Python VS Space Junk

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Speaker

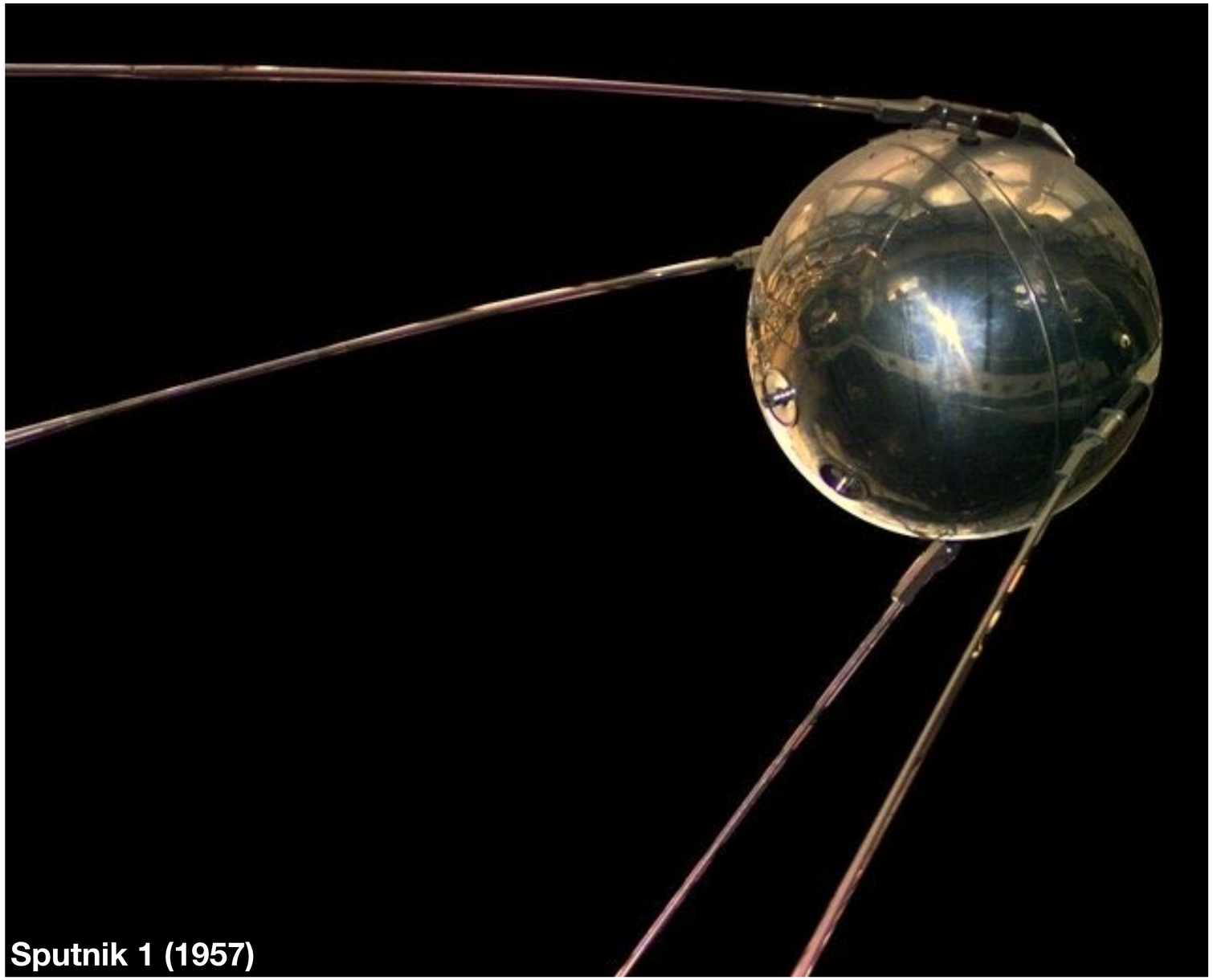
- PhD Candidate
- Computer and Data Scientist
- Tech Author
- Conference Speaker and Organiser
- Creator of STEM Educational Materials
- Doer of many things

Australia Telescope Compact Array (ATCA)

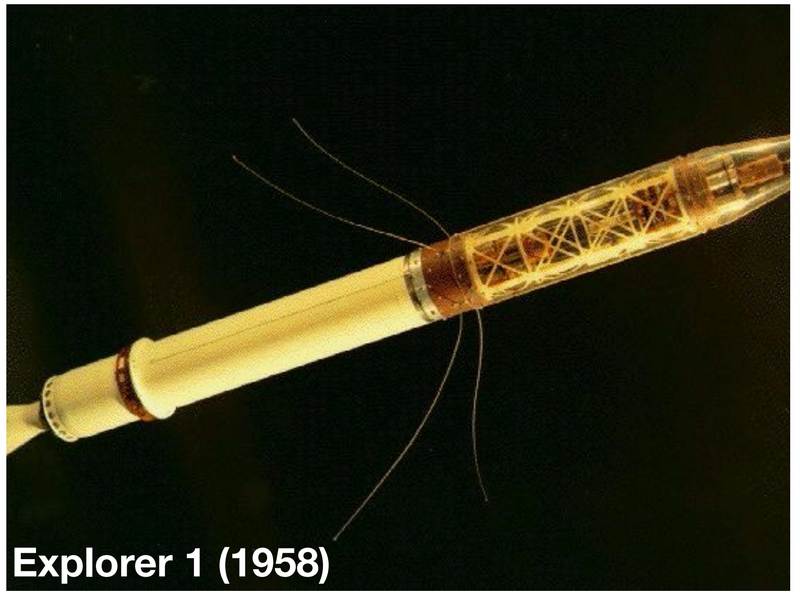
Topics

- What is “space junk”?
- Where does it come from?
- What should we do about it?
- Why can’t we do those things?
- What do we do about it?
- How does Python play a part?

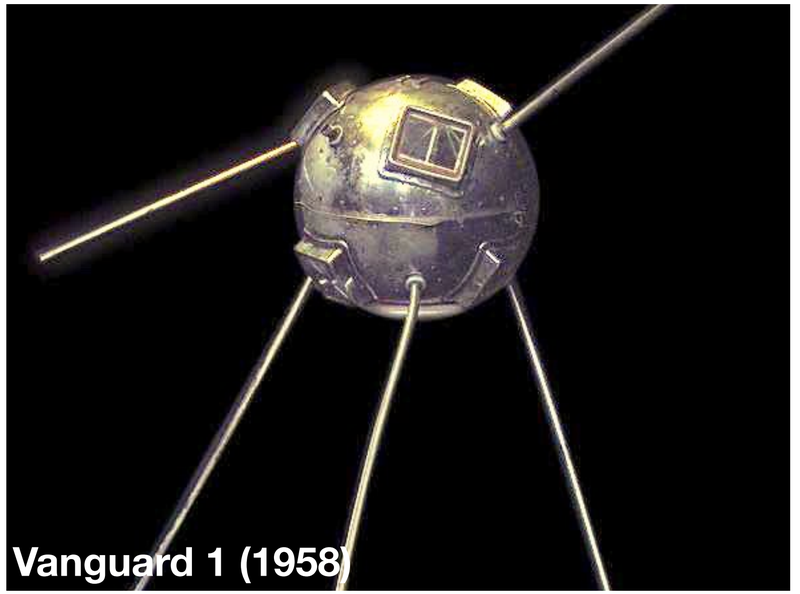
What is “space junk”?
Where does it come from?



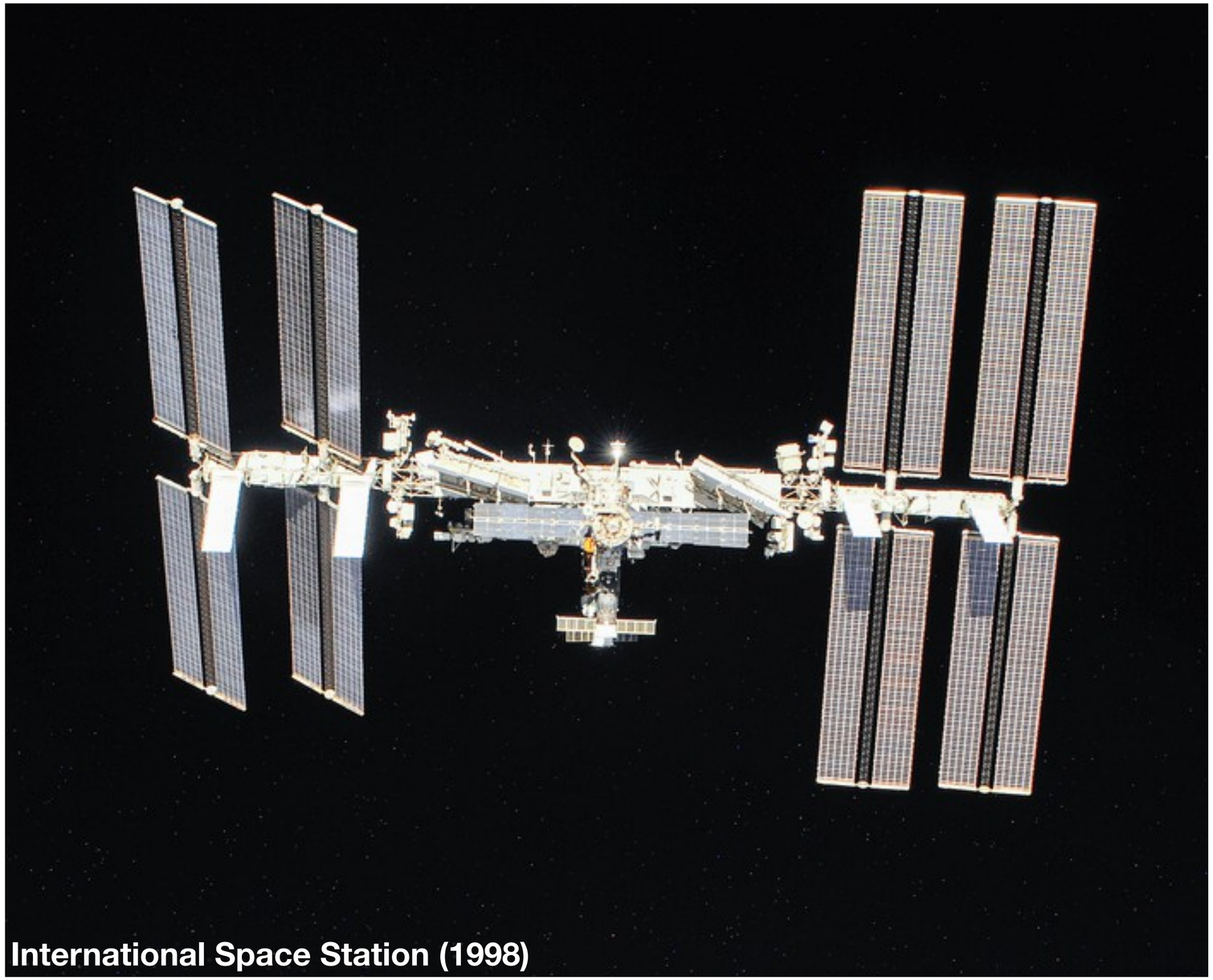
Sputnik 1 (1957)



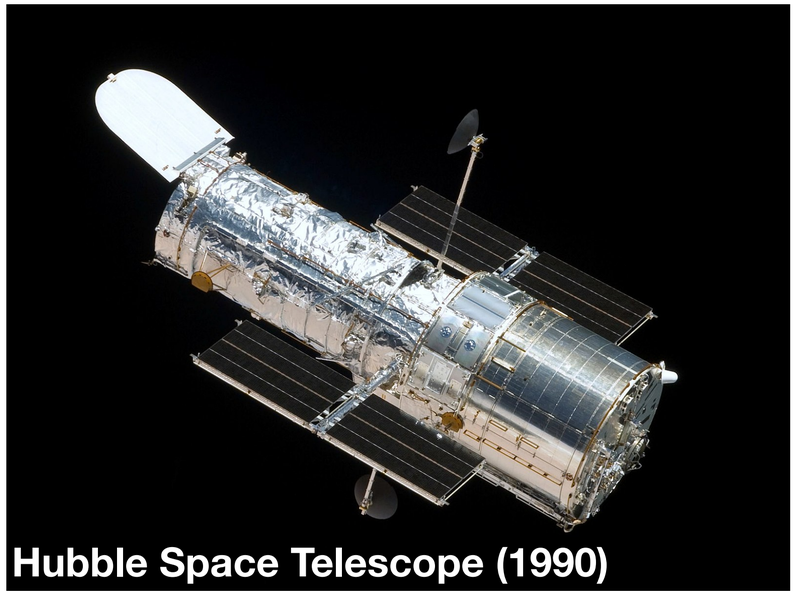
Explorer 1 (1958)



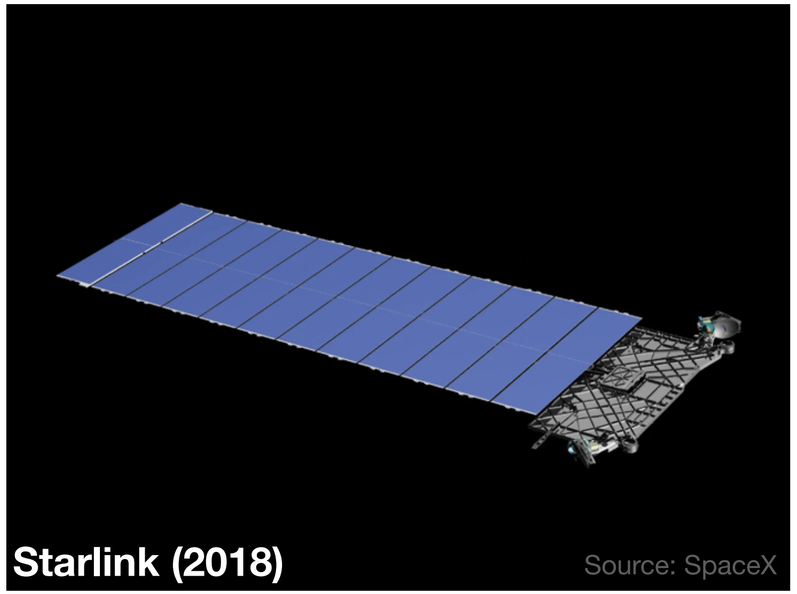
Vanguard 1 (1958)



International Space Station (1998)



Hubble Space Telescope (1990)



Starlink (2018)

Source: SpaceX


Skylab (1973)


ESTABLISHED 1833

The West Australian

ESTABLISHED 1833

PERTH FRIDAY JULY 13 1979

64 PAGES 12c*

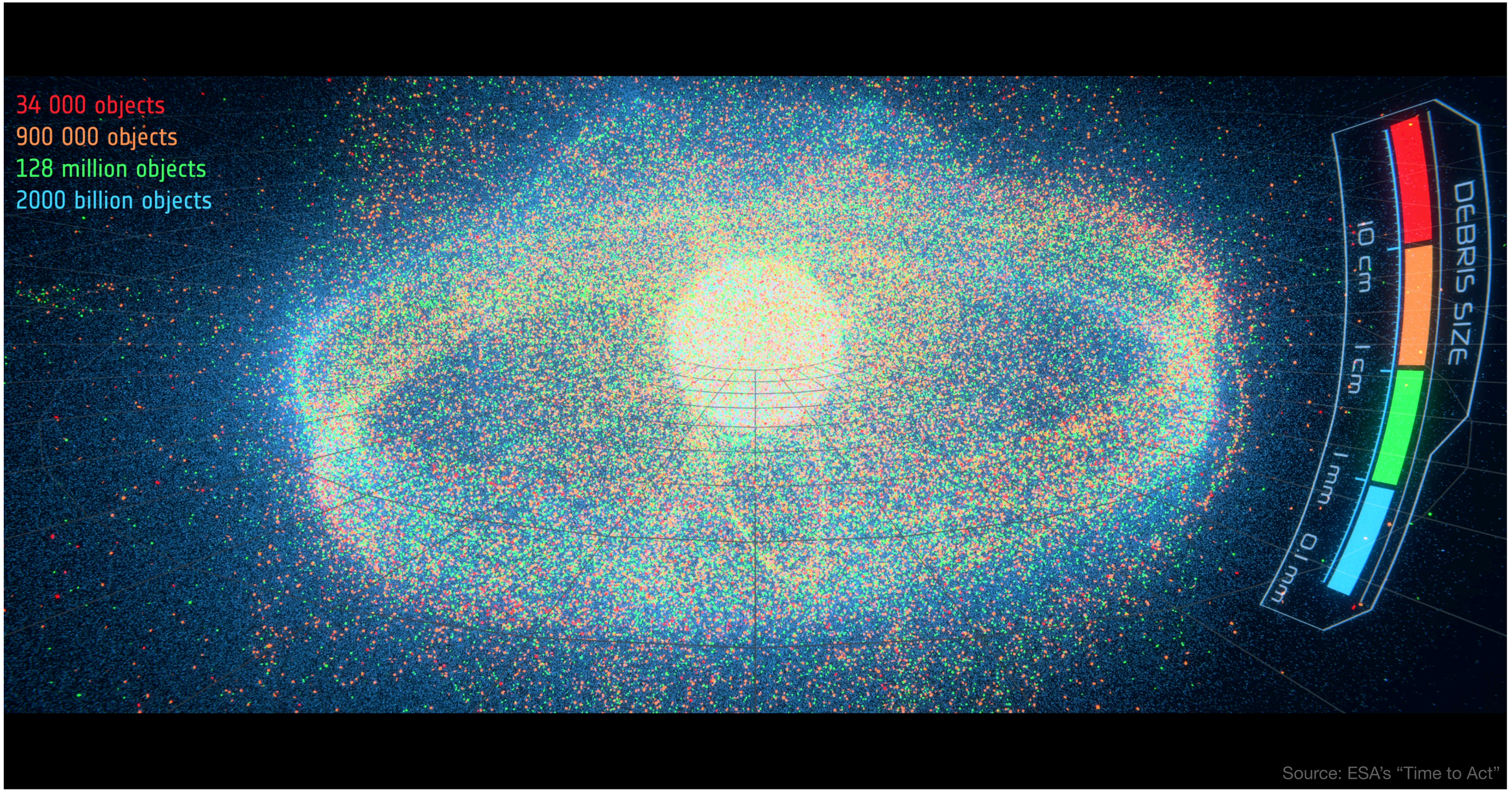
TREASURE HUNT

Balladonia has day of glory —Page 2

Skylab rains a fortune in debris

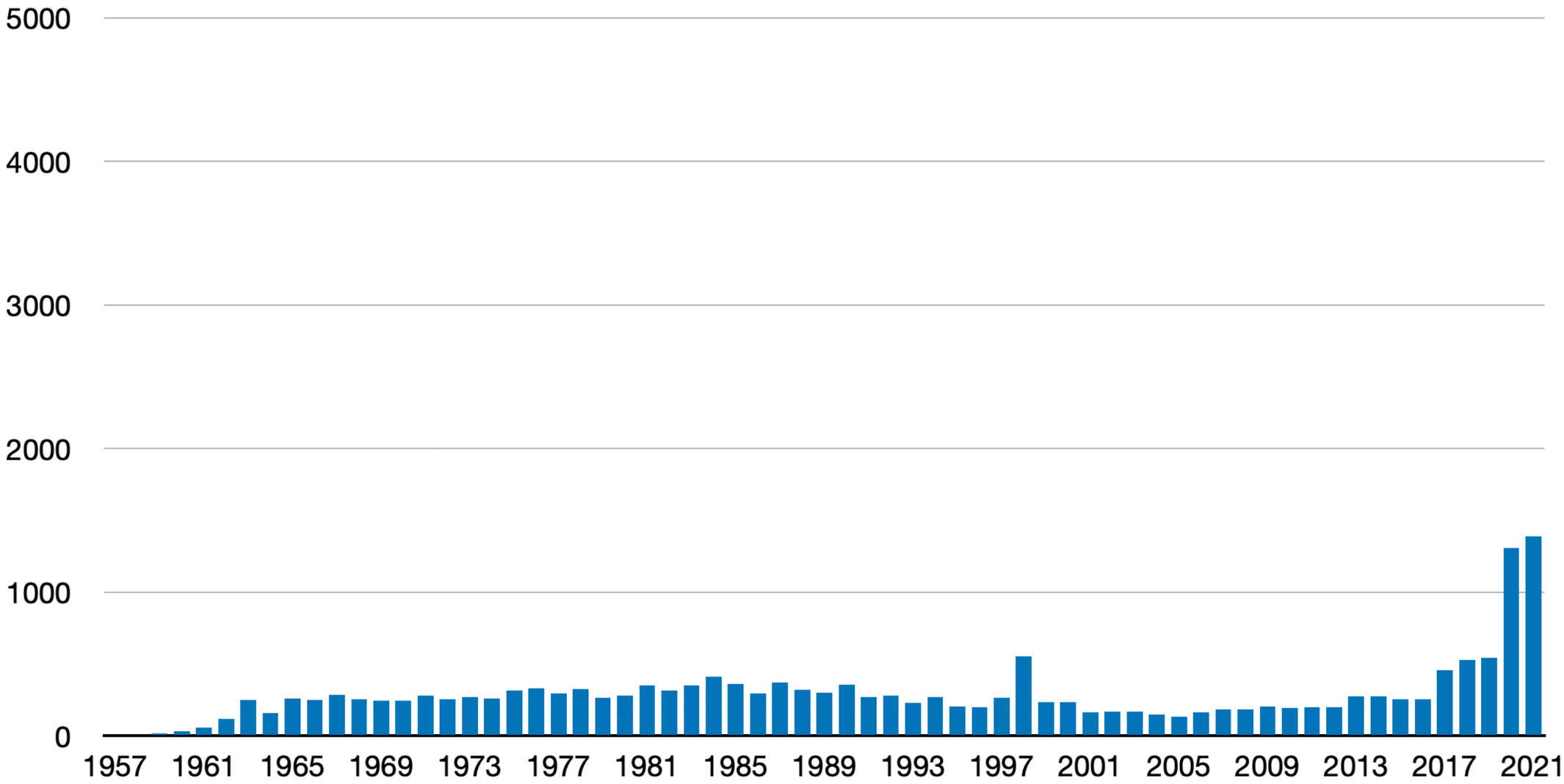
Skylab's sensational disintegration over WA could spark


Credit: Geoff Grewar



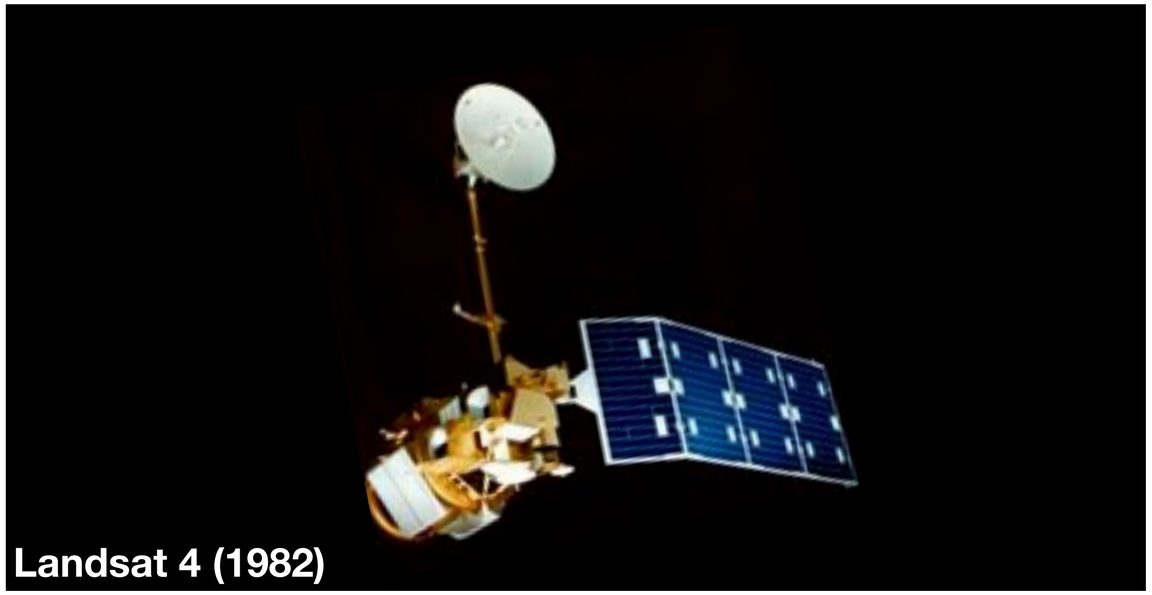
Source: ESA's "Time to Act"

Launch Volume

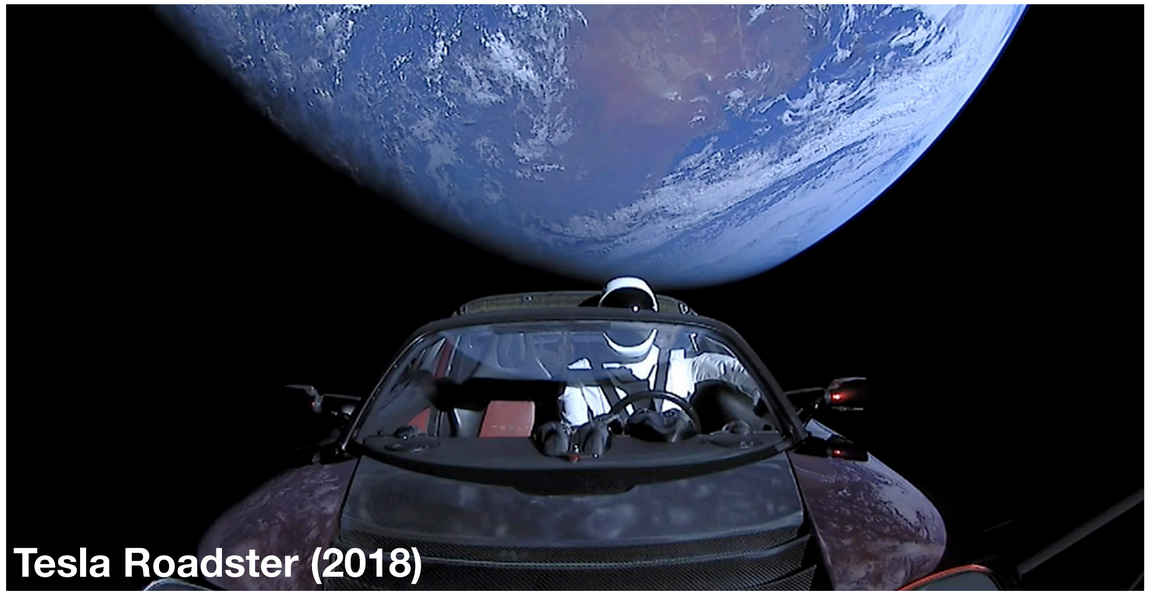


Debris Accumulation

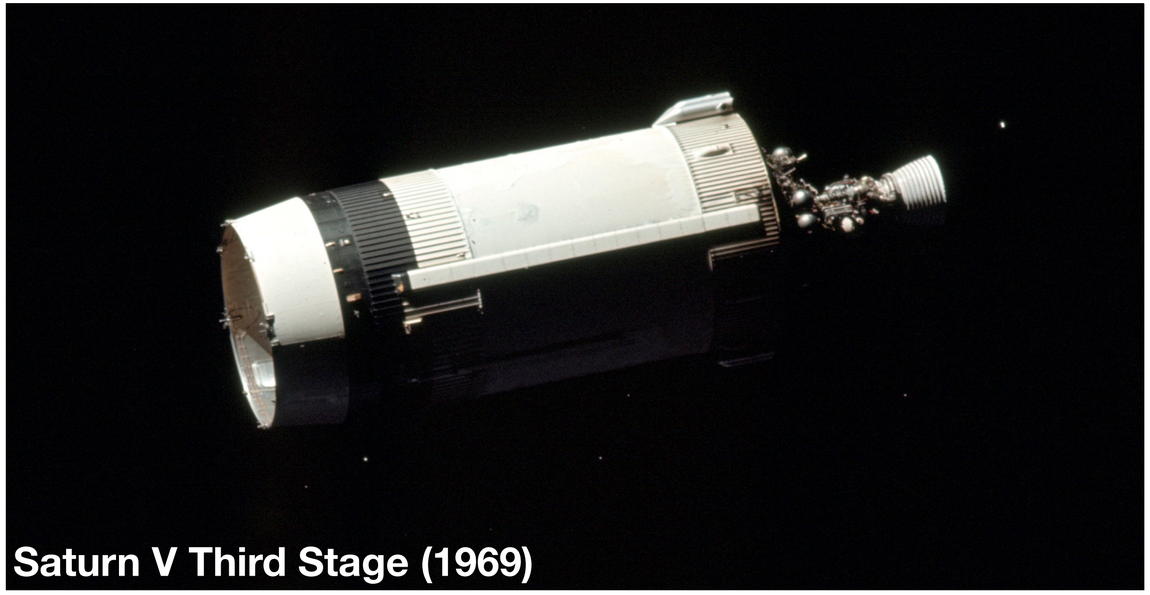
- Satellites that have broken run out of power
- Launch experiments
- Launch waste
- Astronaut error



Landsat 4 (1982)

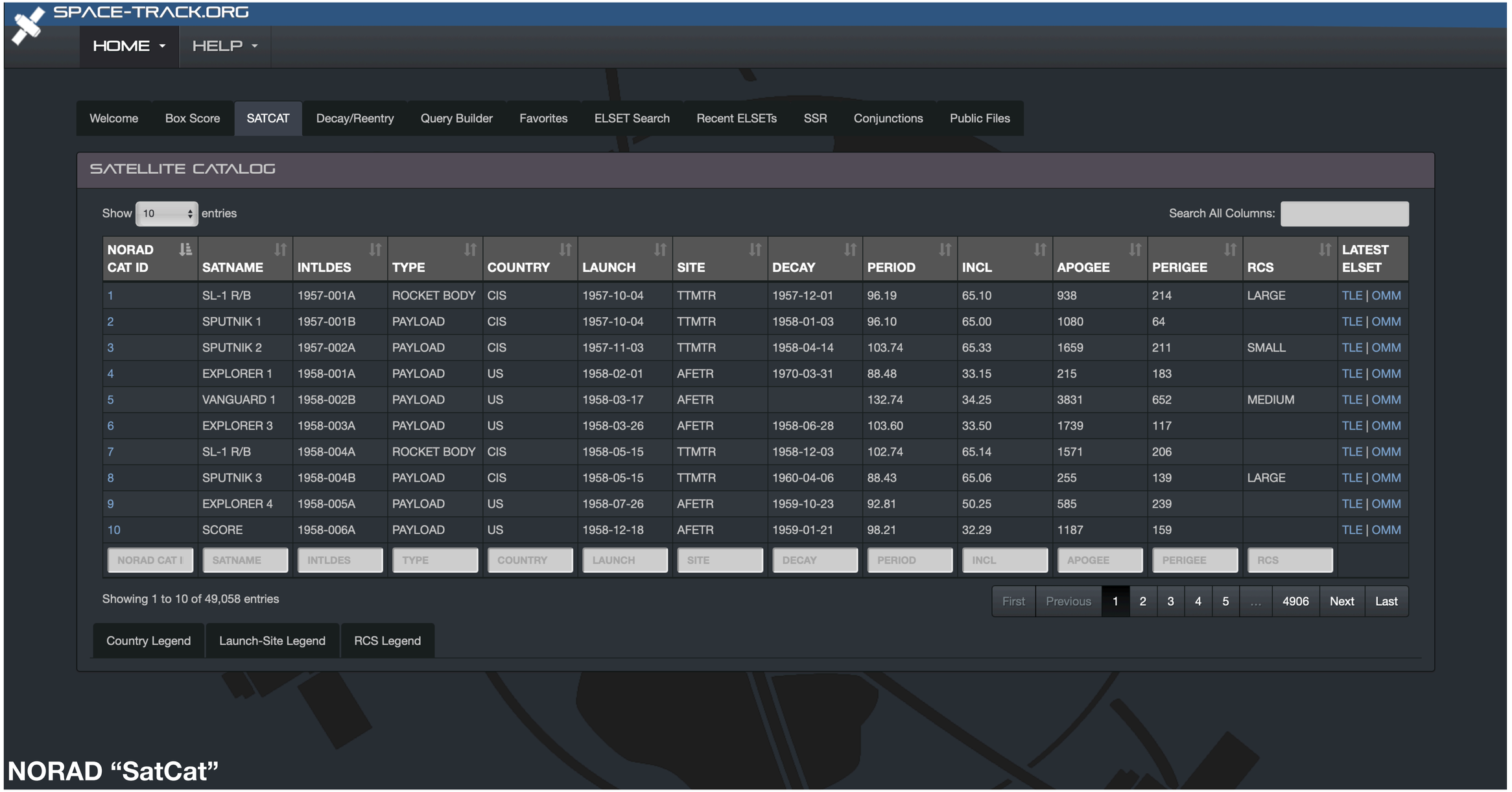


Tesla Roadster (2018)



Saturn V Third Stage (1969)

Astronaut Tool Bag (2008)



NORAD “SatCat”

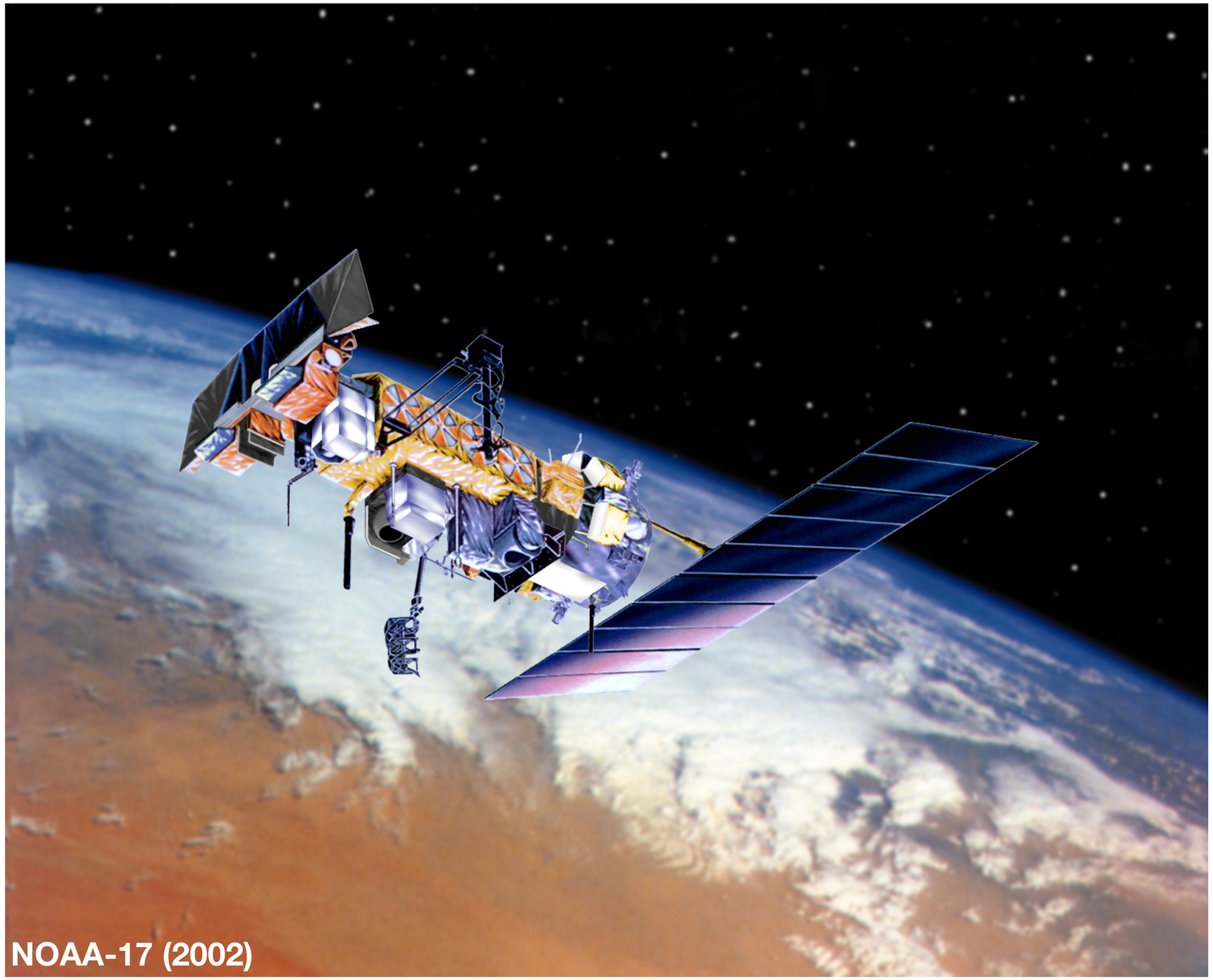
Debris Formation

- On-orbit explosions
- Material degradation + drag
- Anti-satellite weapons (ASATs)
- Collisions

Long March 4B (1999)

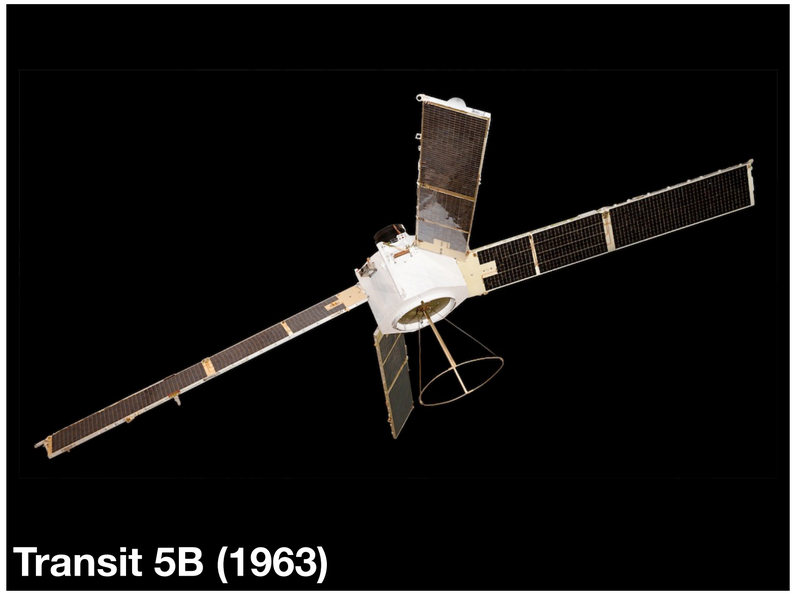
Ariane 1 (1986) Source: ESA

Proton-M Briz-M (2006) Source: KSP

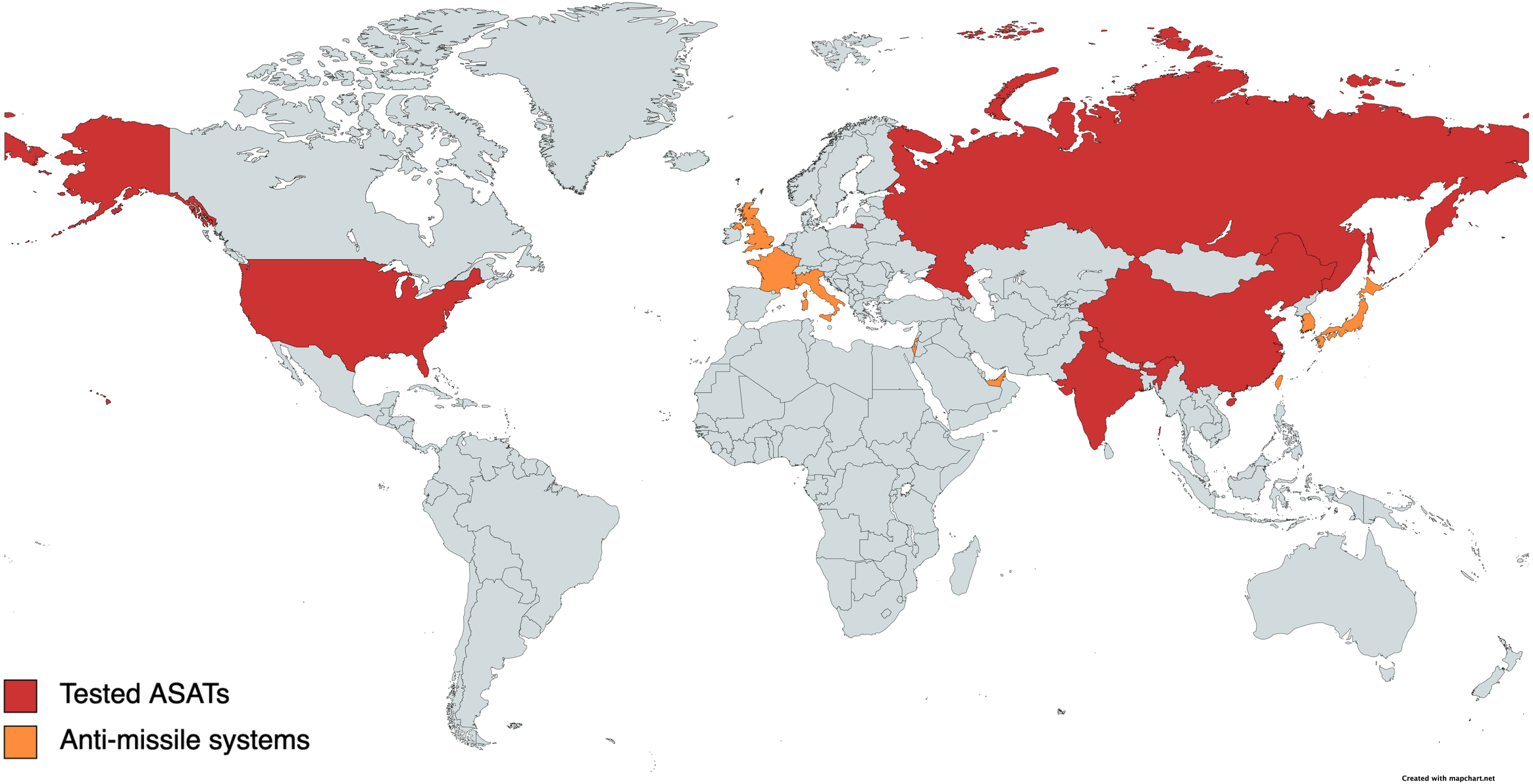


NOAA-17 (2002)

Kosmos 2421 (2006)



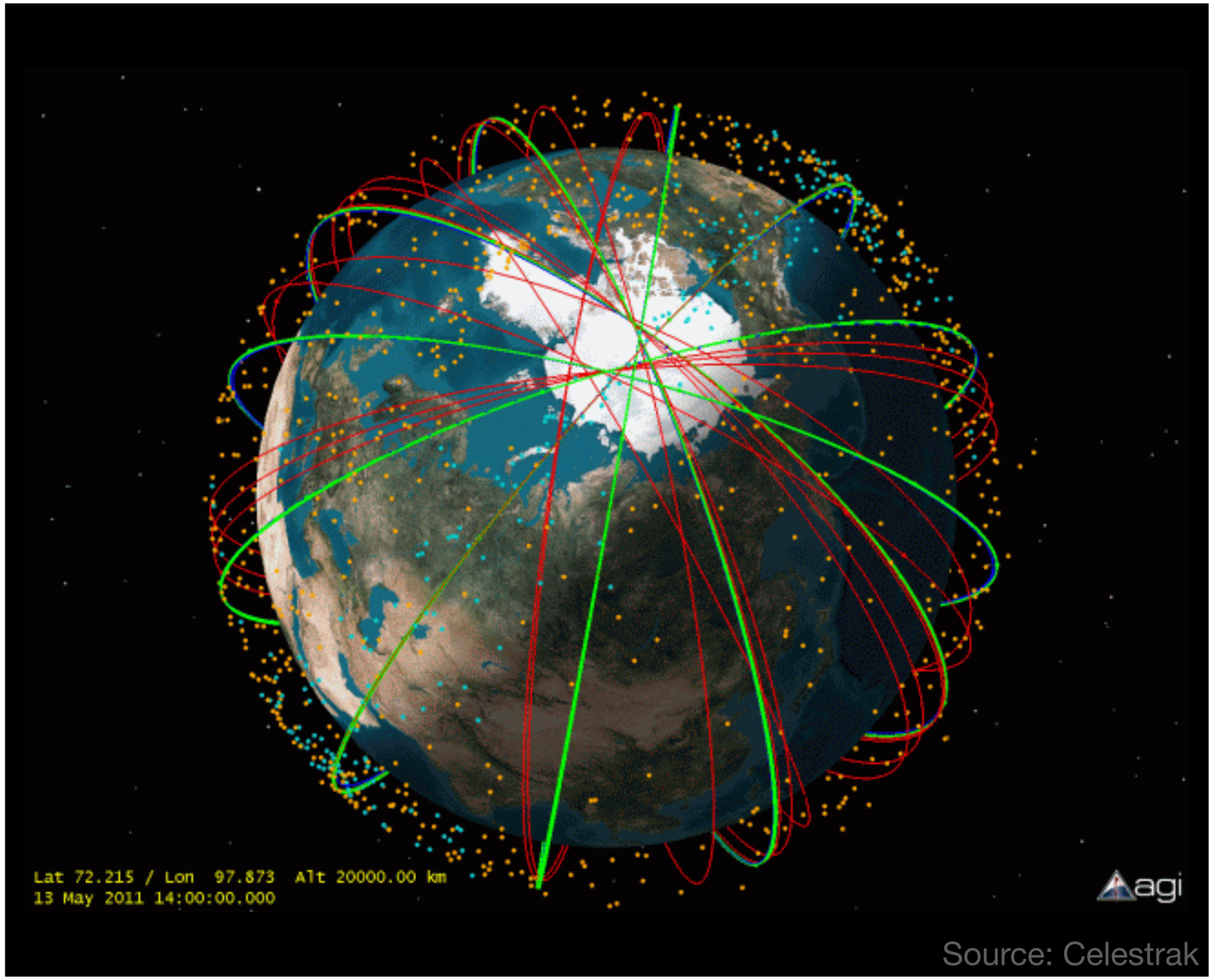
Transit 5B (1963)


Tested ASATs
Anti-missile systems
Created with mapchart.net

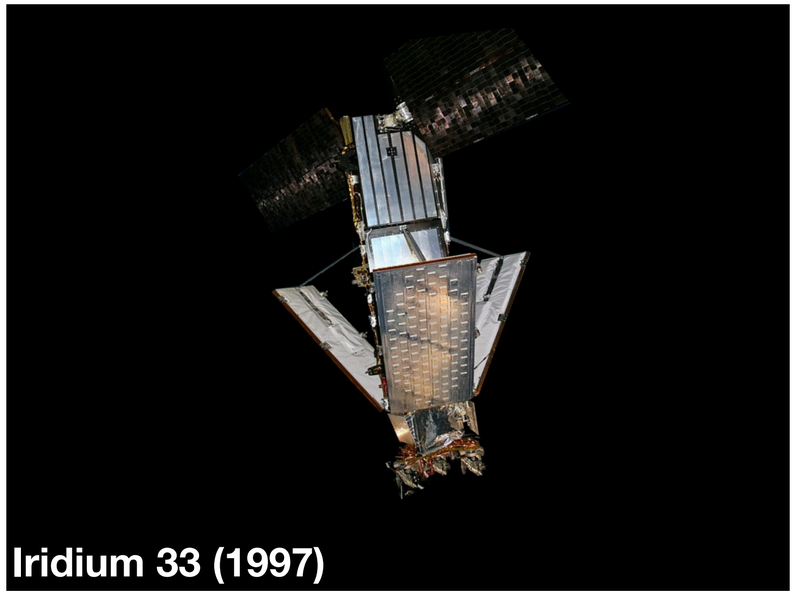
“Operation: Burn Frost” (2008)

“Celestial Eagle” Launch (1985)

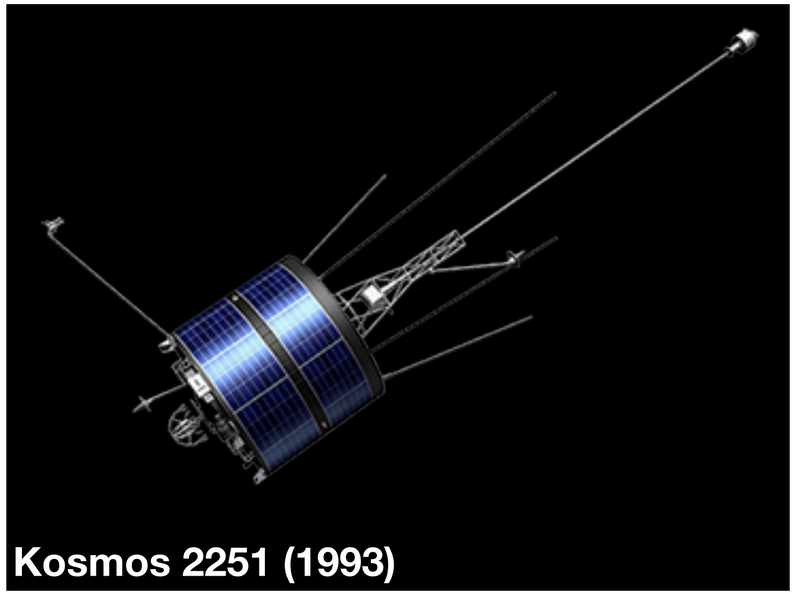
“Project 437” Missile (1962)



Source: Celestrak



Iridium 33 (1997)



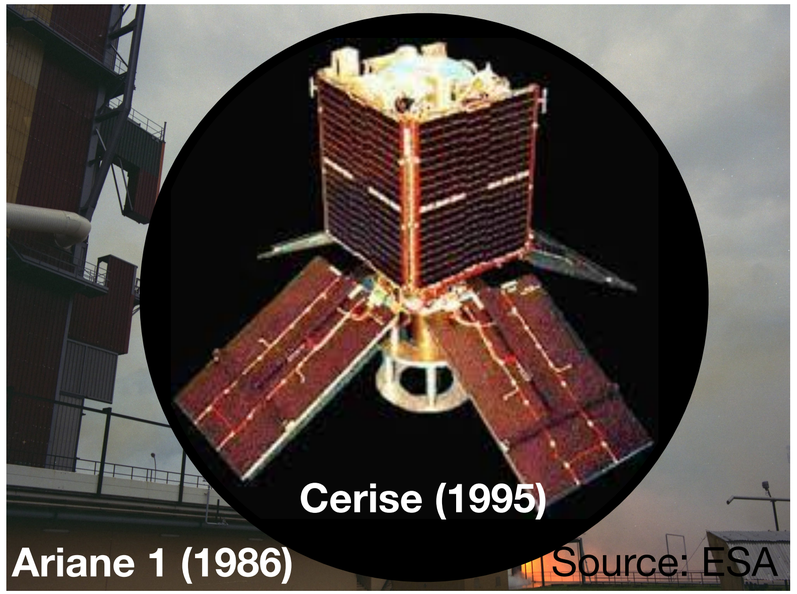
Kosmos 2251 (1993)

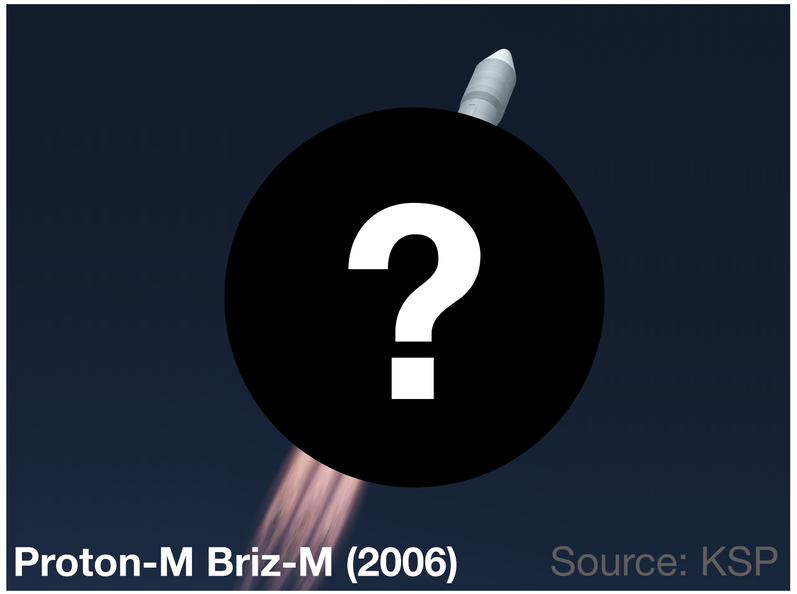
Long March 4B (1999)

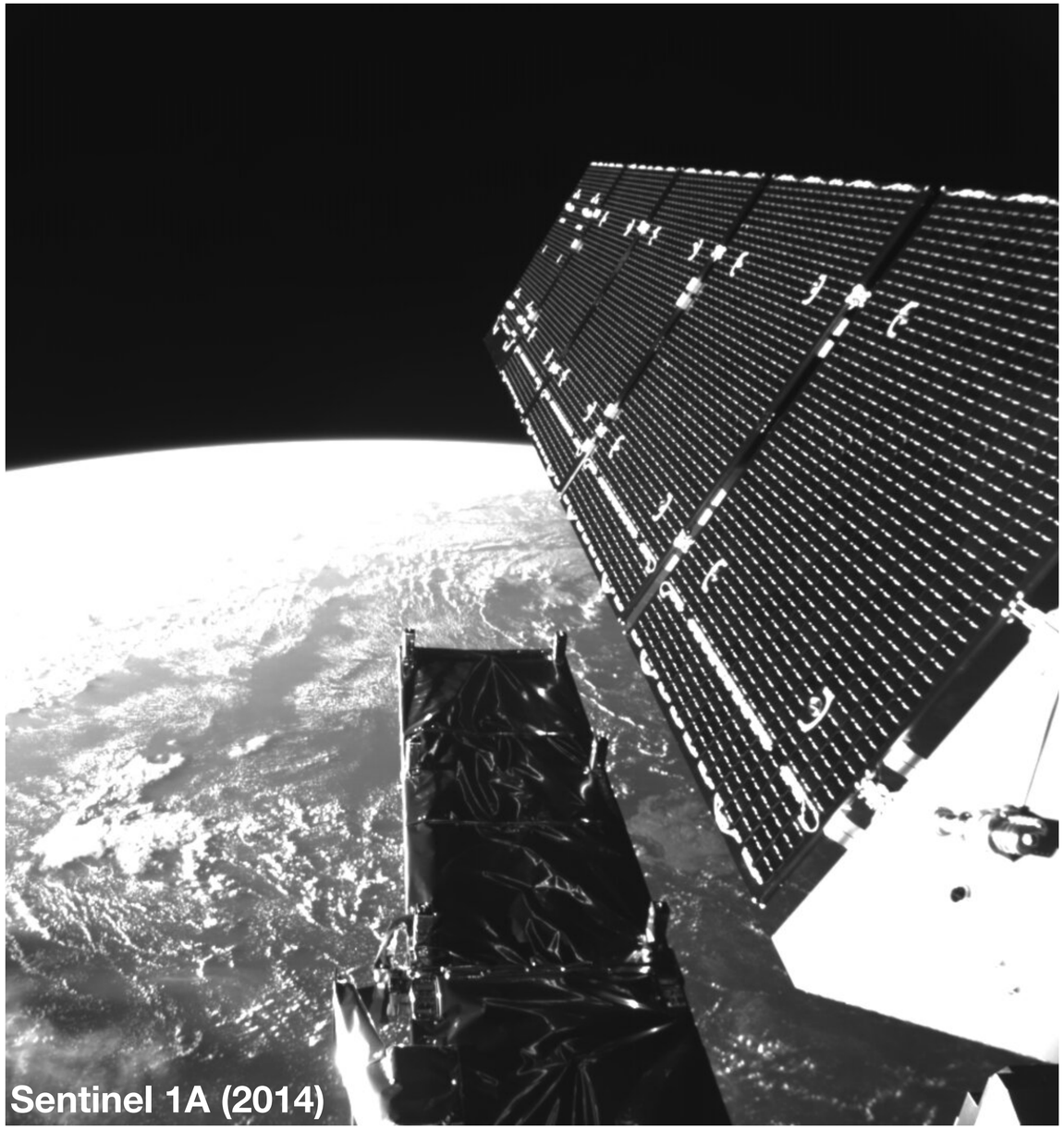
Ariane 1 (1986) Source: ESA

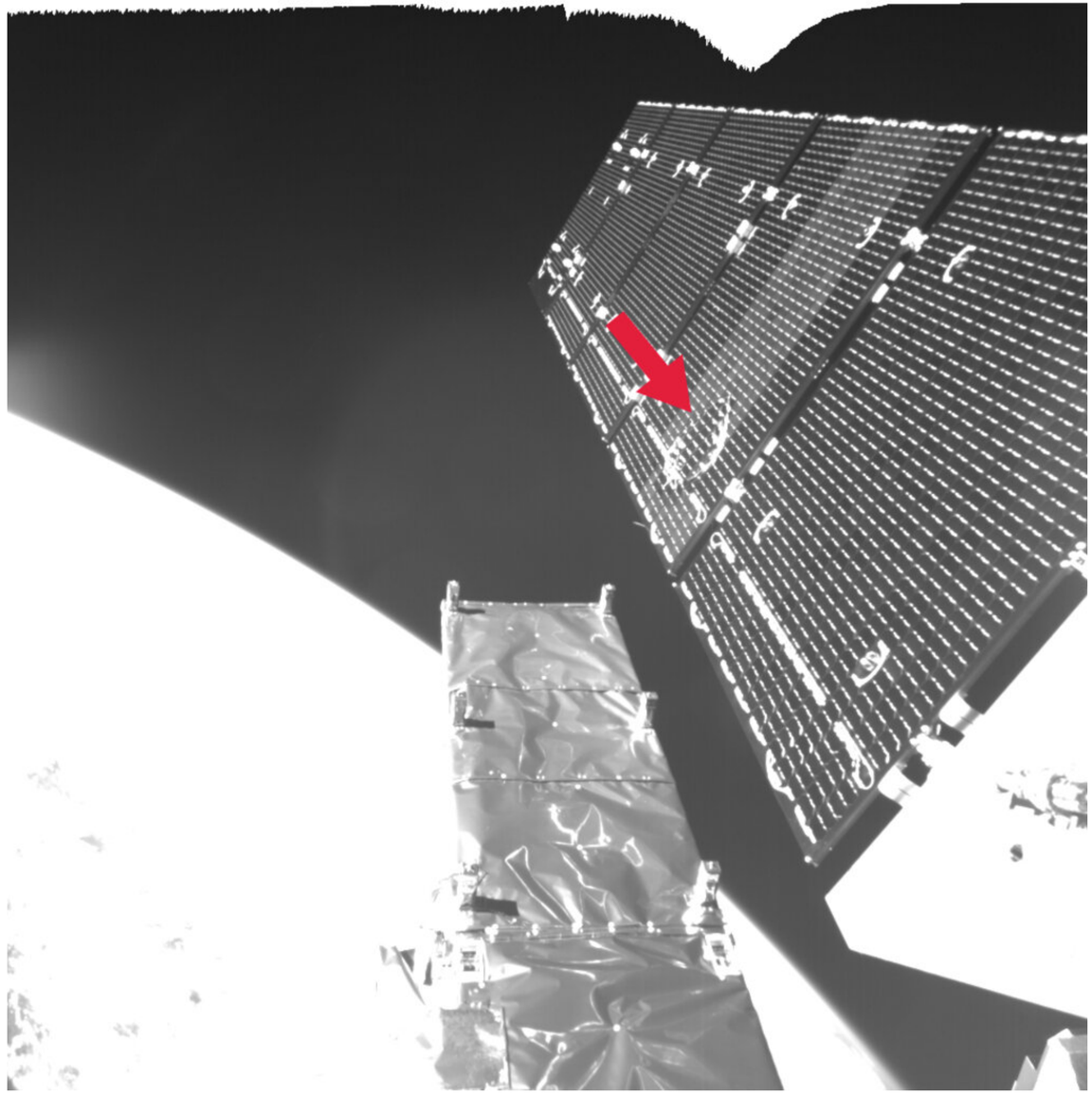
Proton-M Briz-M (2006) Source: KSP


Thor Burner 2A (1974)
U S AIR FORCE
Long March 4B (1999)


Cerise (1995)
Ariane 1 (1986)
Source: ESA


?
Proton-M Briz-M (2006)
Source: KSP

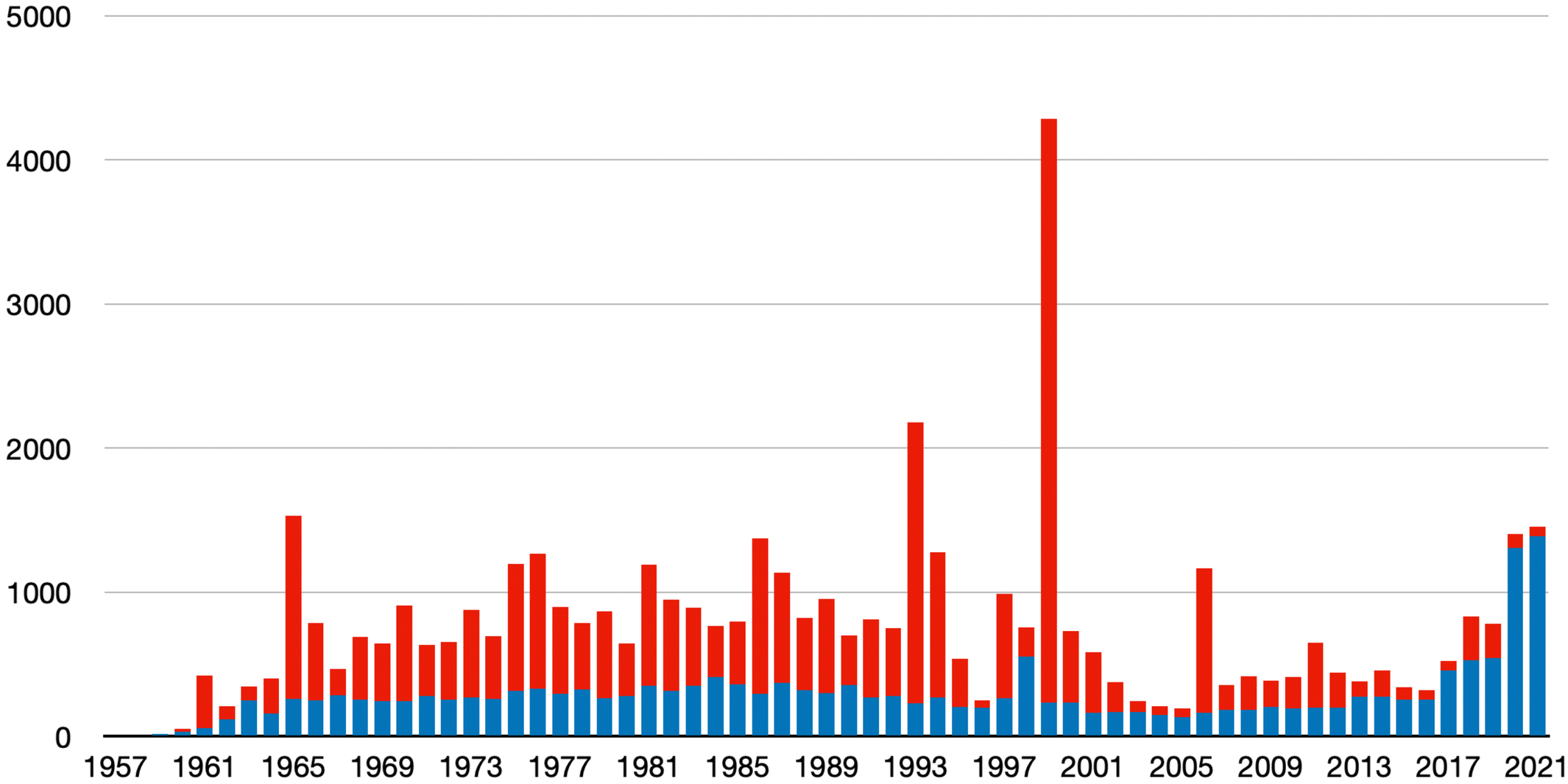

Sentinel 1A (2014)




ISS Canadarm2 (2001)
Canada
Canada

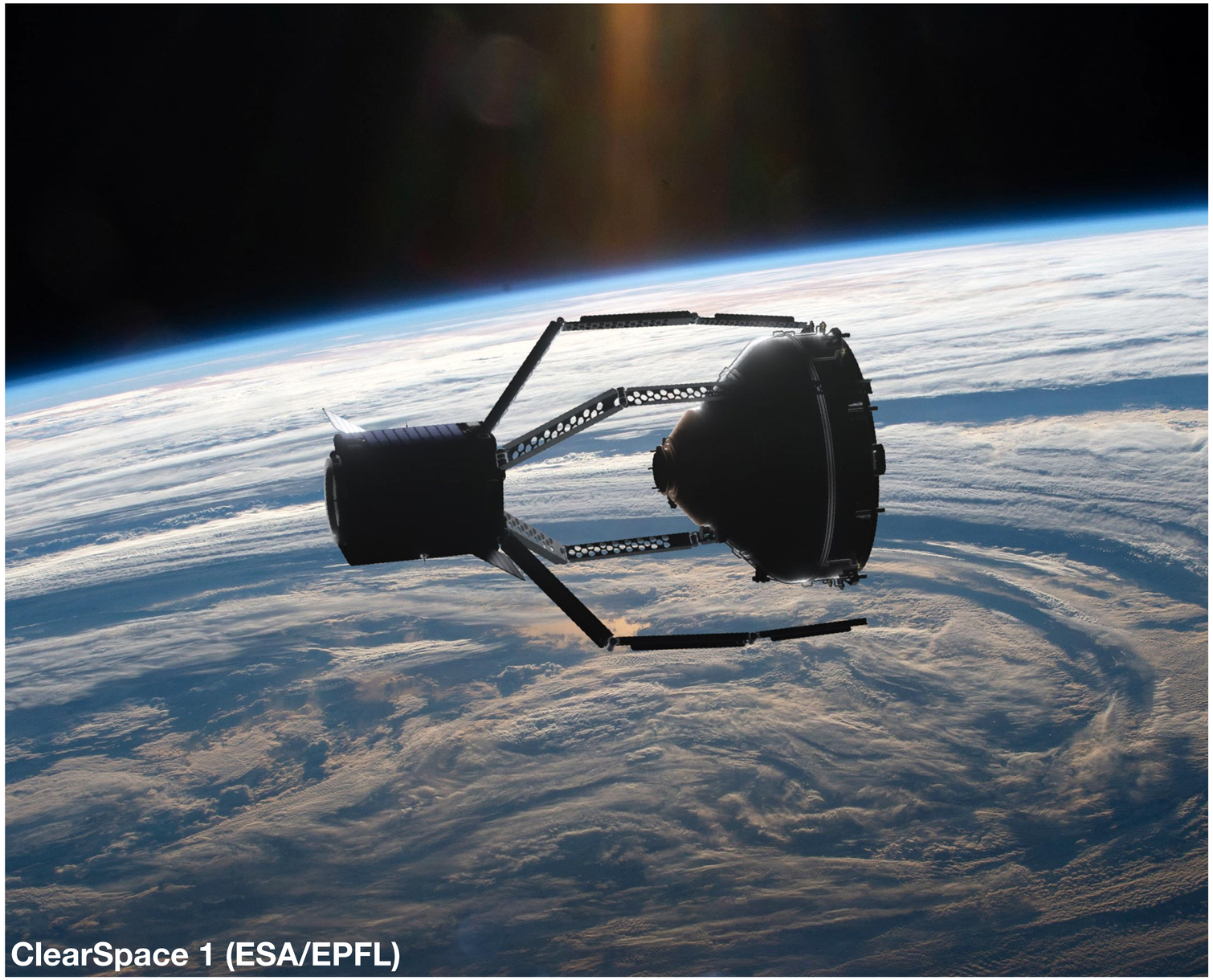

Source: CSA

Debris Volume

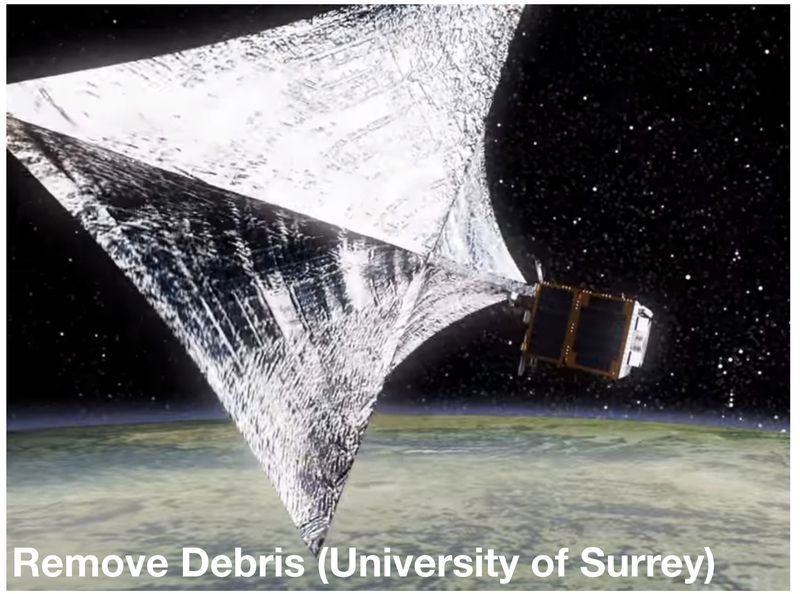


What should we do about it?
Why can’t we do those things?

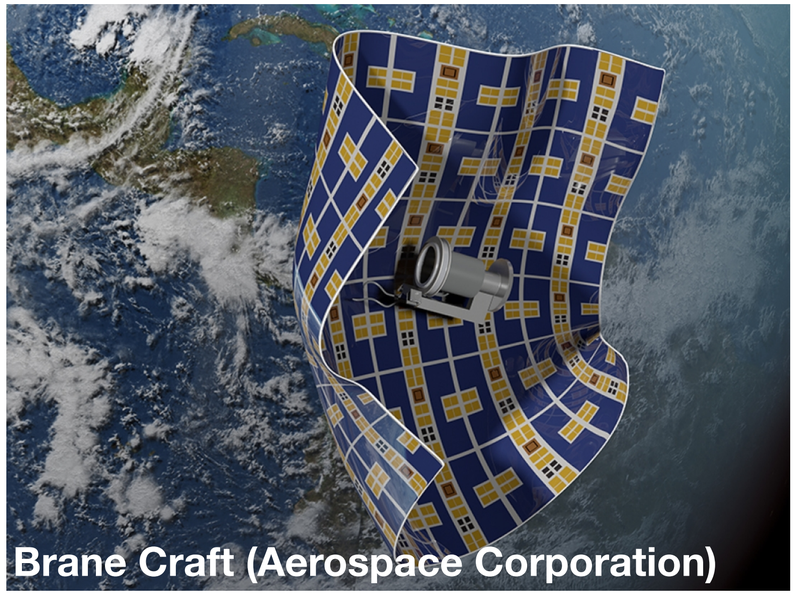
Active Debris Removal



ClearSpace 1 (ESA/EPFL)



Remove Debris (University of Surrey)



Brane Craft (Aerospace Corporation)

Challenges

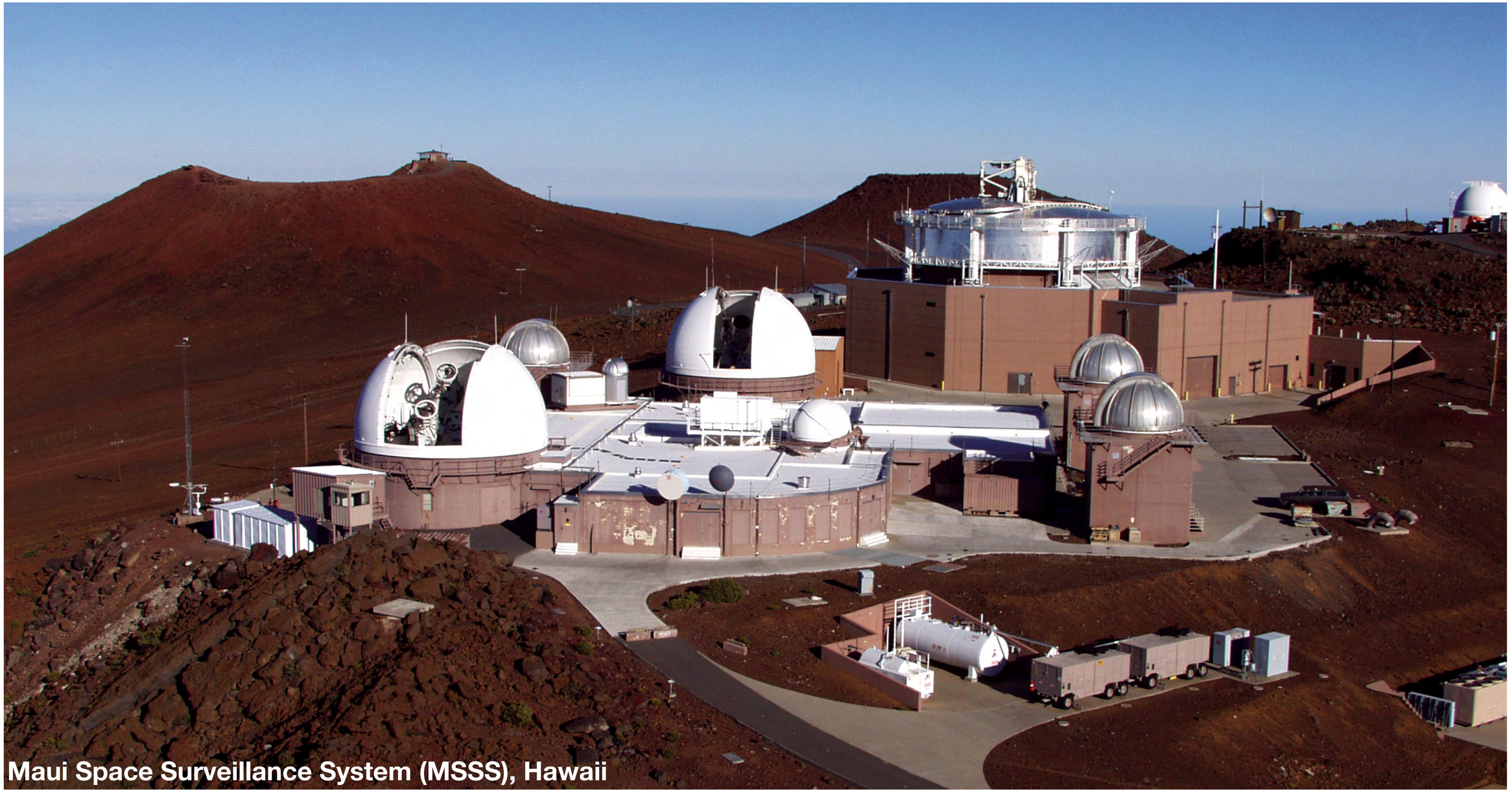
- Rely on highly accurate and precise location information
- Cannot be deployed at scale
- Failure = adding to the problem
- Some things still need to be in orbit

What do we do about it?

Space Traffic Management

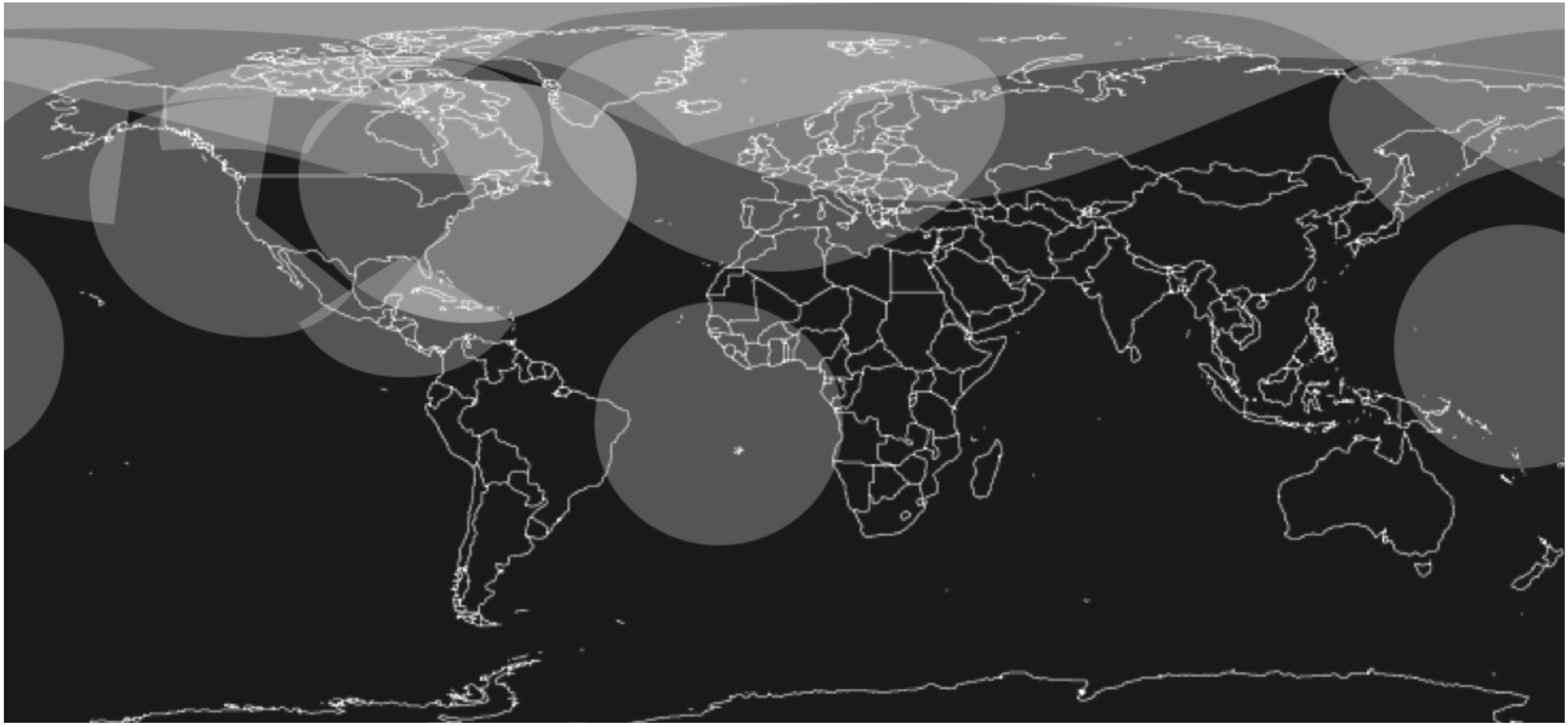
Challenges

- No transponders
- No GPS/SATNAV
- Unreliable tracking
- Unmanoeuvreable objects
- Complex movement
- Impact by random events (e.g. solar flares)



Maui Space Surveillance System (MSSS), Hawaii

Space Surveillance Network




Credit: Eddie Yip

Harold E. Holt Naval Communications Station, WA

Source: Sitzler

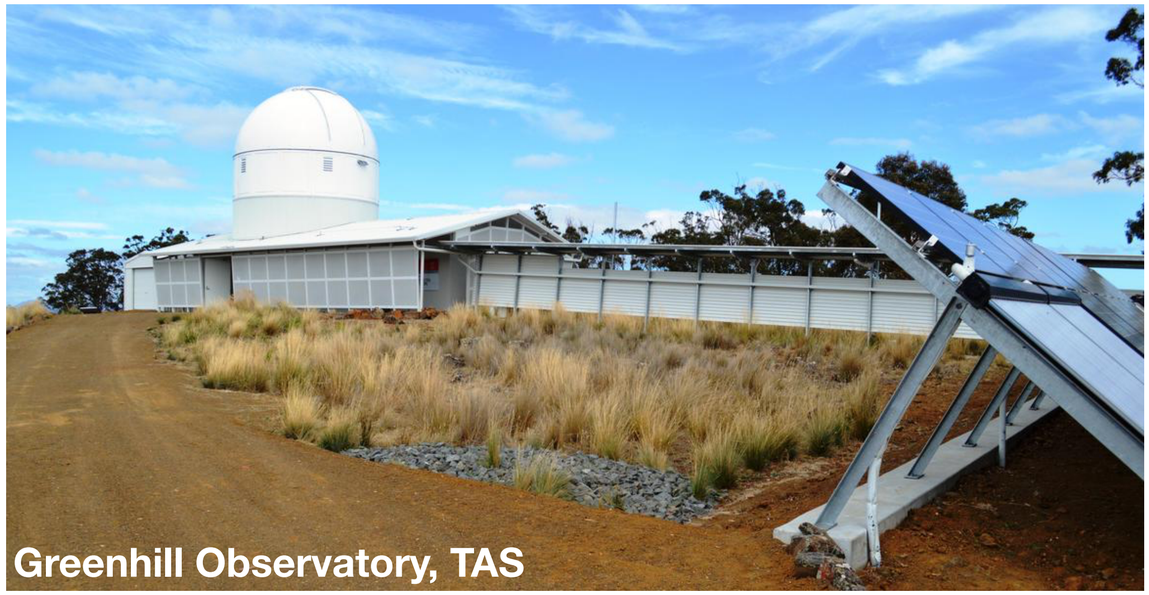
Source: AU SKA Office

Murchison Wldefield Array, WA

Source: Silentium Defense

Maverick Radar, SA


Mt Pleasant Observatory, TAS


Greenhill Observatory, TAS


Ceduna Observatory, SA


Parkes, NSW

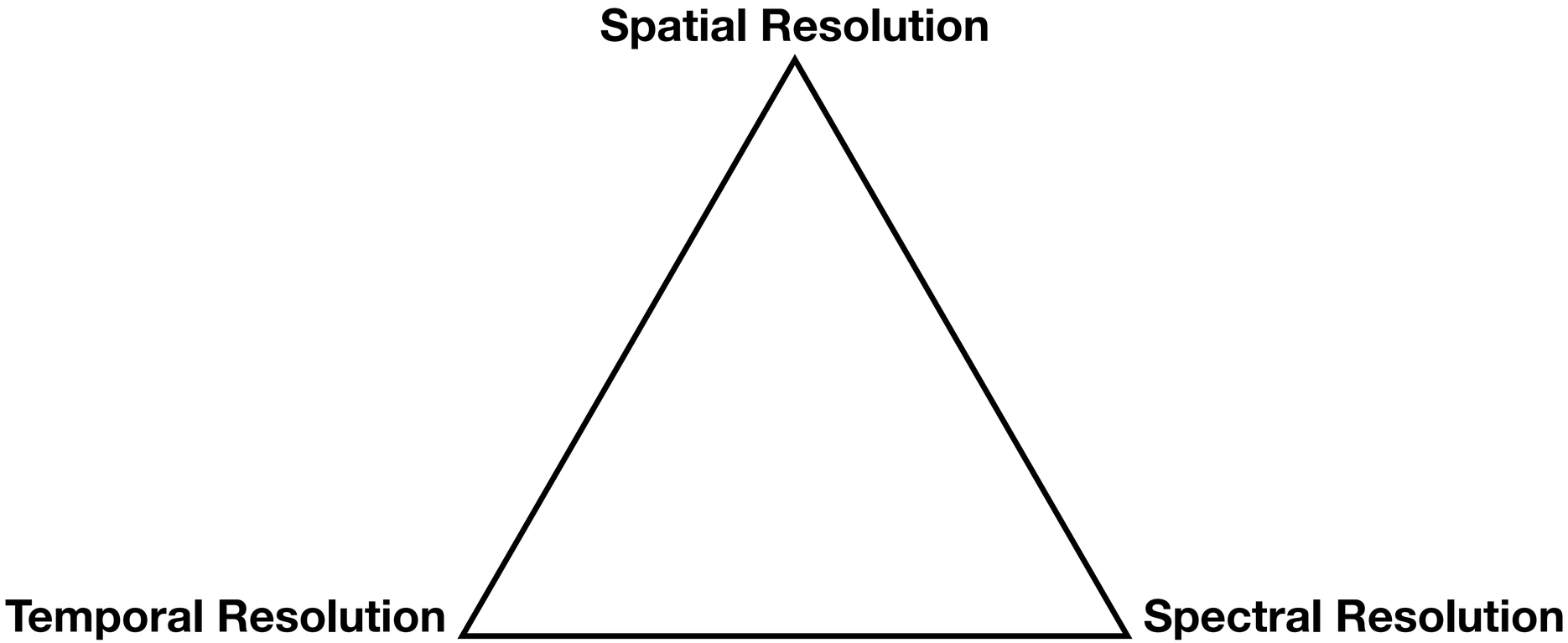
Why not use those?

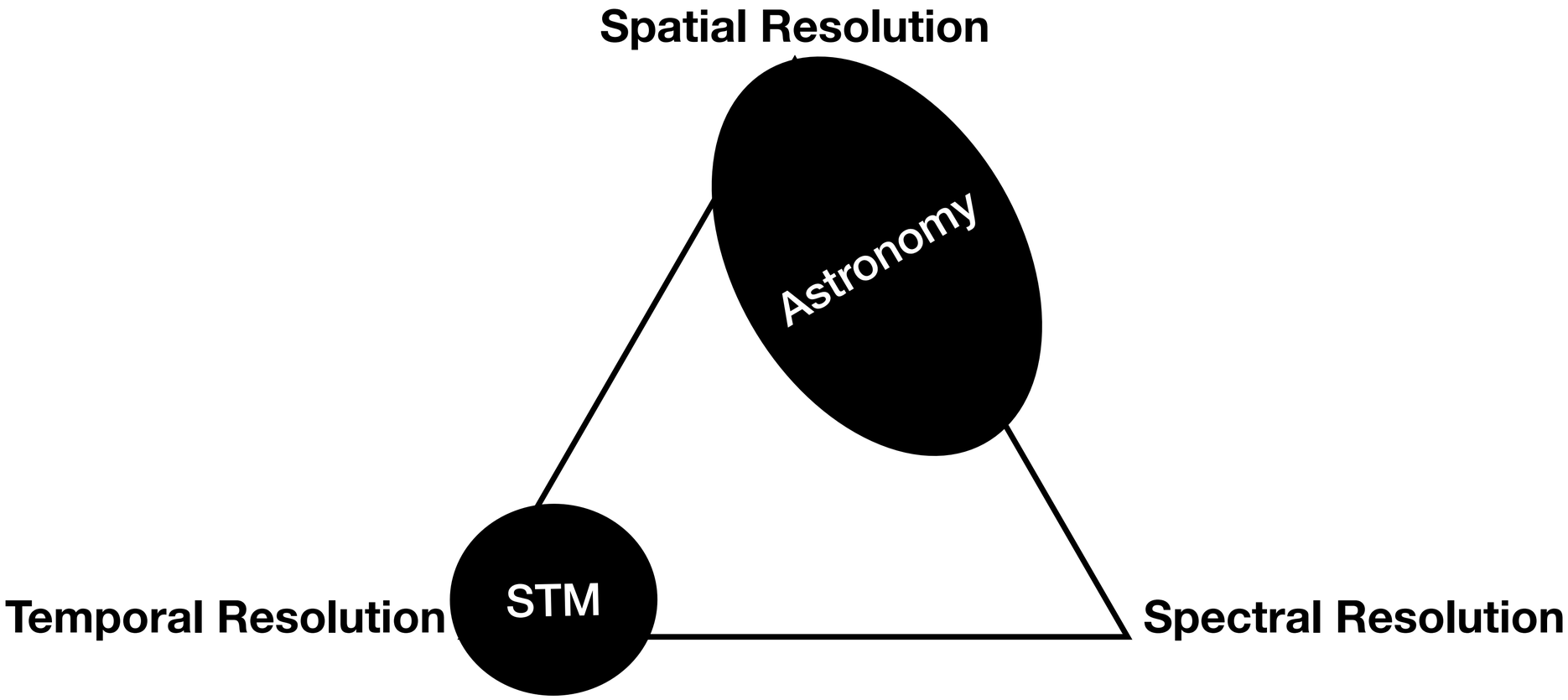
1. Astronomy systems are needed for astronomers to do their work, and STM is not systematically profitable.

2. Astronomy systems are not the same as STM systems, so it's a lot of work (or sometimes impossible) to adapt them.

AKA **Why would we allocate time away from doing astronomy *well* just to do STM *poorly*?**

(Some people are working on it)

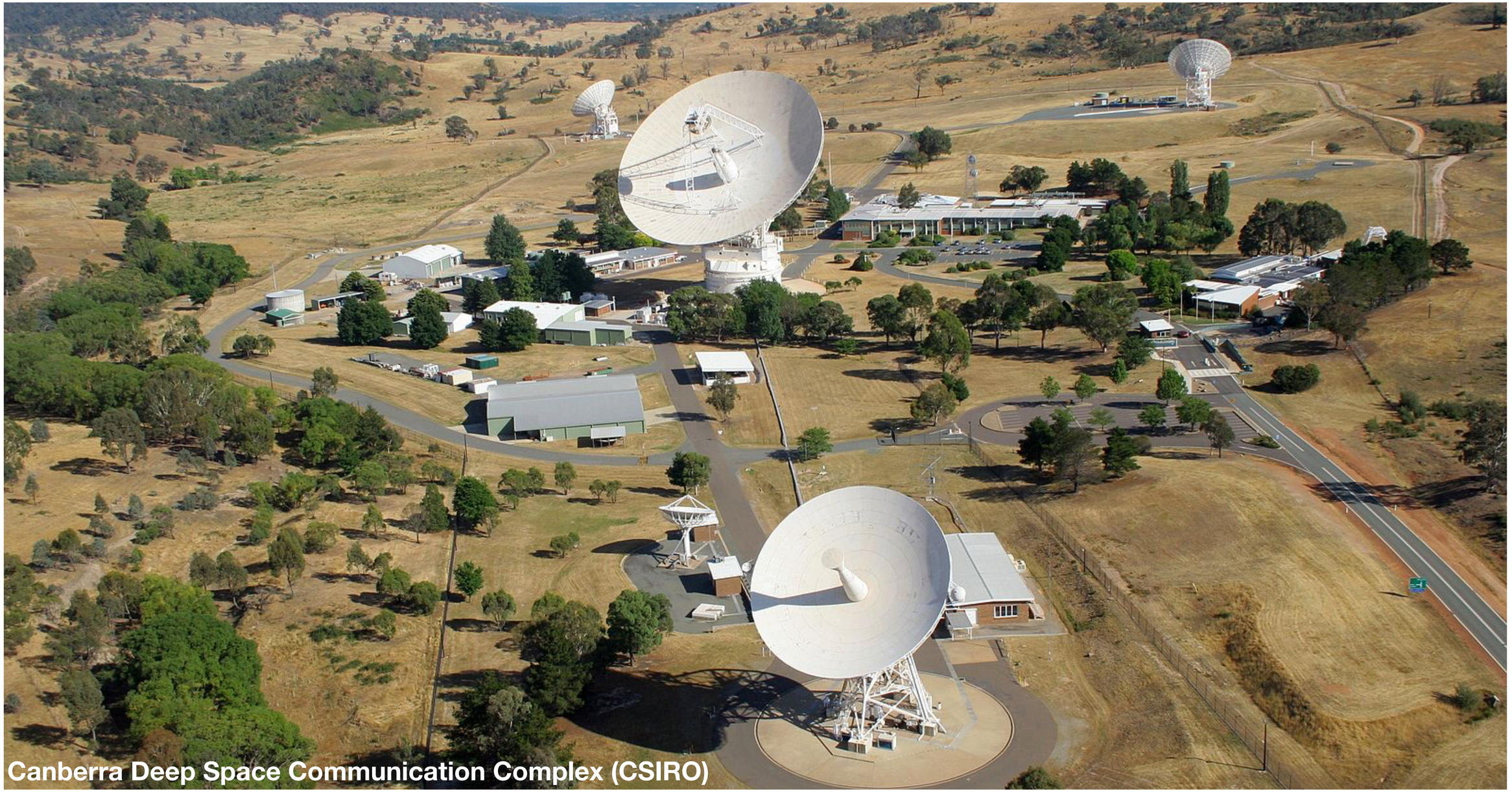

Spatial Resolution
Temporal Resolution
Spectral Resolution


Spatial Resolution
Astronomy
STM
Temporal Resolution
Spectral Resolution


ATCA

Further Limitations

- Optical tracking doesn’t work in most weather conditions or times of day
- Radio signals used to track source locations may be perturbed by passing through the ionosphere
- No transmitter = cannot observe inactive debris without cooperation from a transmitting site



Canberra Deep Space Communication Complex (CSIRO)

Dedicated Systems

Kiwi Space Radar (LeoLabs)

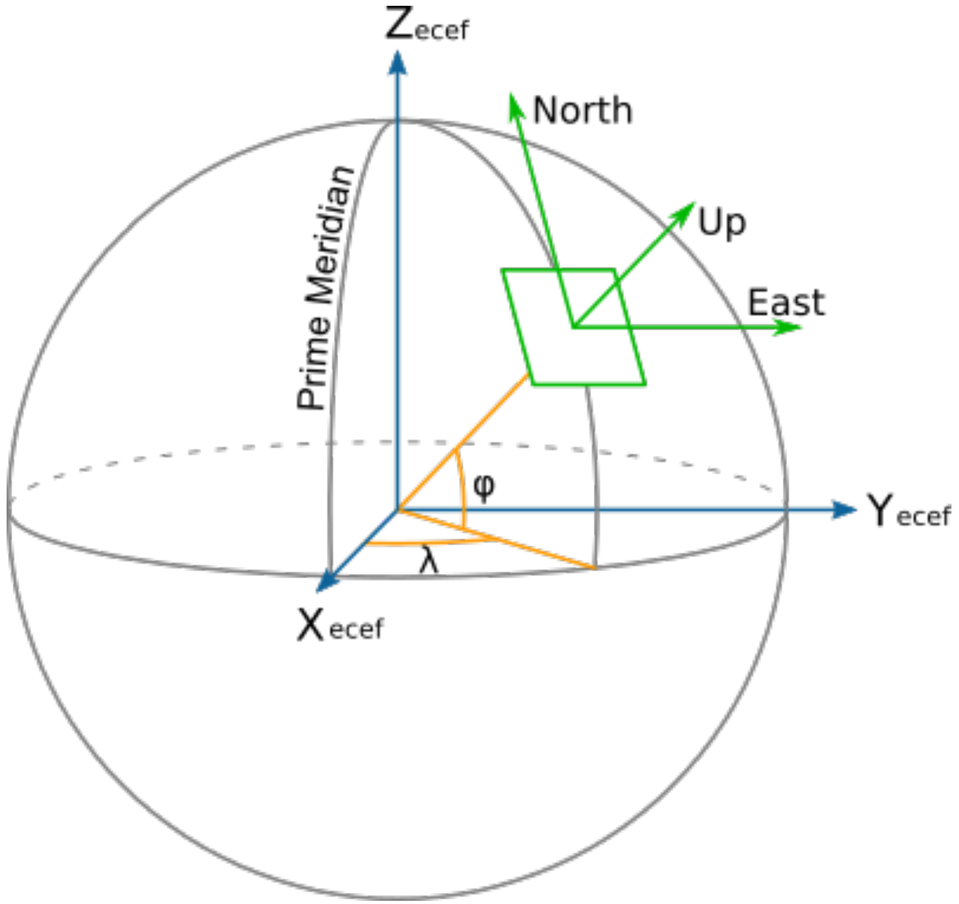

LAUGHS IN AUSTRALIAN

How does it work?

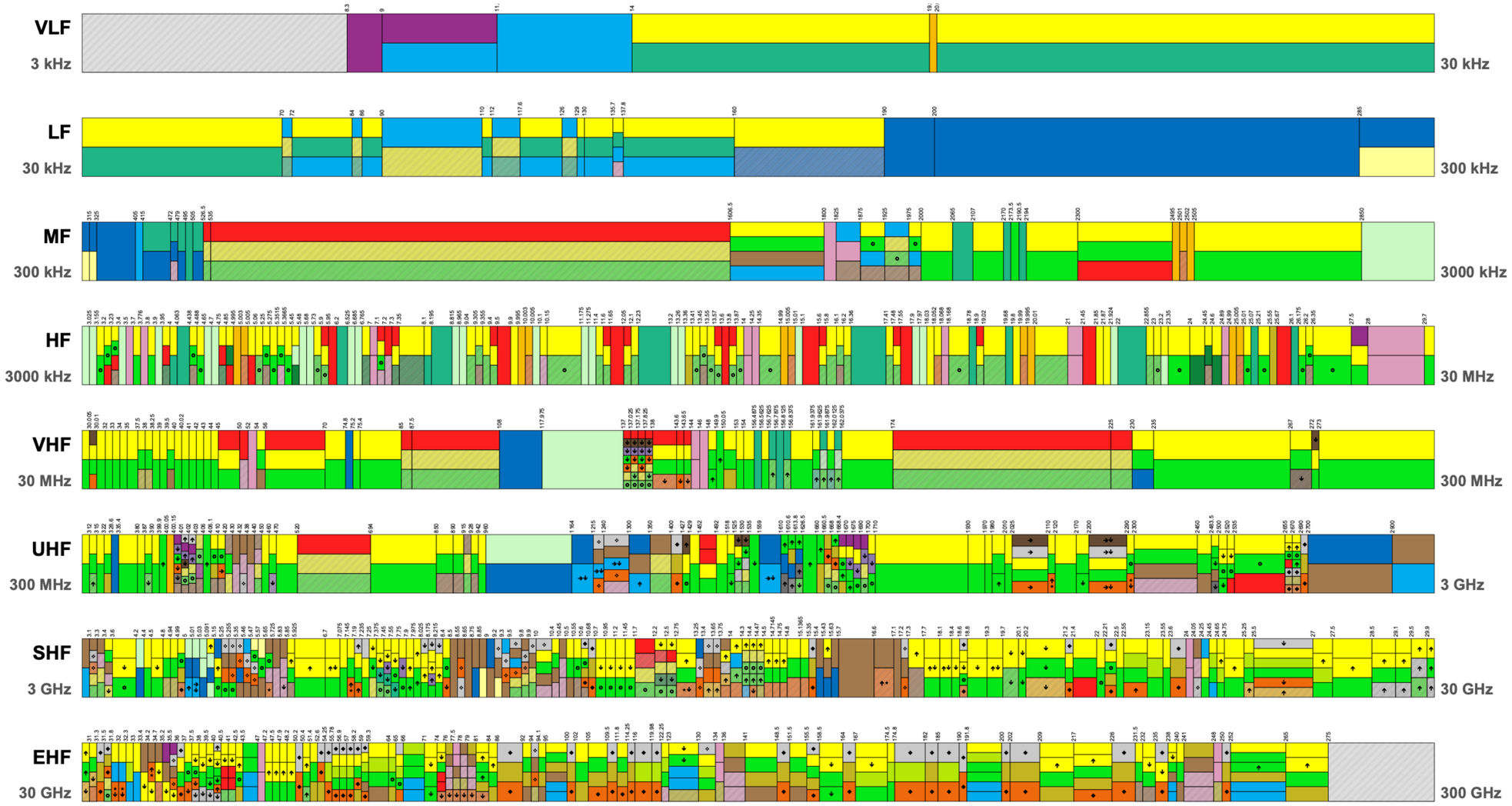
Space Traffic Management

1. **Target** an object or region of space
2. (Optional) **Transmit** a signal to observe reflection
3. **Collect** data using some optical/radio sensor
4. **Analyse** data to identify and locate objects
5. **Predict** future trajectory of observed objects
6. **Adjust** trajectory of objects where necessary

Step 1: Target



Step 2: Transmit

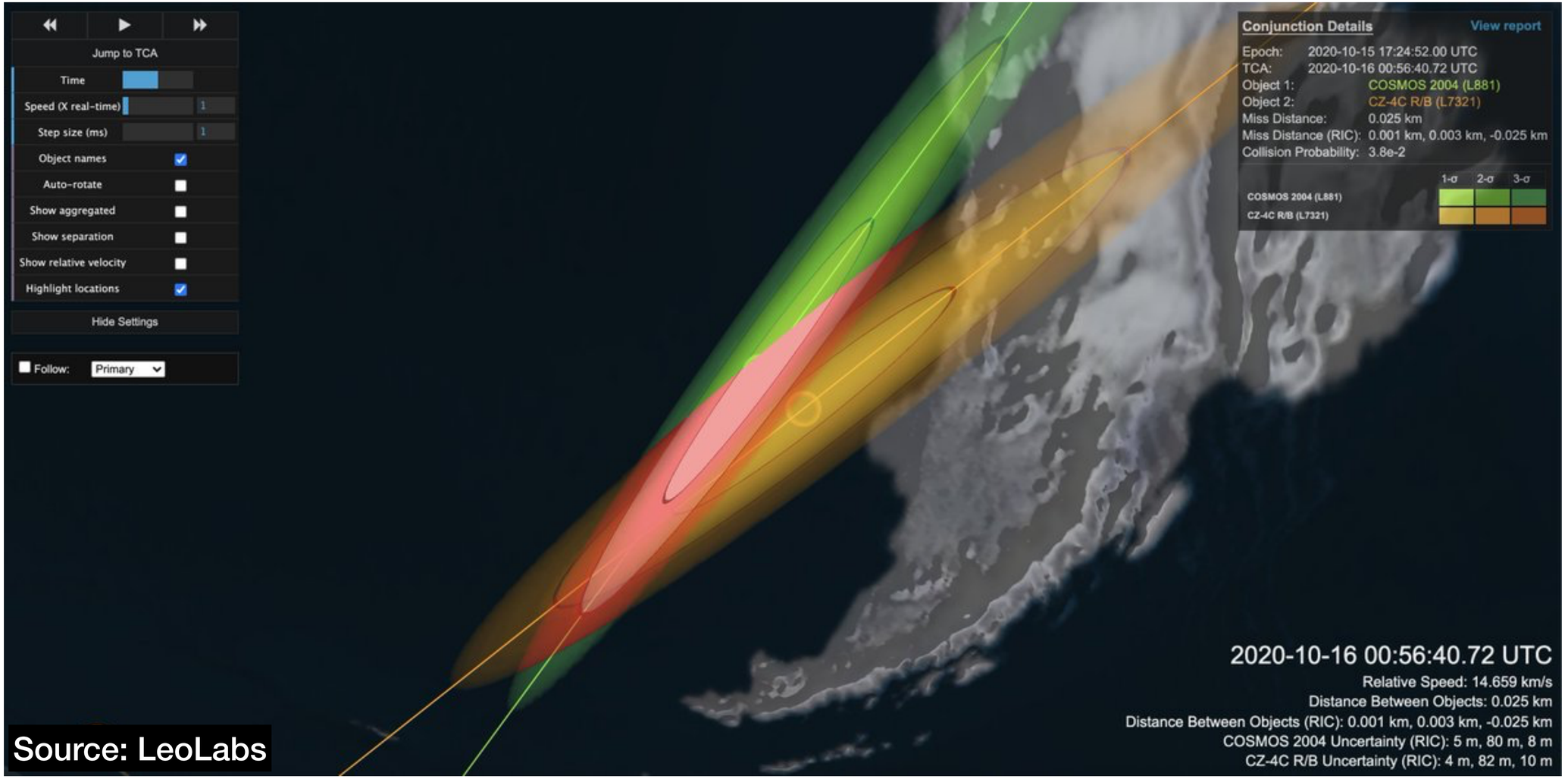


Step 3: Collect

Step 4: Analyse

- Extrapolate source location, trajectory, speed
- Convert from telescope-relative to Earth-relative coords
- Identify, associate with known object record if possible
- Classify current movement behaviour

Step 5: Predict



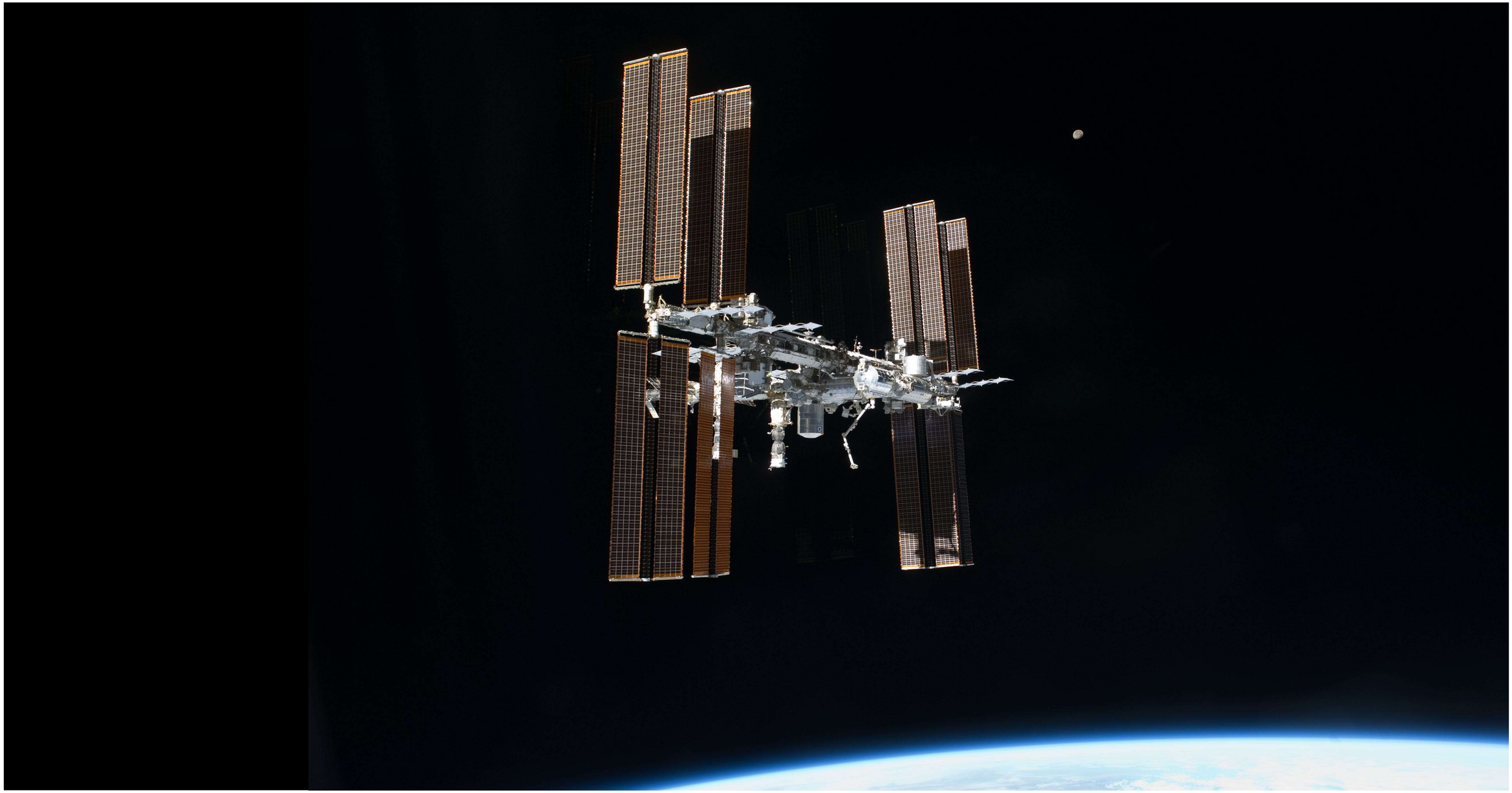
Source: LeoLabs

SGP4

(Simplified General Perturbations set, model 4)

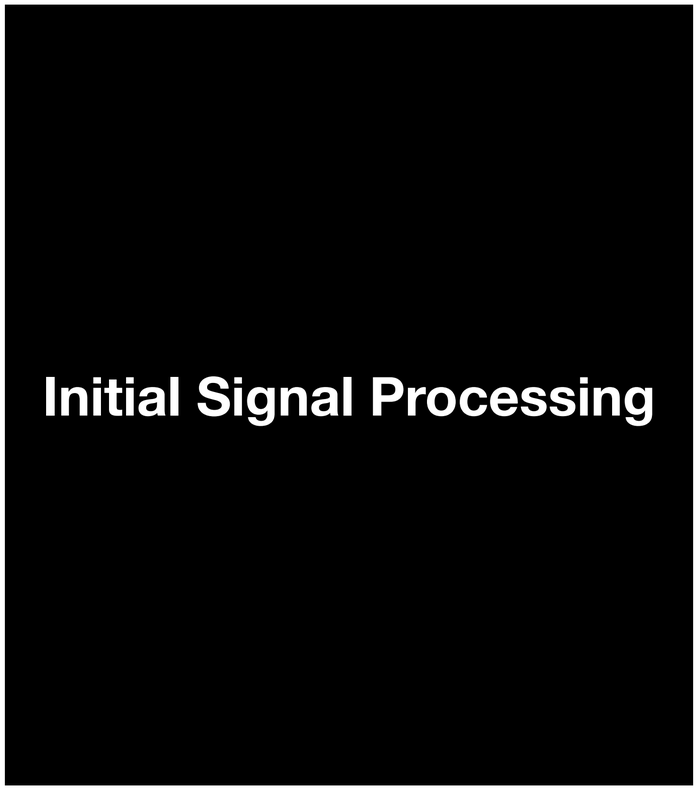
Step 6: Adjust

1. Calculate likelihood of collision between two objects
2. If high, check if either has power and ability to move
3. If yes, compute new trajectory for movable object
4. Check new trajectory for new collisions
5. If yes, go back to 3
6. If no, send manoeuvre instructions

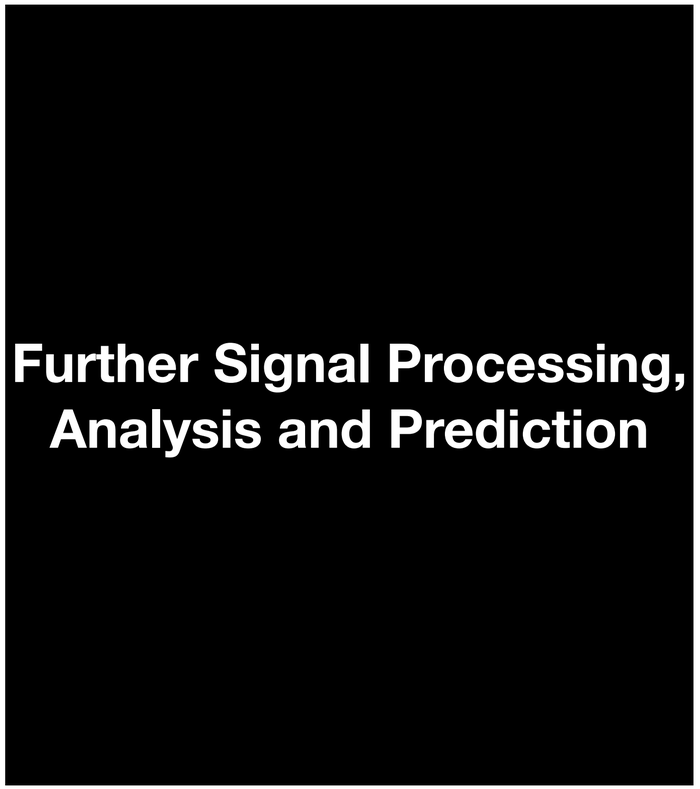


How does Python play a part?

Coordination System

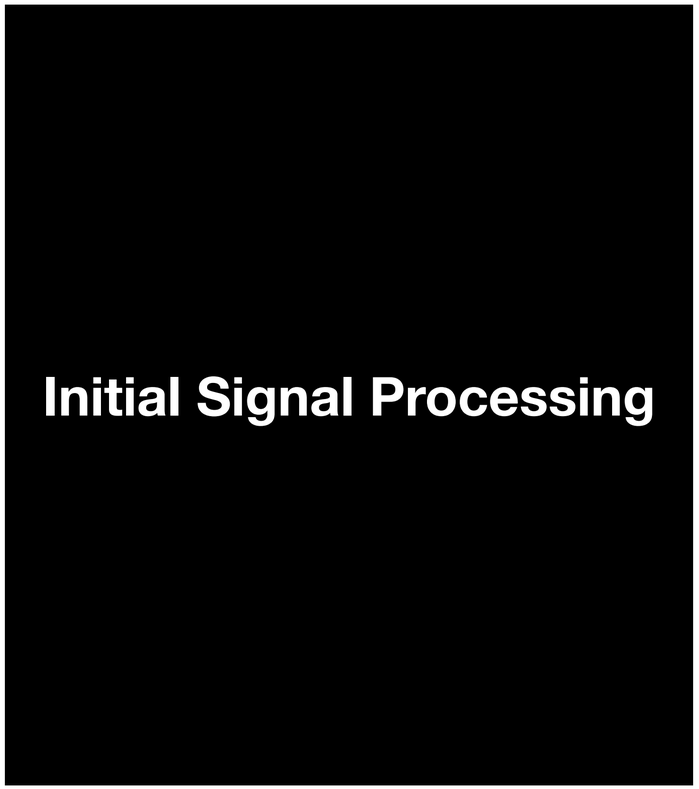


Processing Backend

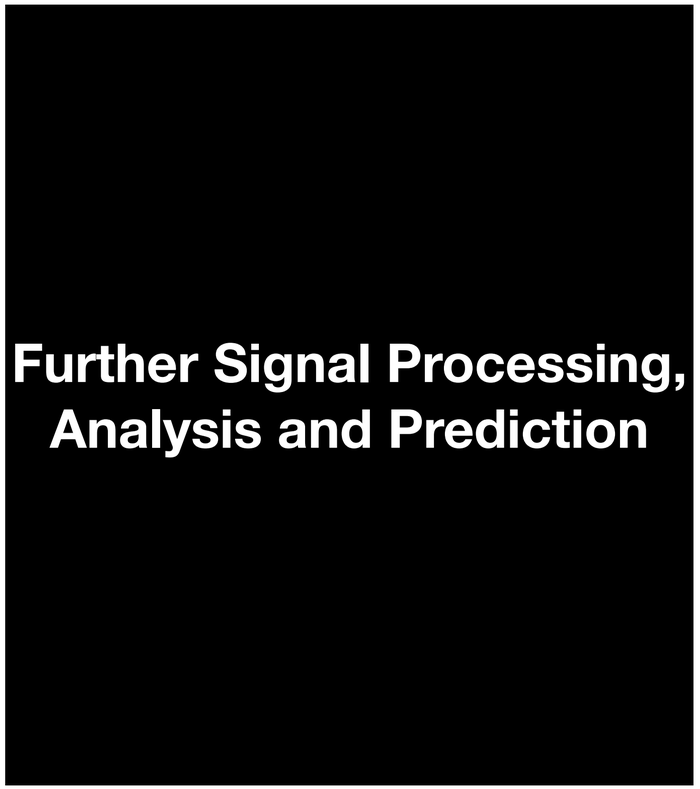


Dedicated Subsystem

C/C++



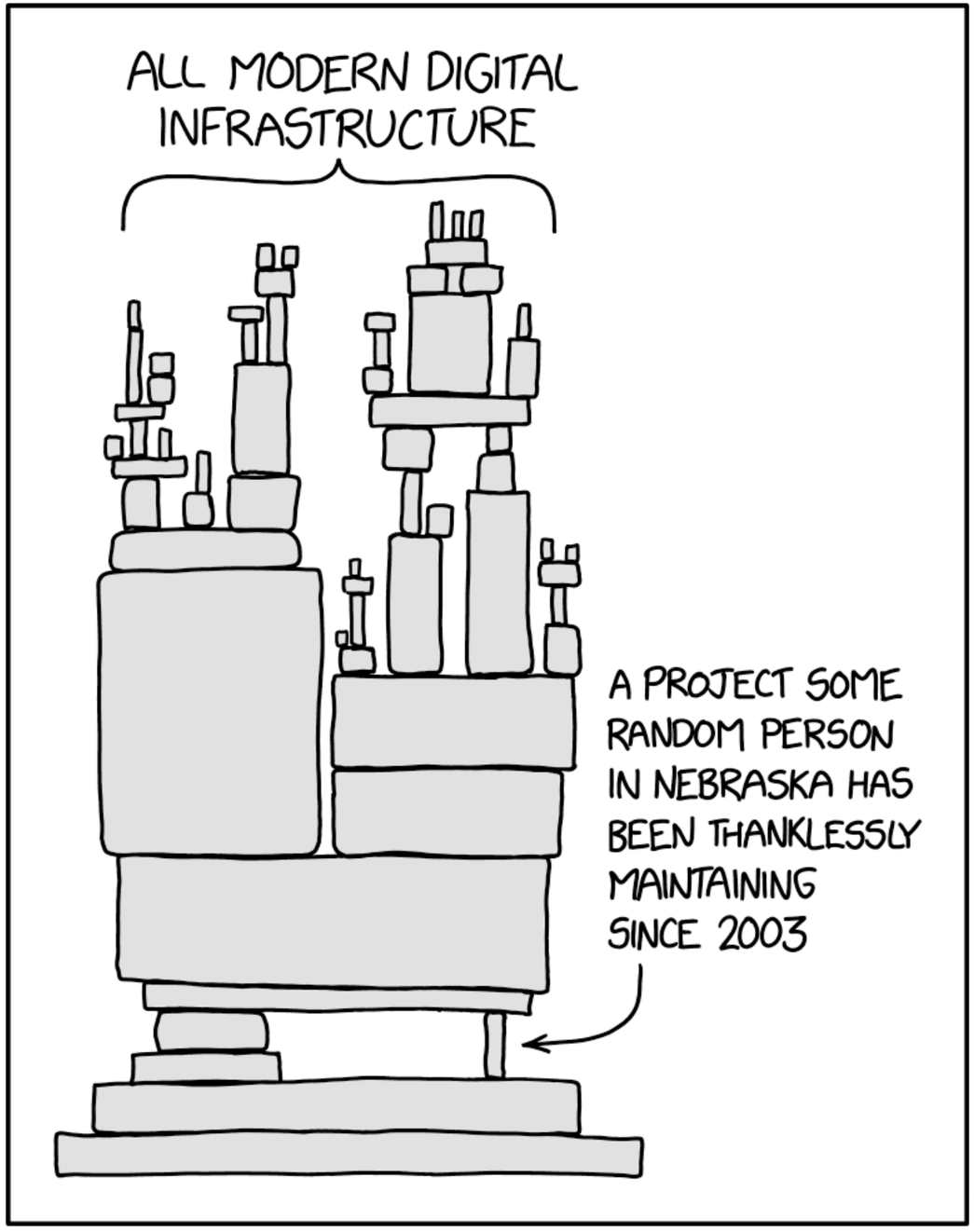
C/C++/Java/
FORTRAN/Tcl



Often Python

OREKit (CS Group)—Apache 2.0

Skyfield (Brandon Rhodes)—MIT



“Dependency” by xkcd

Opportunities

- Develop faster or more accurate propagation heuristics
- Benchmark existing propagation models against each other
- Analyse different types of prediction error over time
- Develop special-case models for hard-to-track behaviours (especially small, tumbling, or irregularly orbiting objects)
- Implement easier multithread/GPU support for models

space-track.org

```
pip install Skyfield
```

themartianlife.com/pyconau2021

themartianlife.com/pyconau2021

Thanks for listening!

Mars Buttfield-Addison | @TheMartianLife | hello@themartianlife.com

References + Thanks

- Celestrak (who has a public mirror of the SATCAT)
- Gunter’s Space Page (who has great images of rare sats)
- NASA (who put all their images in the Public Domain)
- Space archivists (for their documentation of space history)
- OREKit + Skyfield devs (for their contribution to STM)