SATELLITE INDUSTRY SUB-WORKING GROUP OUTCOMES:

2021 Dark & Quiet Skies Conference

Presented to Scientific & Technical Subcommittee,
UN Committee on Peaceful Uses of Outer Space
February 15, 2022

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Chair, Industry Working Group on Satellite Constellations

Industry Working Groups at 2021 Astronomy & Satellite Constellation Workshops

- Satellite Constellations 2 Workshop (“SATCON2”)
  - 12 – 16 July 2021, sponsored by American Astronomical Society (IAU)
  - Purpose: “To discuss how to implement the mitigation strategies that emerged from SATCON1 (2020) to minimize the negative impacts of satellite constellations on astronomy and the night sky.”

- Dark & Quiet Skies for Science and Society 2 Conference (“D&QS”)
  - 3 - 7 October 2021, sponsored by the International Astronomical Union and UN Office of Outer Space Affairs (UNOOSA) and the Government of Spain
  - Purpose: “To focus on implementation of 2020 D&QS recommendations, in particular identifying both the technical and political actions needed for their effective realization, as well as which stakeholders and partners would need to collaborate to implement a satisfactory solution for the preservation of a dark and quiet skies.”

Industry Working Group: 2021 Dark & Quiet Skies

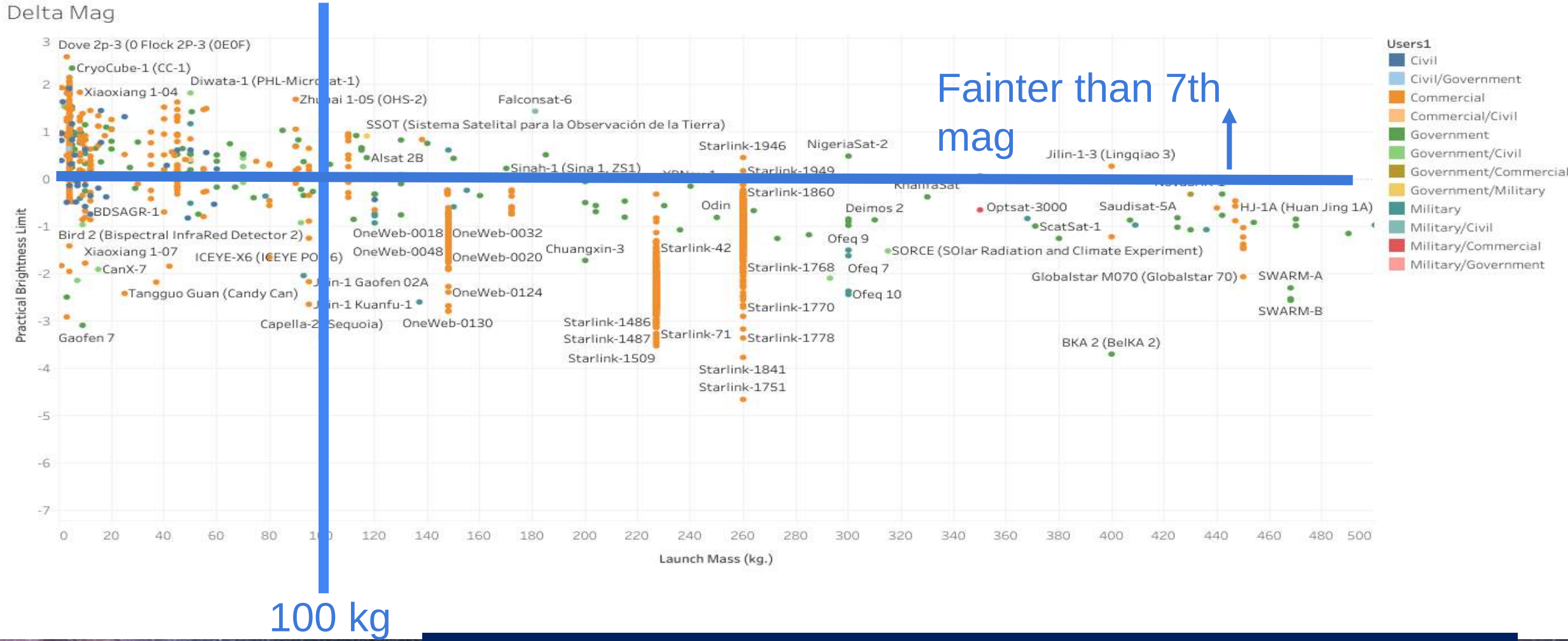
- 29 members including expert astronomers, representatives from industry (Amazon Kuiper, SpaceX, OneWeb)

Objectives:

- **Raise Awareness within Commercial Satellite Industry** that satellite constellations and even smaller satellites have potential to impact astronomy
- **Further Develop Recommendations and Mitigations** from SATCON1 and D&QS 2020
- **Identify Steps and Tools needed to Implement Recommendations** by commercial satellite operators

Raise Awareness within a Dynamic Commercial Sat Industry

- Low-Earth Orbiting (LEO) satellite industry stakeholders are diverse and evolving
  - LEO satellite proposals coming from a growing list of countries
  - Many one-off LEO projects emerging, due to decreasing launch and satellite costs
- Communications satellites in LEO weighing 100+ kg typically exceed the brightness target of 7th magnitude and should consider mitigations
  - Three advanced satellite broadband constellation projects are collaborating with astronomers and applying mitigations
  - Many additional satellite constellations continue to be proposed and deployed
  - Commercial earth sensing constellations with larger satellites ~100+ kg may exceed the recommended brightness target
- Even smaller satellites merit evaluation for visibility
  - Earth sensing constellations of smaller satellites 10kg+ are likely fainter
  - Cubesats are not all below the brightness limit



Data source: Union of Concerned Scientists Satellite Database and MMT-9 Database.
Interactive data: https://public.tableau.com/app/profile/therese.jones/viz/DeltaMagvsmass/DeltaMag

SATCON2/D&QS Recommendations for Industry

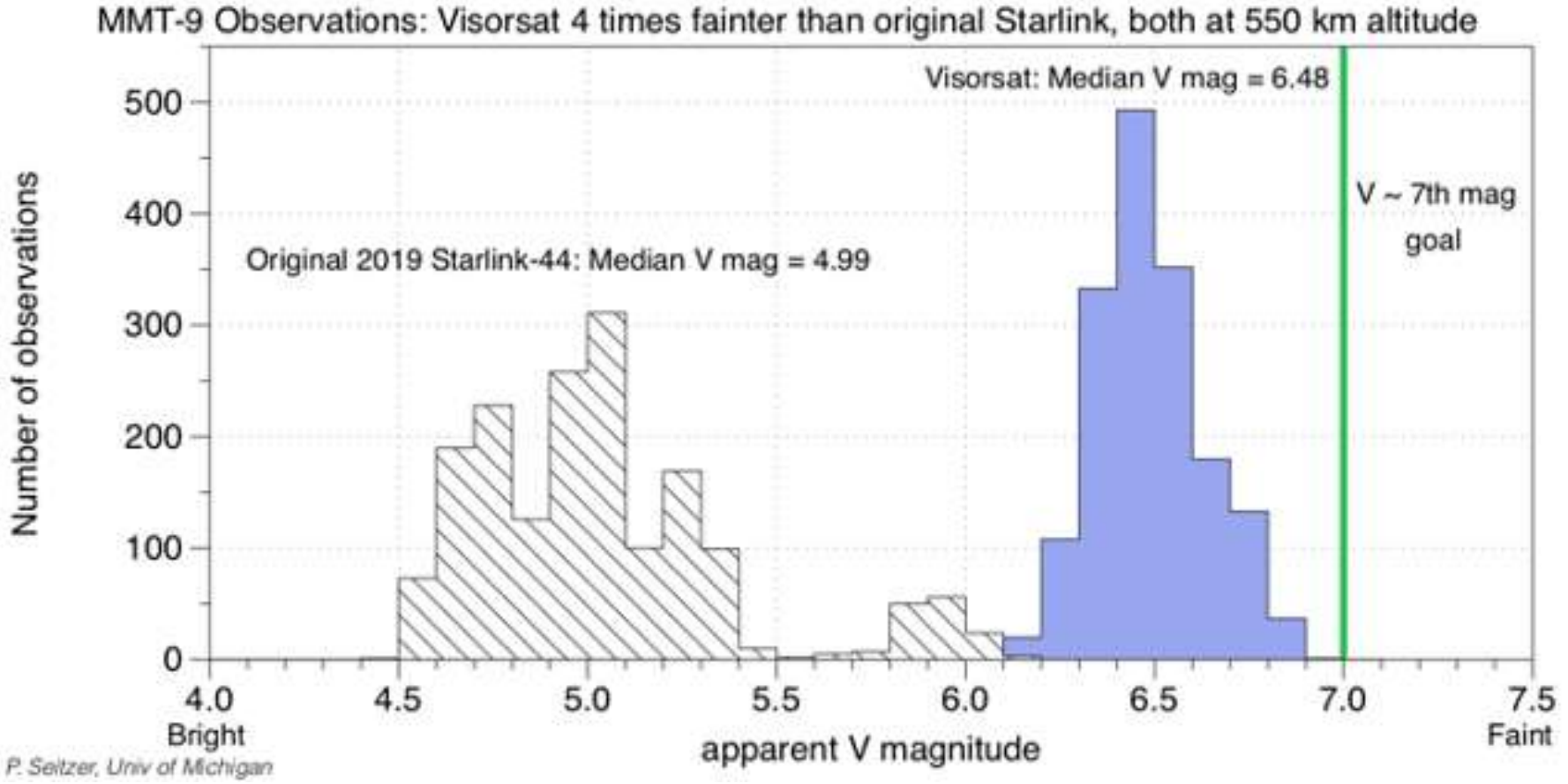
Increase Precision of Satellite Tracking Information

- Encourage individual satellite operators to share precise ephemerides for astronomers' use
- Global space safety interests are driving improvements in tracking and data-sharing
- Shared database approach in development for increased transparency
  - e.g. "Open Architecture Data Repository" (OADR) program led by U.S. Department of Commerce
  - Astronomers seeking level of data precision higher than currently envisioned for collision avoidance databases

Incorporate Mitigations to Reduce Visibility and Negative Impacts

- Operations: Fly lower, deorbit at end of mission, adjust orientation during orbit raise
- Spacecraft Design: Darken elements, use less reflective materials or incorporate sun-shades
- Still Early in R&D – further mitigation innovation and approaches still to be discovered

Mitigation Techniques Are Effective in Approaching Target Visibility of 7th Magnitude - Sunshade Mitigation on Starlink "Visorsats"



Industry Working Group: Implementing Recommendations

- The most effective best practices – and those most likely to be voluntarily adopted by industry – are well-defined, with performance-based metrics that leave room for customization and innovation

- For widespread pre-deployment adoption, predictive tools must be accessible and affordable, further work needed on:
  - Ground laboratory testing for satellite prototypes, including Bi-directional Reflectance Distribution Function (BRDF) measurements
  - Modelling software for visibility of prototype satellites in design/test stage
  - Further basic research on reflectivity of spacecraft materials and designs

Industry Working Group: Implementing Recommendations

Collaboration between satellite industry and the astronomy community is essential

- Continued outreach to LEO proponents globally will build familiarity and improve voluntary adoption of best practices and mitigations
- Ongoing collaboration in technical analysis and impact evaluation will expand insights across both communities
- Measuring brightness and evaluating effectiveness of mitigations fielded requires a comprehensive, scientific and reliable observation approach, both prior to any mitigation and after to assess effectiveness
- Further advancements in mitigation options and best practices needed ahead:
  - Spacecraft design and materials usage are evolving as new use-cases for LEO emerge
  - Telescope technology is also evolving, with many observational parameters to consider

Questions?

D&QS Industry Sub-Working Group of the Satellite Constellation Working Group

- Four recommendations assigned to this group
  - Sat_Con 3. Raise awareness of the impacts on astronomy amongst designers, investors, regulators, manufacturers and operators, and include impact mitigations as a core component of corporate social responsibility and sustainability strategies.
  - Sat_Con 4. Design missions to minimize negative impacts on astronomical observations by: a) minimising operational altitudes — satellites in constellations with higher orbital shells are illuminated by the sun for longer during the night and appear more ‘in focus’ to telescopes; in general, the impact on astronomy increases with constellation altitude. Scientific analysis shows that orbits on the order of 600 km or below offer a compromise between brightness and the length of time satellites are illuminated during the night; b) minimizing the number of satellite units as second priority to altitude while maintaining safe operational practices; c) minimising the time spent in orbit when not in service.
  - Sat_Con 6. Provide timely, transparent and reliable data to the astronomy community and observatories to allow sufficient planning to avoid impacts and post-hoc analysis of incurred impacts. Data required include: spacecraft design, brightness data, mission designs and orbital profiles, attitude control, and predicted and real-time orbital elements. Developing best practices list for satellite operators, initially developed by the American Astronomical Society

D&QS Industry Sub-Working Group of the Satellite Constellation Working Group

- Fourth recommendation assigned to this group
  - Sat_Con 5. Design satellites to minimize negative impacts on astronomical observations by: a) guaranteeing that all satellites appear fainter than 7.0 Vmag +2.5 × log(SatAltitude / 550 km) with a minimum value - corresponding to maximum brightness - of visual magnitude (Vmag) 7 during all flight phases, which makes them undetectable to the unaided eye; b) minimizing antenna sidelobe emissions such that their indirect illumination of radio observatories and radio quiet zones do not interfere, individually or in the aggregate; c) preventing direct illumination of radio observatories and radio quiet zones with a satellite's main antenna beam.