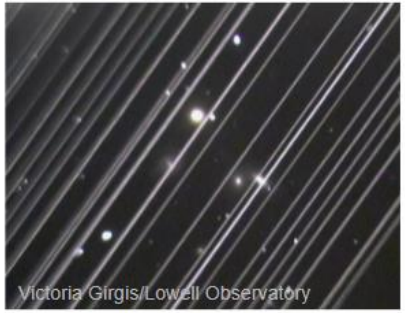


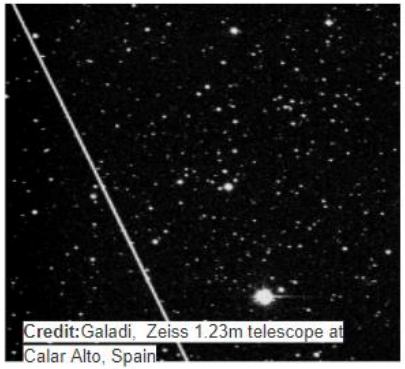



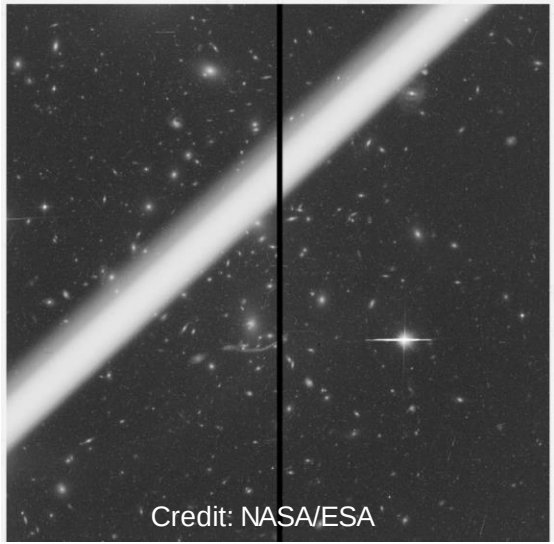

Lawler, Boley, Rein, 2021, Astronomical Journal

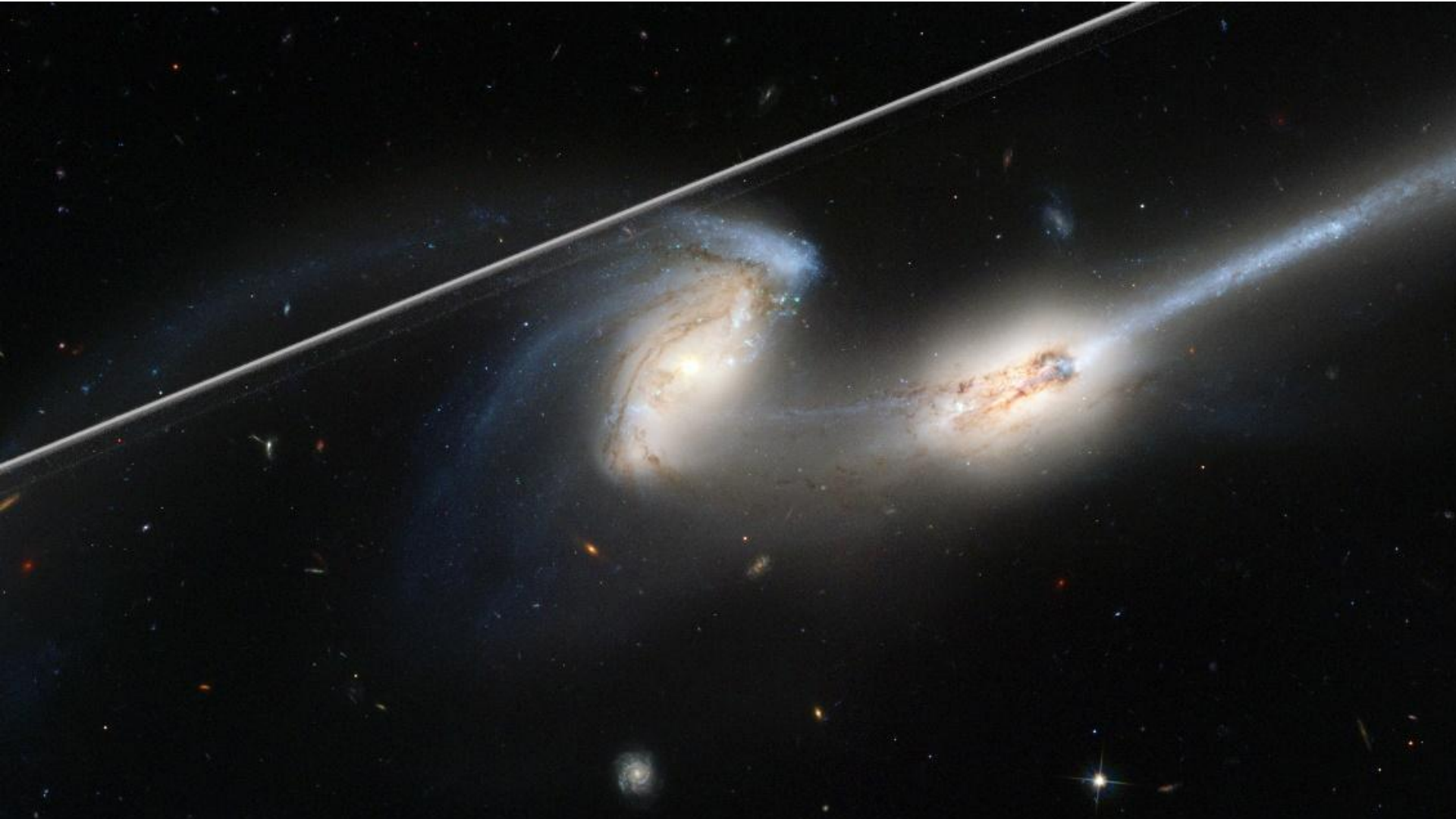
# Unintended impacts (optical)



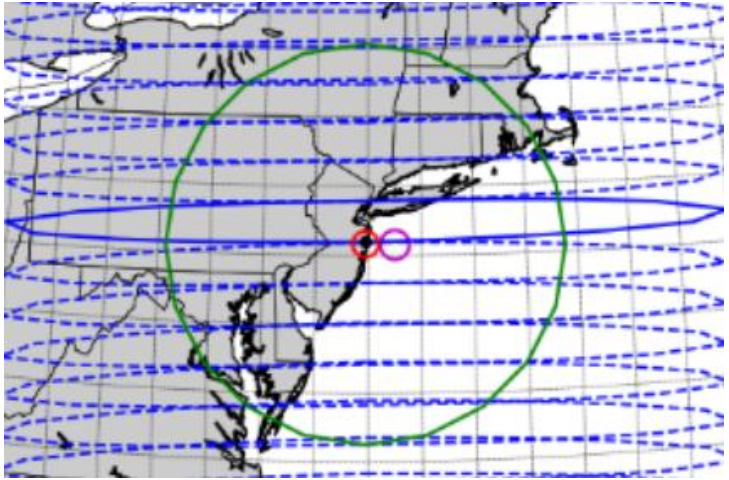



# Impact on Astronomy

*Radio Astronomy*

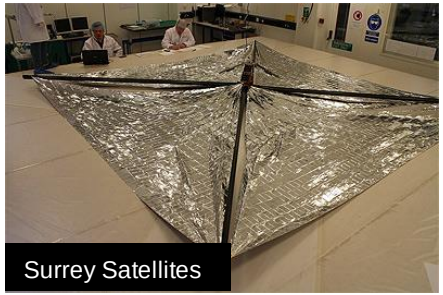
1. High power transmissions beamed directly into radio observatories (unlikely, but bad)
2. Radio interference in the frequency bands protected for astronomy by ITU
3. Space-based radio transmissions in radio quiet zones
4. Unintentional electromagnetic radiation from satellites
5. Reflection of strong terrestrial transmissions



del Portillo, Inigo, Bruce G. Cameron, and Edward F. Crawley. "A technical comparison of three low earth orbit satellite constellation systems to provide global broadband." *Acta Astronautica* 159 (2019): 123-135.

# Why think of Dark and Quiet skies?

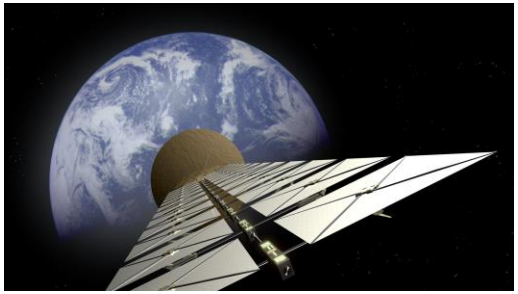
## Passive De-orbiting Sails



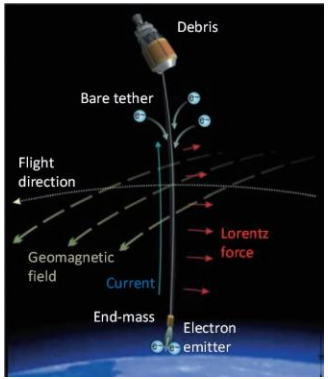
Surrey Satellites

Purdue University

## Space-based Solar Power



## Electrodynamic tethers



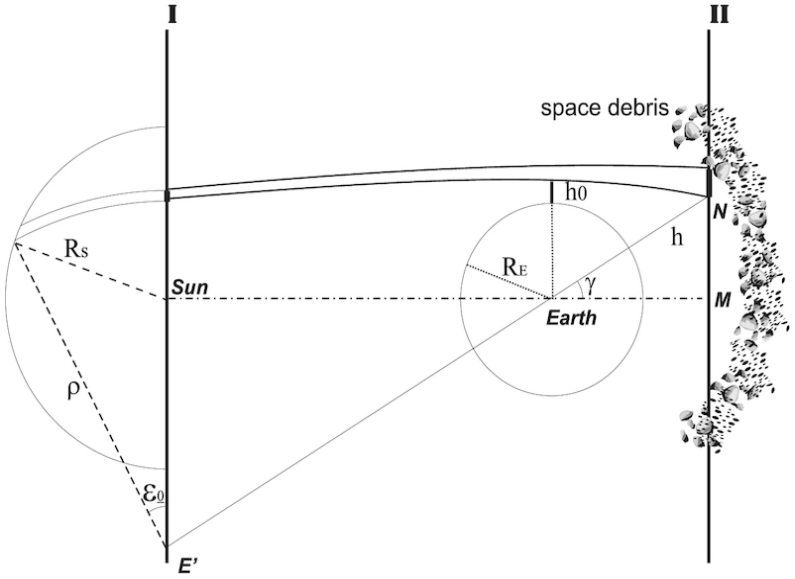

Credit: AST Mobile

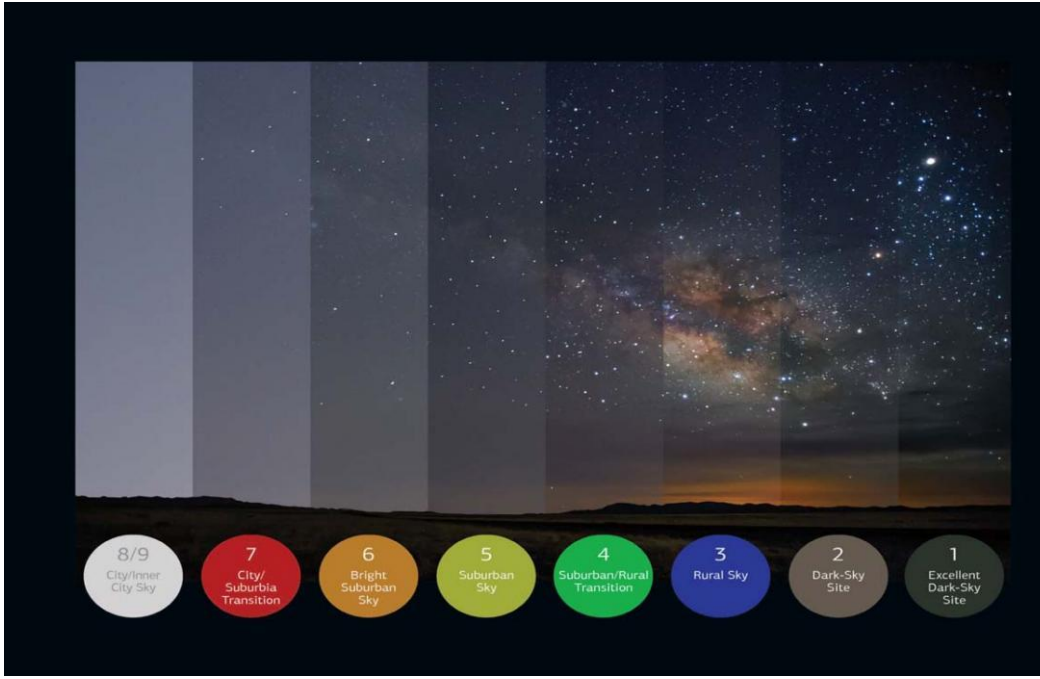
## Cell Phone Towers in Space


## Space Advertising


## Commercial Space Stations

# Space debris / Satellite population will likely increase night sky background light

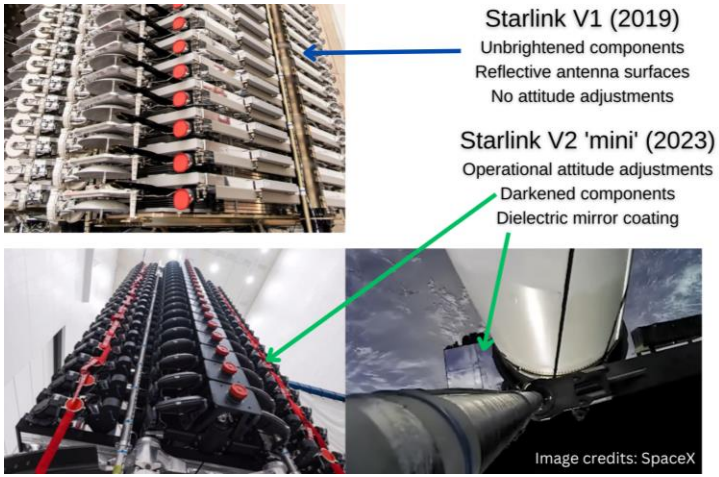



*Mon Not R Astron Soc Lett*, Volume 504, Issue 1, June 2021, Pages L40–L44, https://doi.org/10.1093/mnrasl/slab030

# Our approach

- Working with industry to develop best practices
- Establishing voluntary practices and norm development
- Raising awareness in policymaking and industry circles
- Influencing space regulation
- Actions at the international level – COPUOS
  - Advocate for an Expert Group and Agenda item



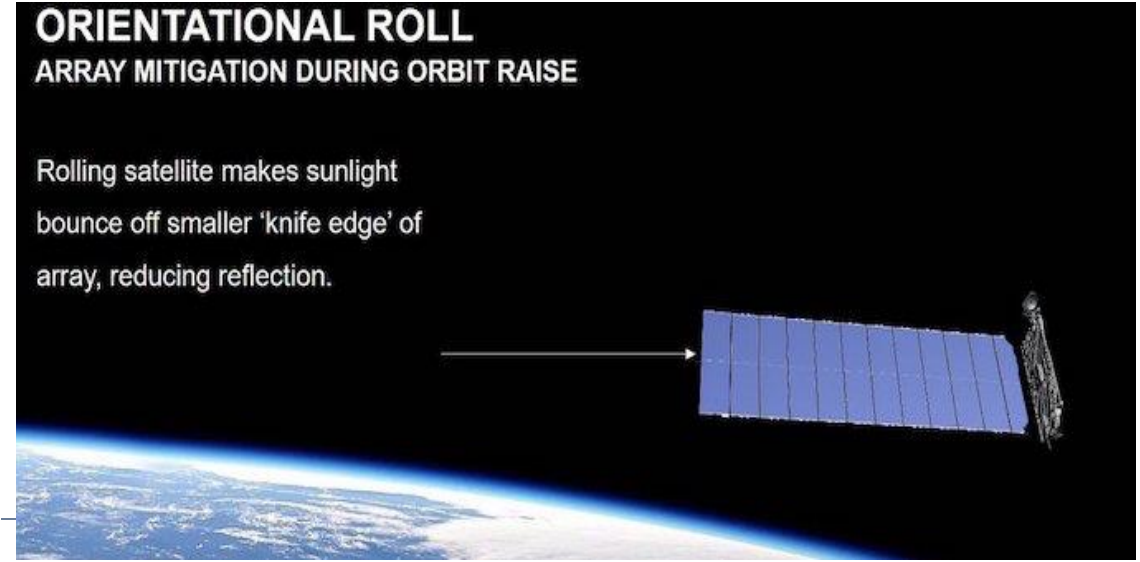

# Requirements

*Brightness of Space Objects*

- Assumption that meeting the condition of the telescope with the highest etendue (field of view x effective area) satisfies the limits for most other telescopes.
- Brightness limit set by calibration limit of parallel cross- talk streaks in Vera Rubin Observatory CCD camera = coincidentally same as limit of human eye
- **V = 7th mag + 2.5 log ($R_{orbit}$ / 550 km);**

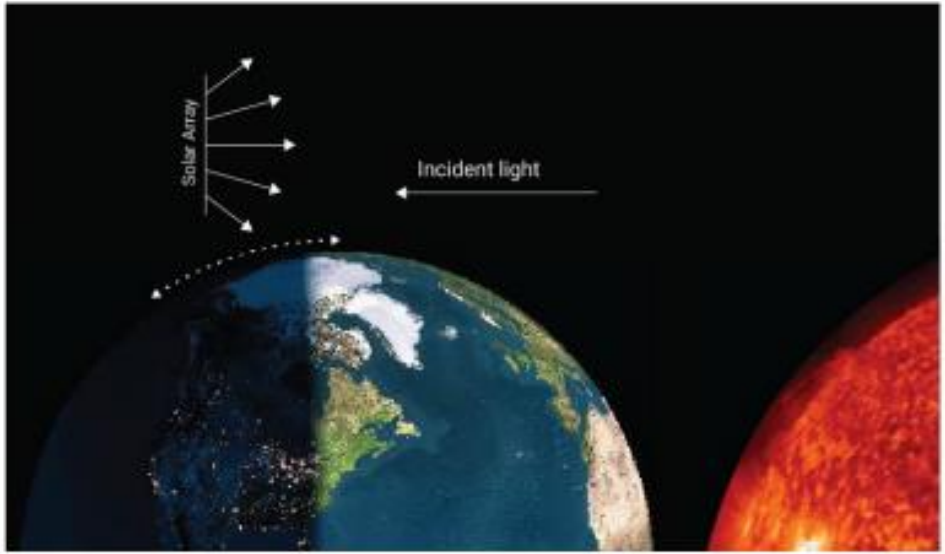
# Operational Practices

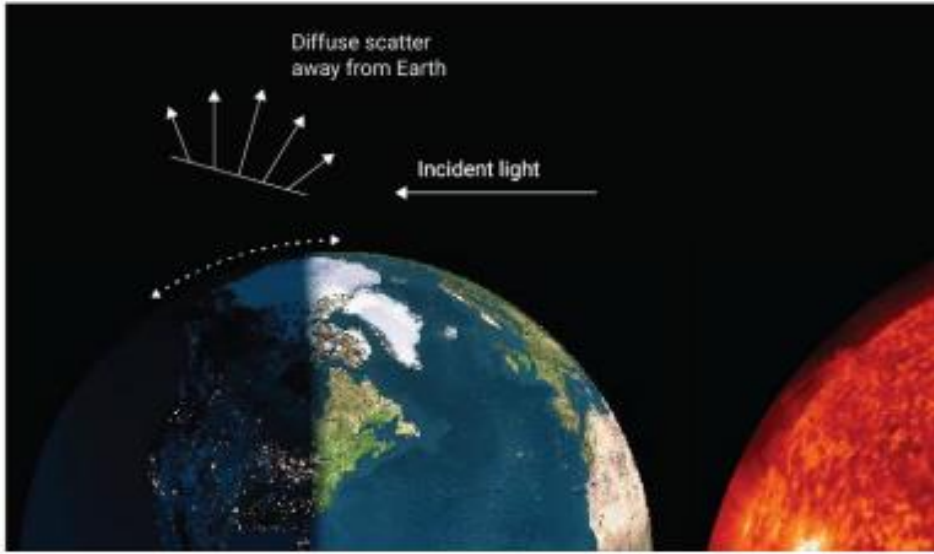
- Minimize visible brightness during orbit raise and de-orbit by appropriate attitude adjustments; clump during orbit raise to minimize transit time of these bright objects through any field of view.




# Operational Practices

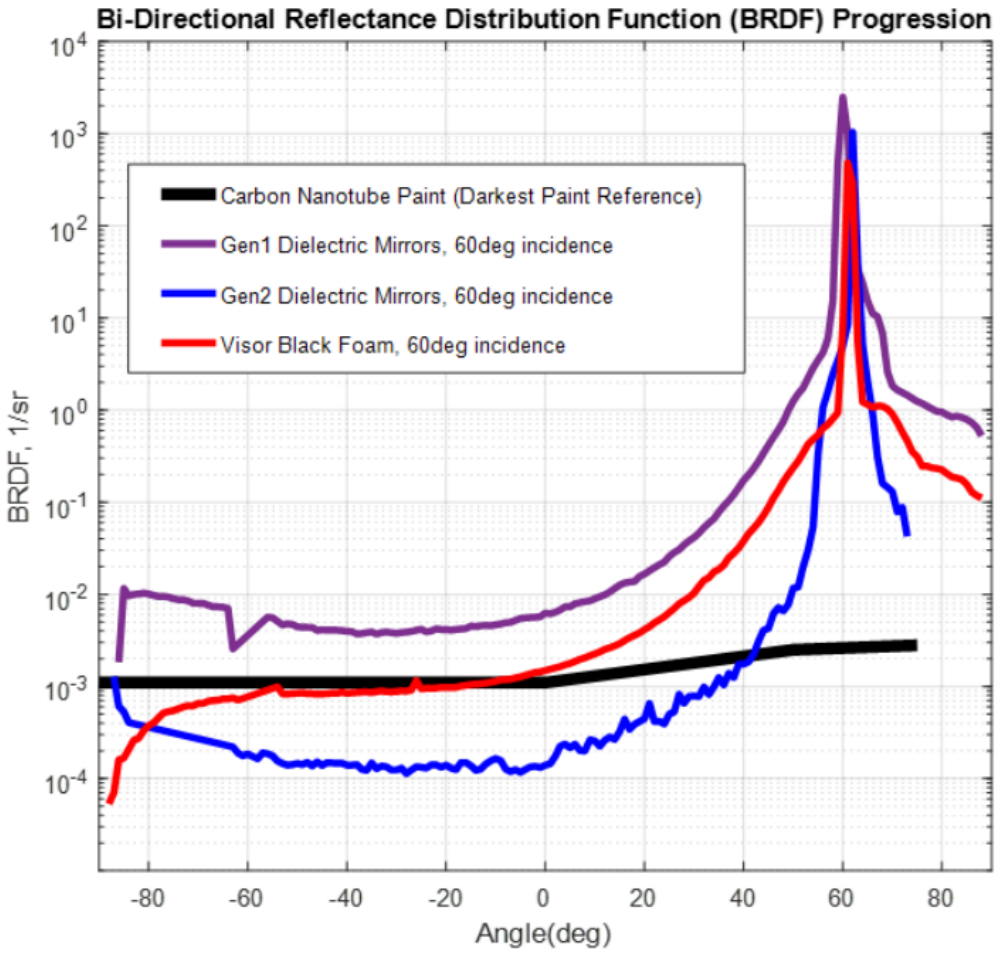
- Minimize visible brightness during operations



# Materials

- Predictive modeling of total apparent brightness through valid BRDF measurements of surface materials.



# Ephemerides

- Provide accurate ephemerides with covariances on an agreed cadence. (Step up from old-time TLEs)
- Agree on standard format and include planned maneuvers for prediction.
- Allows for observation planning, and pointing avoidance when necessary.
- Desired tolerances are 1-second timing along track, and 1 arcsecond cross-track positional accuracy (currently arcminutes).

# Next Steps

- Publication of detailed requirements list by IAU
- Identification of further technical work
  - Flares, glints, thresholds of harm
- IAU CPS Industry Hub outreach
- Working with national regulators