IAU CPS SatHub and Mitigation Actions for All Stakeholders

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UN/SKAO D&QS for Science & Society - 9-11 Dec 2025

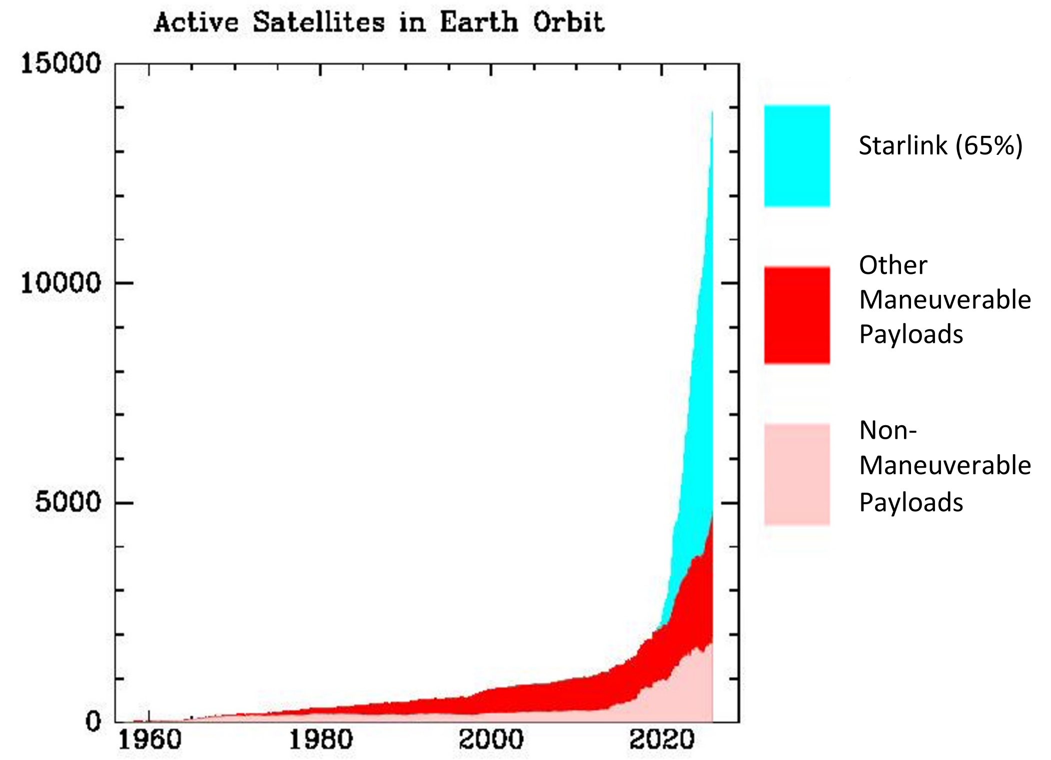
We need remote internet connectivity…

Credit: By NASA - https://eol.jsc.nasa.gov/, Public Domain

- Weather
- Disaster Comms
- Telemedicine
- Climate change

Hurricane Ian viewed by the Expedition 67 crew on the International Space Station on September 28

Motivation: Growth in Number of Satellites



Data collated by J. McDowell/CfA

Active Satellites

2019 Sept: ~2200

2025 Dec: ~11800 (<600km)

~12800 (<1200km)

~13800 (all heights)

Total Planned LEO sats in constellations

~ 548,000 (most likely: 100K to 200K)

At any time:

~4% of LEO sats above the horizon

~0.6% of LEO sats above 30 deg

[J. McDowell, planet4589.org]

CHALLENGES

Motivation: Satellite Visibility & Brightness

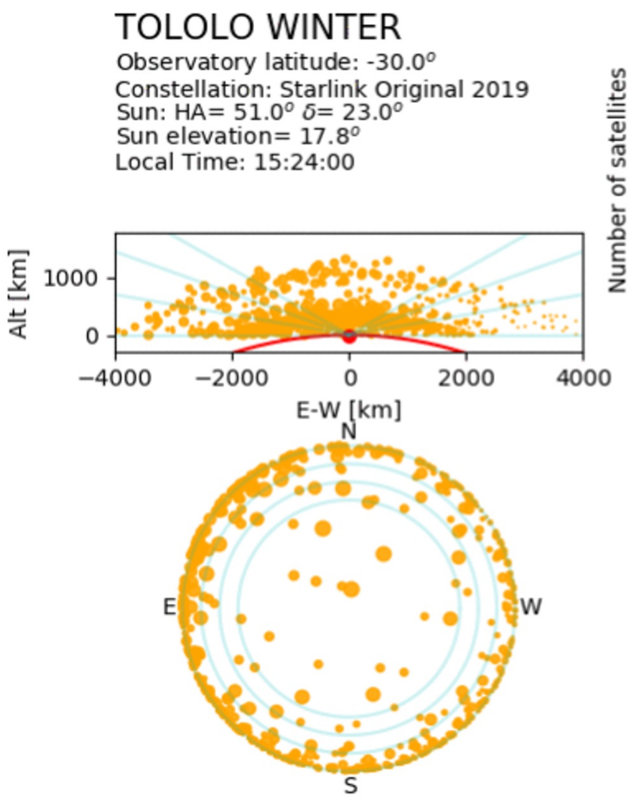
Illuminated

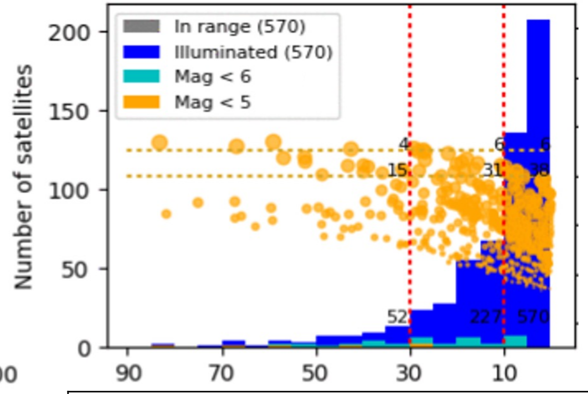
Shadow

View from Space

View from Earth

Credit: O. Hainaut, ESO (https://www.eso.org/~ohainaut/satellites/plots.html#compare)

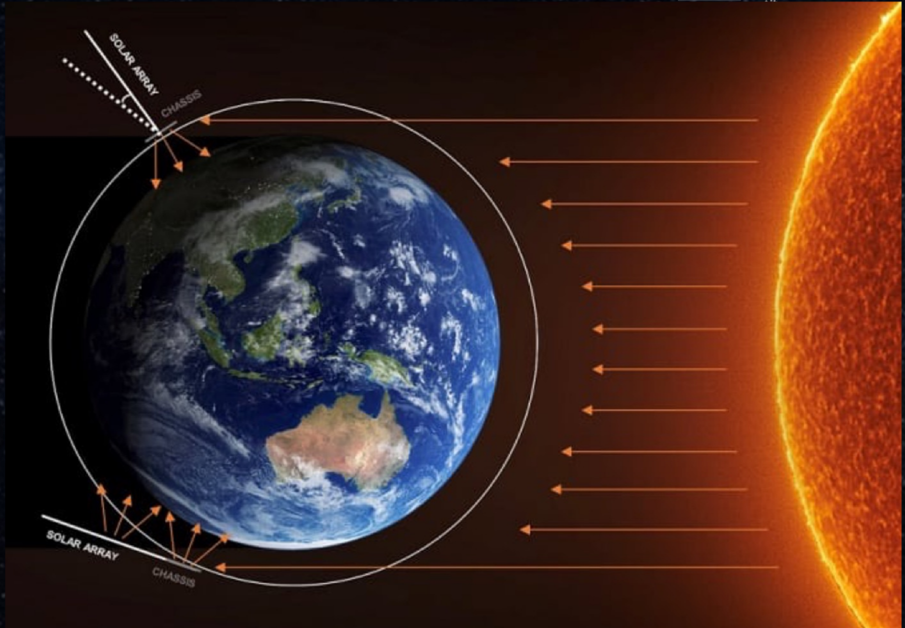




Data Points: Starlink Gen 1	
ALTITUDE (km)	# of SATELLITES
<500	9102
1200	2825
TOTAL:	**11,927**

Satellites are “seen” mostly during twilight

- Sunlight can be reflected by satellites’ bodies
- Depends on: area, materials, altitude, orientation, …
- Brighter than “magnitude 7” is visible with the naked eye
- Brightest during early evening and early morning

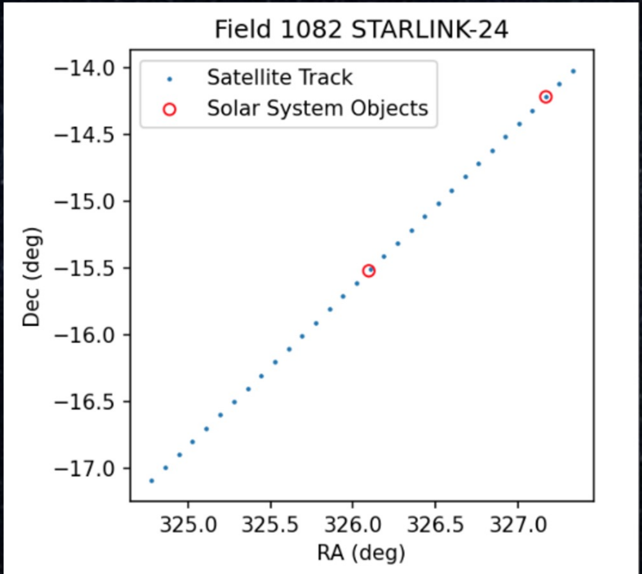


Credit: SpaceX

CHALLENGES

Impact on Optical Astronomy

- A satellite streak makes a small part of an image unusable (lost data), and may distort other areas of the image too
- Impacts to science (and society) include:
  - ➤ **Loss of orbit recovery of Potentially Hazardous Asteroids**
  - ➤ Loss of time series for variable stars in nearby galaxies
  - ➤ Confusion with subtle distortions in the shape of distant galaxies by Dark Matter weak lensing
  - ➤ For spectroscopy, contamination of faint object spectroscopic measurements by reflected sunlight

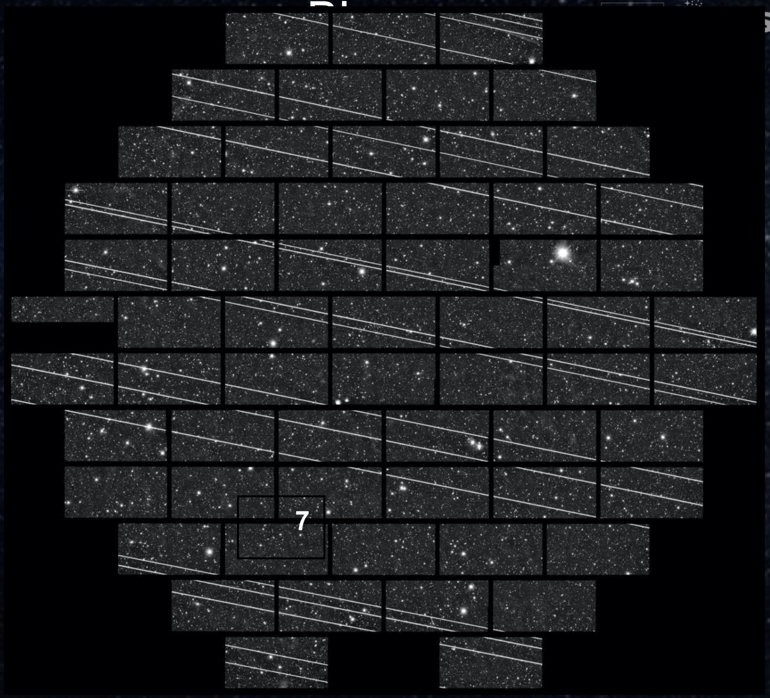


Credit: S. Eggl (UIUC)

CHALLENGES

Impact on Optical Observatories

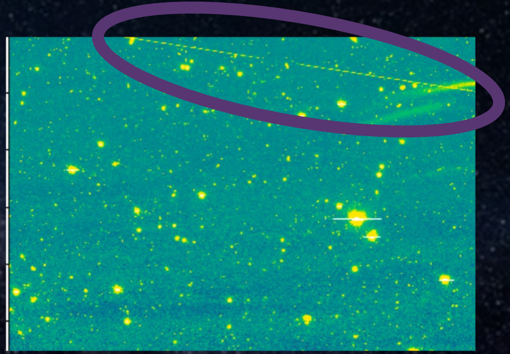
- **Narrow field** (Gemini, Keck, ESO's VLT, ELT): **~10% of frames** (end of ast. twilight)
- **Wide-field** (Blanco, VST): **50% of frames** (at twilight)
- **Super-Wide-field:** (Rubin Observatory)
  - ➤ **~ most image frames** (at twilight)
  - ➤ Many frames — during whole nights

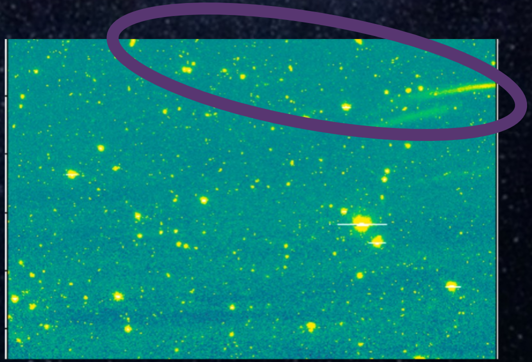


Credit: CTIO/NOIRLab/NSF/AURA/Decam DELVE Survey, 2019

SOLUTIONS

Mitigations by the Astronomy Community

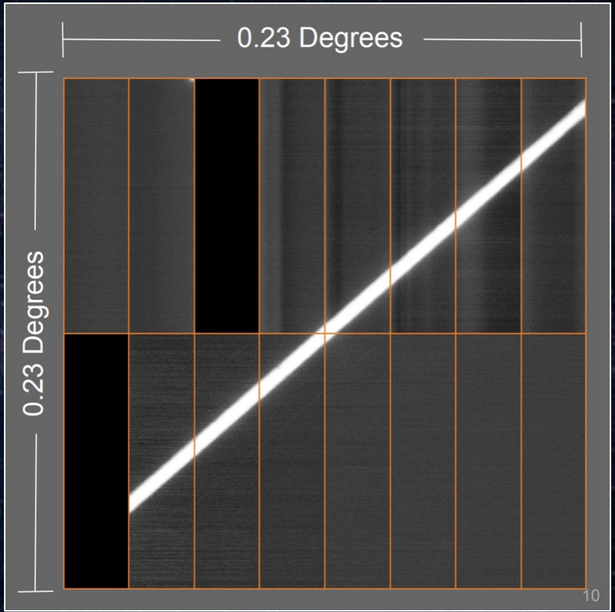




- Modelling / Simulations
- Software to avoid satellites
- Observations to verify mitigations
- Closing telescope shutter when satellite overhead
- Redoing observations
- Post processing of data (masking)

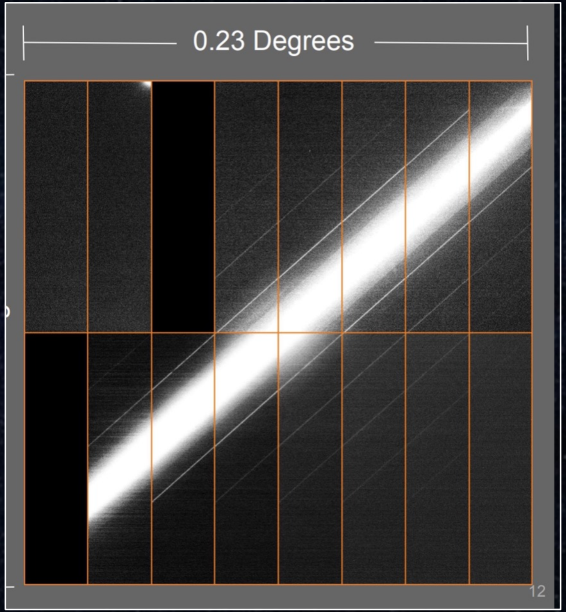
Brightness tests with Rubin Observ.'s Camera

CPS recommended brightness



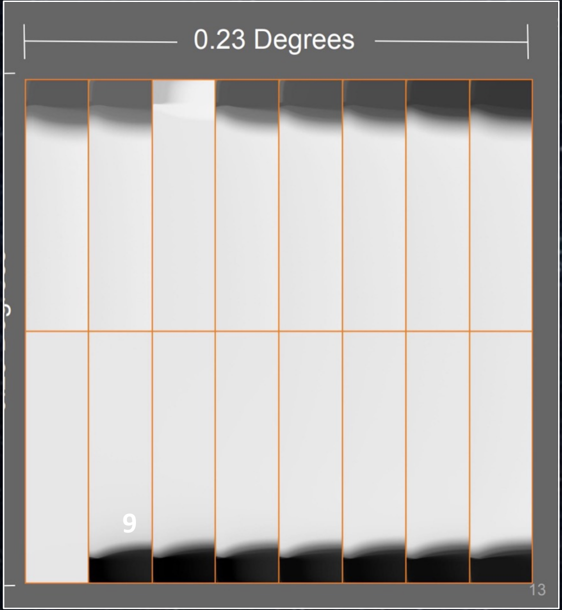
~**7 mag**, largely correctable.
Affects some faint object science

Fainter Direct To Cell



4–5 mag, "correctable" with larger error bars.
Affects most science

Brighter Direct To Cell

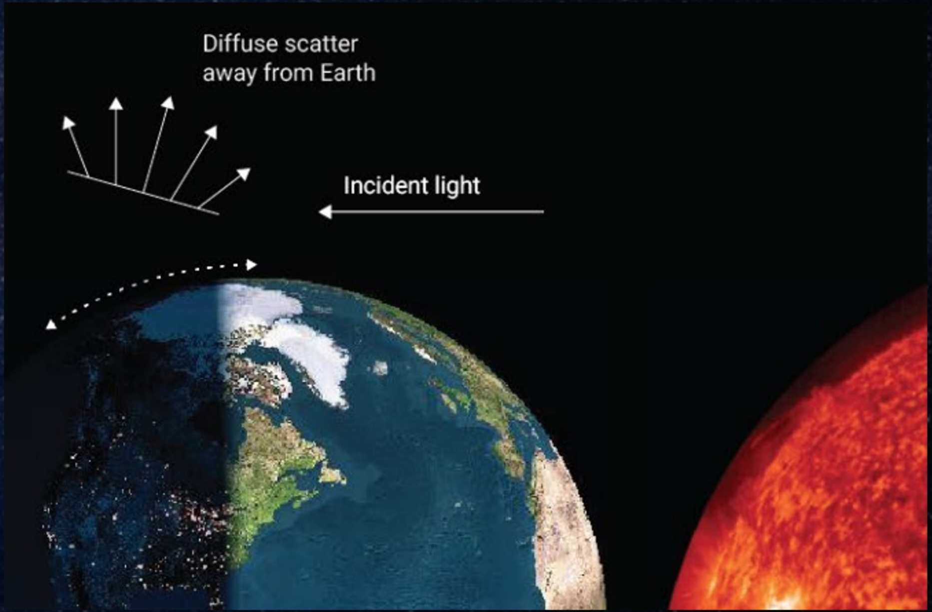


0–1 mag, not correctable; observing time lost

images courtesy Dan Polin

SOLUTIONS

Mitigations by the Satellite Operators



- Fewer satellites (?)
- Smaller satellites
- Lower satellites
- Darker materials — Sun visors
- Directionally reflective coatings
- Attitude adjustment
- Sharing position data + attitude + BRDF

SOLUTIONS

No observatory can do this work alone

From Meredith Rawls

SatHub at the IAU CPS coordinates satellite observations, provides feedback to operators, shares technical expertise, builds software, and develops recommendations

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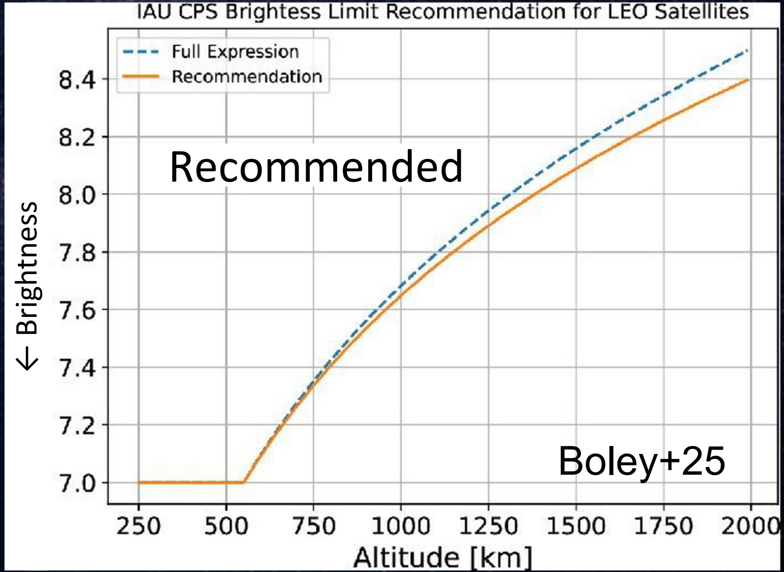
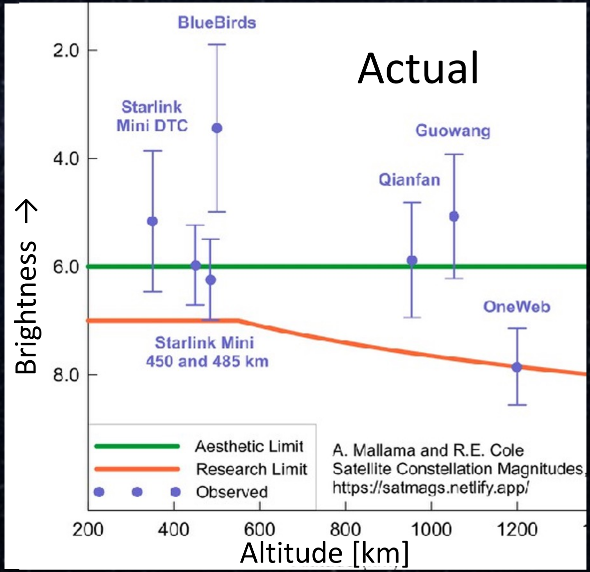
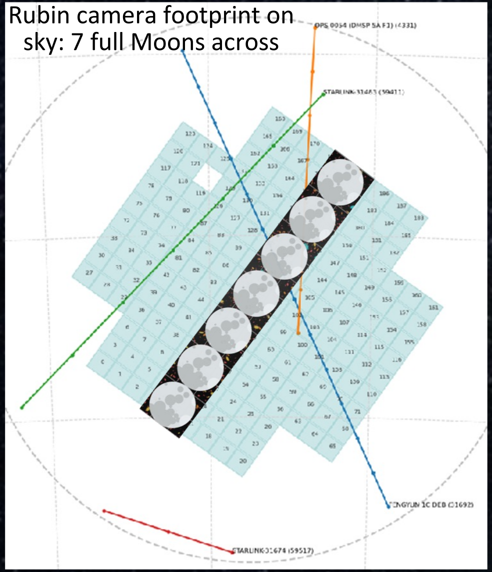
CPS

IAU NOIRLab SKAO







satchecker.readthedocs.io

SOLUTIONS

Develop software mitigation tools for observatories

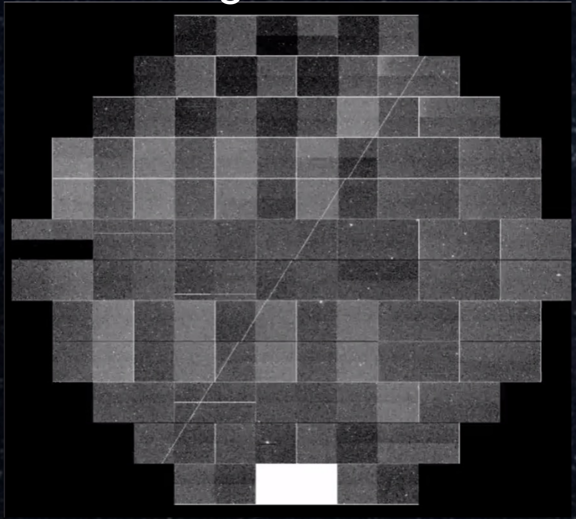
NSF SWIFT-SAT award: NOIRLab + U. Illinois totaling $750K over 3 years

Main Goal: Expand web-based software tools to develop satellite position and brightness forecasting tools.

WIth this, CPS SatHub is developing:

- **SatChecker** (pass & brightness forecasts) & **SCORE** (Satellite Constellation Observation REpository)
- Database of accurate satellite orbits cleared by the US government through Aerospace Corp
- Detailed brightness model (presently possible for Starlink & other satellites, because of shared BRDRs)

← 2.2 degrees across →



Validation of the SatChecker tool using DECam instrument on 4m Blanco, Chile

SOLUTIONS

IAU CPS SatHub - Goals

- **Assess constellation impact on optical (and radio) astronomy** via independent observation campaigns and peer reviewed publications
- **Develop software mitigation tools** for observatories
    - **SatChecker** satellite position prediction service
    - Satellite Constellation Observation REpository: **SCORE**
    - Field-Of-View / active satellite avoidance service
    - Radio astronomy impact modeling (SCEPTER)
- **Strengthen relations** with key players:
  Privateer, The Exclosure, Slingshot Aerospace, European Centre for Space Safety, The Aerospace Corporation, AST SpaceMobile, SpaceX, Amazon Kuiper, Planet Labs, and more
- **Coordinate mitigation efforts** with all stakeholders, including policy

SOLUTIONS

Satellite Constellation Observation REpository (SCORE)

Getting Started | Submit data | Data access | Data Visualizations | Tools | About SCORE

The Satellite Constellation Observation Repository (SCORE) is a project developed and maintained by the International Astronomical Union Centre for the Protection of the Dark and Quiet Sky (IAU CPS). SCORE serves as a centralized repository for satellite brightness observations. Its primary function is to provide a comprehensive and organized platform for researchers to contribute, store, and access observational data of artificial space objects. Datasets curated in SCORE are free and open for download. If you make use of SCORE data in your research, please add the following paragraphs to your acknowledgments section (as found in the SCORE Use Policy):

"This research made use of data and/or services provided by the International Astronomical Union Centre for the Protection of the Dark and Quiet Sky (IAU CPS) SatHub. The development of SCORE has been supported by the National Science Foundation (NSF) under grant number: AST 2332736. SCORE is hosted at the NSF NOIRLab. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF NOIRLab, the SKAO, the IAU, or any host or member institution of the IAU CPS."

Upload Observation File

New to SCORE? Check out our getting started guide.

Choose file | No file chosen

☐ I have read and agree to the SCORE Use Policy.

Upload

Incorrectly formatted observations will result in an error message. However, correctly formatted observations processed before an error occurs will be saved in the database and won't need to be resubmitted. SCORE will identify duplicate observations and provide the corresponding IDs of the original ones.

The upload process will continue in the background if this page is closed, and email notifications will be sent upon successful completion of all observations. However, any upload errors can only be displayed on this page. For optimal results, this page should remain open until the upload is complete.

Optional fields should be left blank if not applicable. Please avoid using "n/a", none, 0, or other similar values.
All columns must be used in the file uploaded for submission - leave a column blank if there is no data.
For more information, refer to the data format page.

Recent observations

Nov. 22, 2025 05:27 PM - KUIPER-00115
Nov. 22, 2025 05:27 PM - KUIPER-00115
Nov. 22, 2025 05:27 PM - KUIPER-00115
Nov. 22, 2025 05:27 PM - KUIPER-00115
Nov. 22, 2025 05:27 PM - KUIPER-00115
Nov. 22, 2025 05:27 PM - KUIPER-00040
Nov. 22, 2025 05:27 PM - KUIPER-00040

Statistics

31473 observations
544 satellites
21 observers

Observer Map

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CPS

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SOLUTIONS

Data visualisations

Explore satellite observation data through interactive visualizations. View brightness patterns, phase angles, and altitude relationships across different satellite constellations.

Interactive Graphs

Explore interactive scatter plots revealing relationships between satellite brightness, altitude, solar elevation, and phase angle. Pan, zoom, and dynamically filter data by constellation or individual satellite to uncover patterns in observation data.

→ Explore Graphs

All-Sky Plot

Visualize the spatial distribution of satellite observations across the sky. Filter by constellation, brightness, time period, and other parameters to generate customized all-sky plots showing where satellites appear from SCORE data.

→ Explore Plots

Constellation Statistics

Starlink
377 satellites · **2825** obs ·
Avg: **6.11** mag

Kuiper
85 satellites · **2379** obs ·
Avg: **6.17** mag

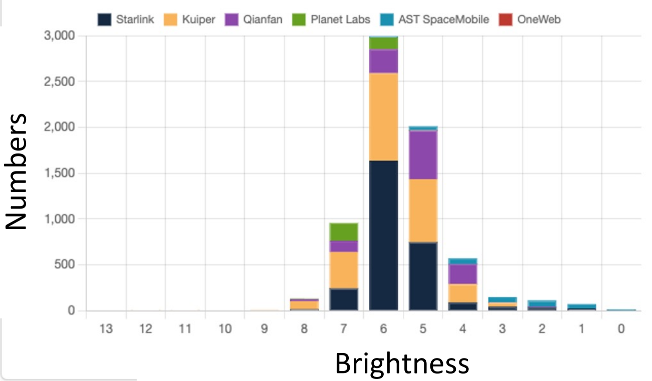
Qianfan
73 satellites · **1165** obs ·
Avg: **5.72** mag

Planet Labs
1 satellites · **338** obs ·
Avg: **7.03** mag

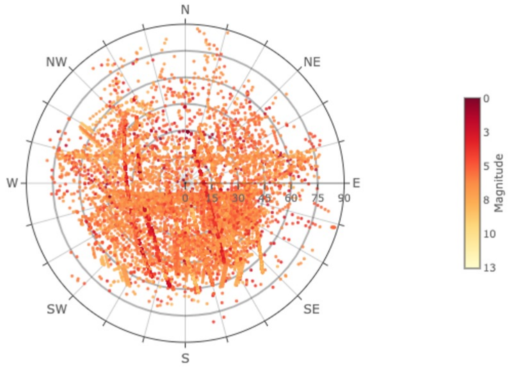
AST SpaceMobile
5 satellites · **301** obs ·
Avg: **3.4** mag

OneWeb
0 satellites · **0** obs

Observations by Apparent Magnitude

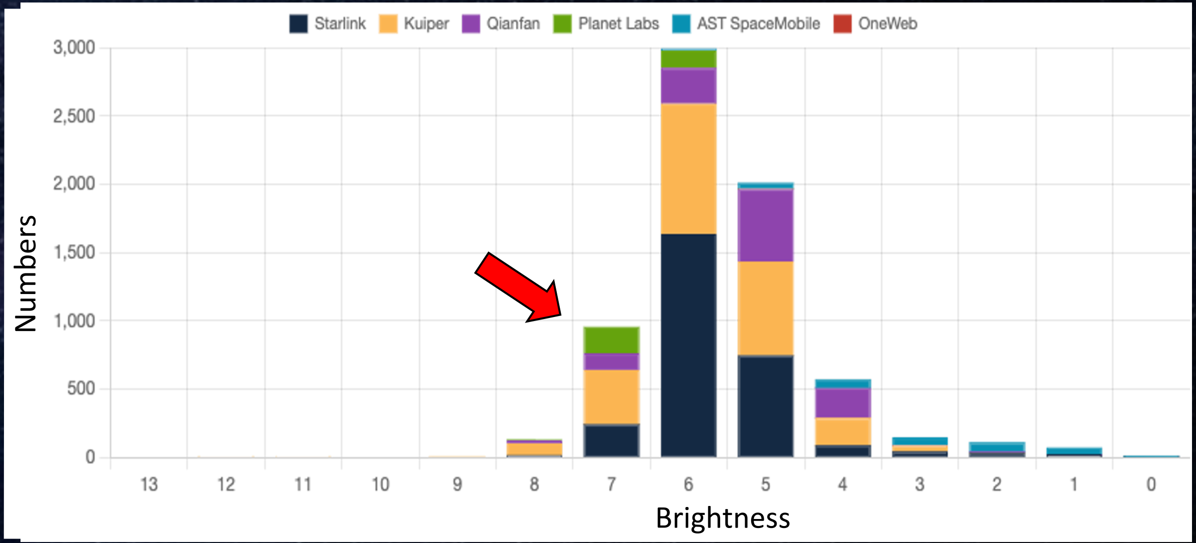


All Observations



SOLUTIONS

Data visualisations:
On the way to achieving 7th mag!



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SOLUTIONS

SatChecker Field of View Prediction Service

SatChecker

Search docs

GENERAL
- Notes

EPHEMERIS API
- Ephemeris API
- API Response Details
- Error Codes

TOOLS API
- Satellite Information
- TLE Data Access

FOV API
- Field of View (FOV) Endpoints
  - Satellite passes Through FOV
  - FOV Task Status
  - Satellites above the horizon

EXAMPLES
- API Examples
- Example Notebook
- Field of View Visualization Notebook
- Satellites Overhead Visualization Notebook

DEVELOPMENT DOCUMENTATION
- src.api package
- Release History
- Acknowledgements

/ Field of View (FOV) Endpoints — View page source

Field of View (FOV) Endpoints

The FOV API provides two main features for checking satellite positions relative to a field of view or above the horizon.

Satellite passes Through FOV

`GET /fov/satellite-passes/`

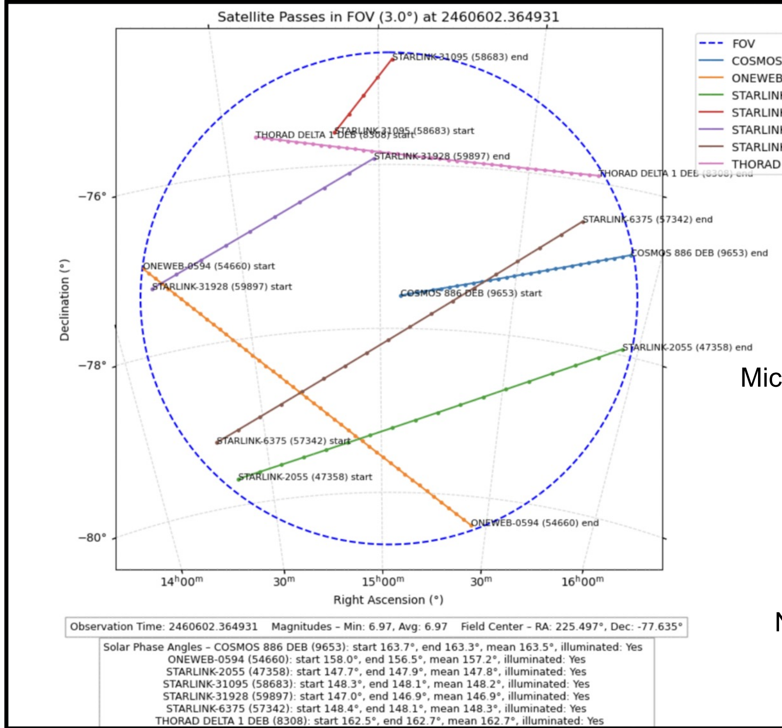
Get satellites that pass through a specified field of view during a time period. The field of view is defined by a center RA and Dec and a radius, both in degrees.

Either a start time or observation mid point time can be provided, but one must be specified.

Important

This endpoint does asynchronous processing by default. For smaller requests (shorter duration, smaller FOV, not using illuminated_only), you can still set the async parameter to False to get the results immediately. This option may be deprecated in the future.

Query Parameters:
- **latitude** – (*required*) – Observer's latitude in degrees
- **longitude** – (*required*) – Observer's longitude in degrees
- **elevation** – (*required*) – Observer's elevation in meters
- **site** – (*optional*) – Site name (e.g. 'greenwich') - if provided, latitude, longitude, and elevation can't be used; see astropy site names for a list of valid site names
- **start_time_jd** – (*optional*) – Julian Date for start of observation window
- **mid_obs_time_jd** – (*optional*) – Julian Date for middle of observation window
- **duration** – (*required*) – Duration to check in seconds
- **ra** – (*required*) – Right Ascension of FOV center in degrees
- **dec** – (*required*) – Declination of FOV center in degrees
- **fov_radius** – (*required*) – Radius of circular FOV in degrees
- **group_by** – (*optional*) – How to group results ("satellite" or "time"). Default is "time" for chronological order
- **include_tles** – (*optional*) – If True, include TLE data used to calculate the passes in the response. Default is False.
- **constellation** – (*optional*) – Constellation name (e.g. 'starlink') - if provided, only satellites from this constellation will be returned.
- **data_source** – (*optional*) – Data source to use for TLEs ("celestrak",

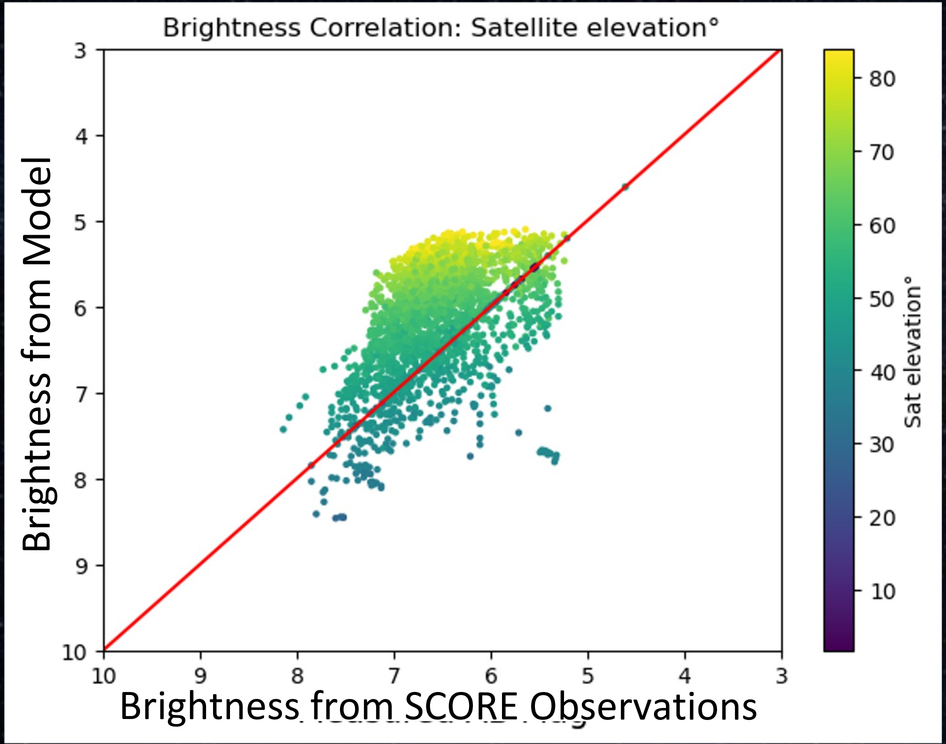


Michelle Dadighat (NOIRLab)

Nayan Jangid (UIUC)

Satellite Constellation Observation Repository (SCORE) — promising brightness modeling

- All SCORE submitted brightness measurements of Starlink v2 mini satellites
- Simple “Phong” brightness model that incorporates solar panel attitude
- Work in progress by Siegfried Eggl & Nayan Jangid, illustrating utility of SCORE



OPPORTUNITY

It takes a village...

The positive outcomes of SCORE and SatChecker, as well as of the CPS SatHub Observation Network, inform

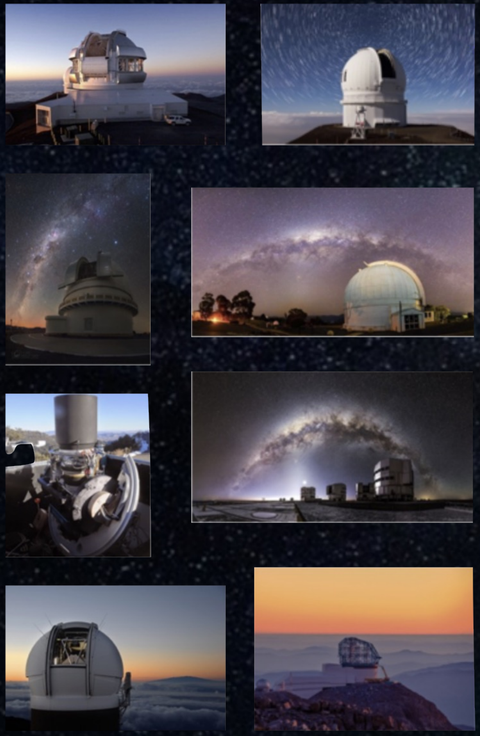
- Astronomers at different observatories (to avoid bright satellites)
- Industry in characterizing their satellites
  - SpaceX
  - AST Space Mobile
- Government officials to help with policies, etc
  - US NSF/ FCC Coordination Agreements with satellite companies
  - UNCOPUOS Group of Friends

And more!

OPPORTUNITY

Stakeholders must continue to work together

- The numbers of satellites are expected to continue to increase over the next decade
- The astronomy community needs access to pertinent information from satellite companies in order to predict satellite brightnesses & positions (to avoid them).
- CPS SatHub is willing to work with industry
- More companies are making efforts towards minimizing satellite brightness, even though not obligated to do so
- Coordination agreements, charters, resolutions, etc. are great; yet international regulations can be more effective
- Astronomers, satellite industry and policy makers need to continue to work together towards successful solutions



We invite you to join CPS!

Visit

cps.iau.org

Or email me at connie.walker@cps.iau.org