Collision Avoidance and Space Debris Mitigation: An Approach

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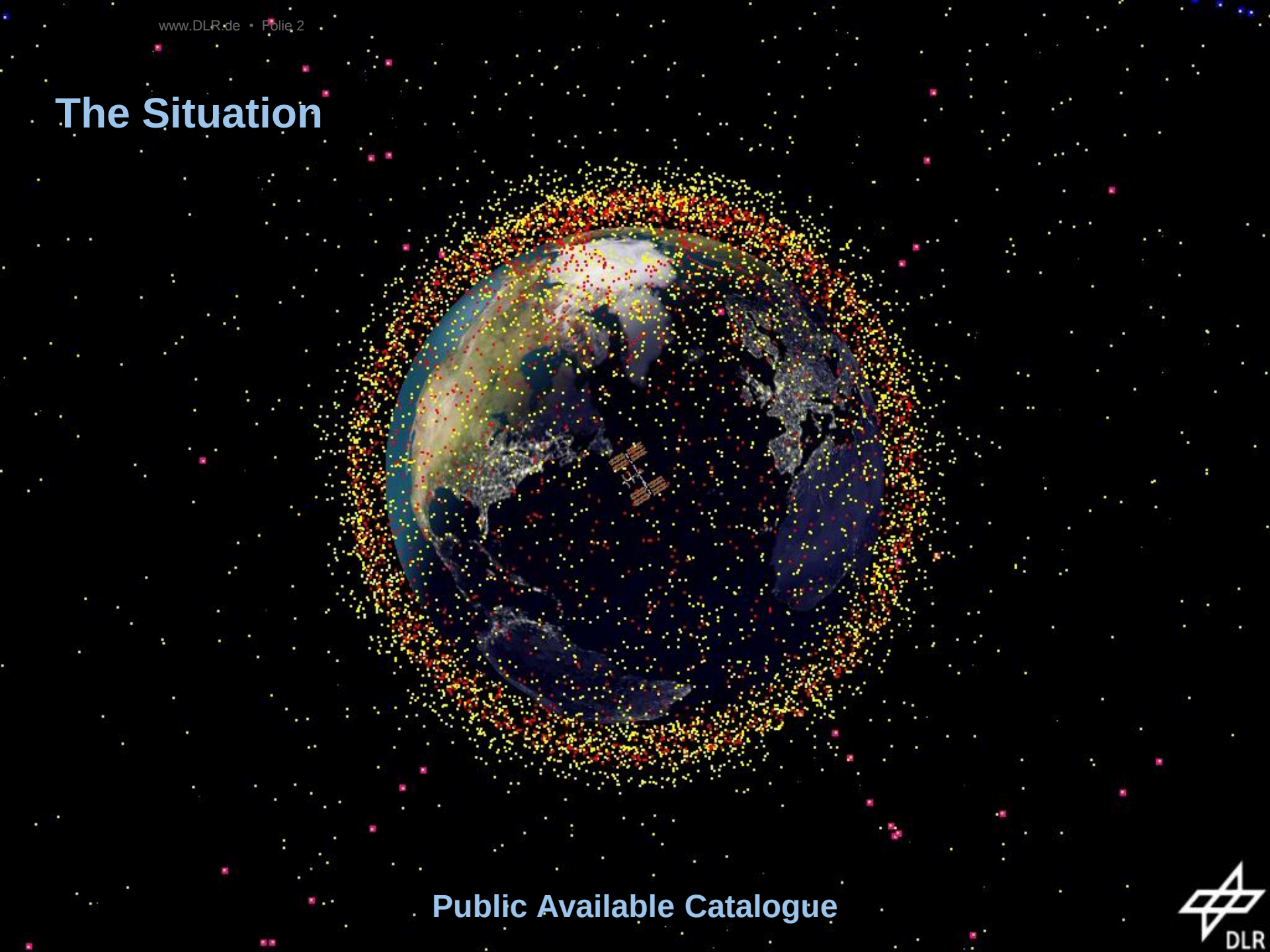
The Situation



Public Available Catalogue

Space Debris Generation

- **Unused Satellites**
- **Explosions (Tank, ca. 5 Tanks per year)**
- **Upper rocket bodies**
- **Collisions**
- **West Ford Dipole**
- **Fragmentation**
- **…**

→Consequences:

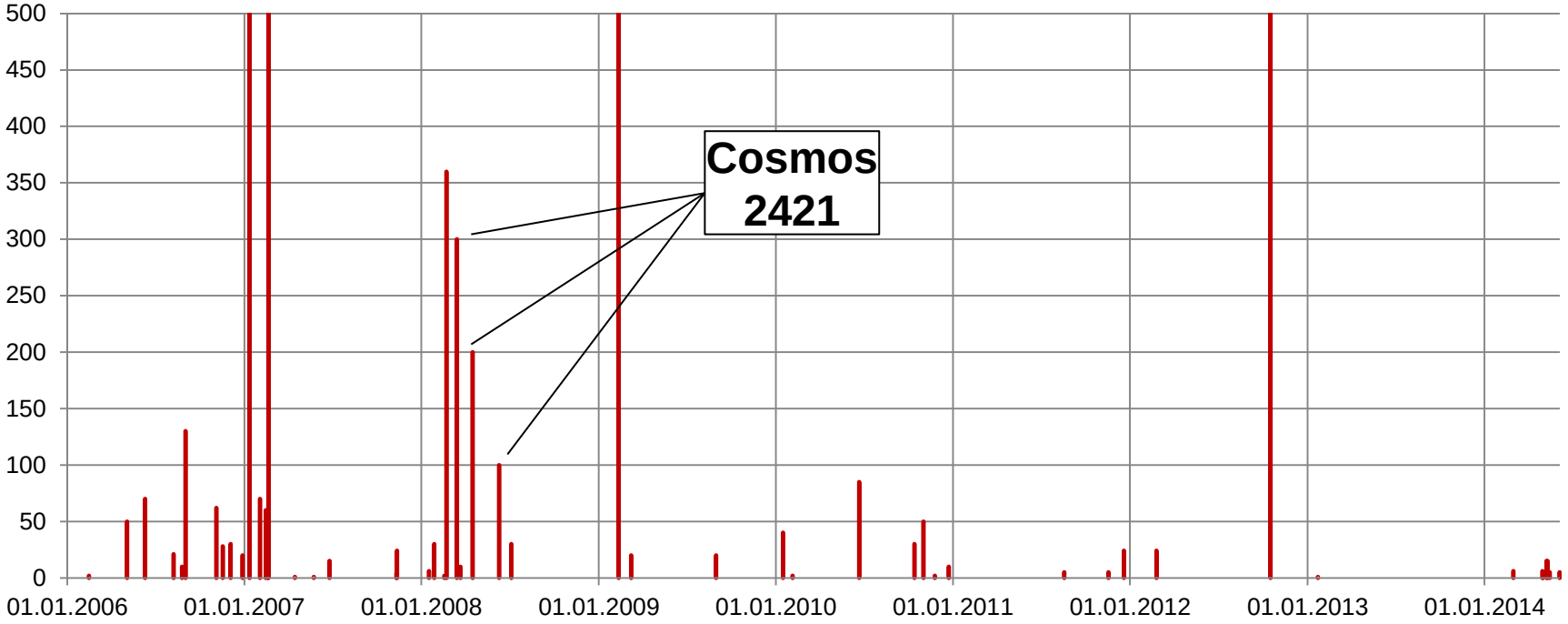
- Tracking prerequisite
- Collision avoidance necessary
- Shorter Mission time
- Loss of mission objectives

Briz-M

Courtesy of Ray Palmer, http://www.thecosmicartgallery.com

New Objects: 2006 – 2014

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Obj.	423	4226	1038	1540	219	34	724	1	54
Frag.	10	10	9	4	7	3	2	1	7



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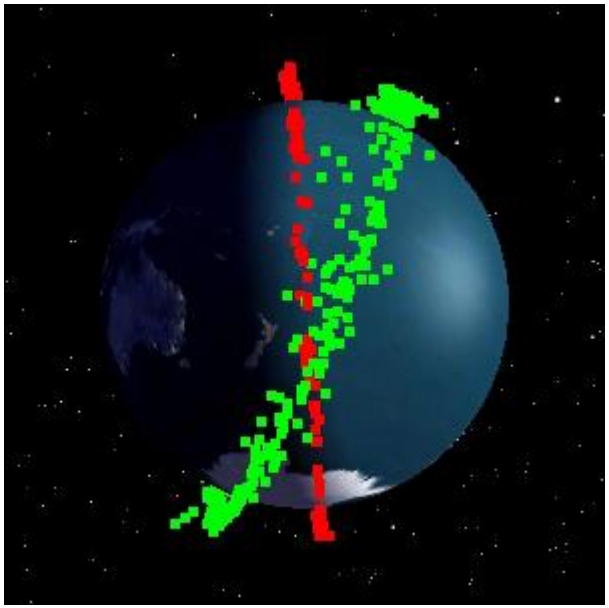
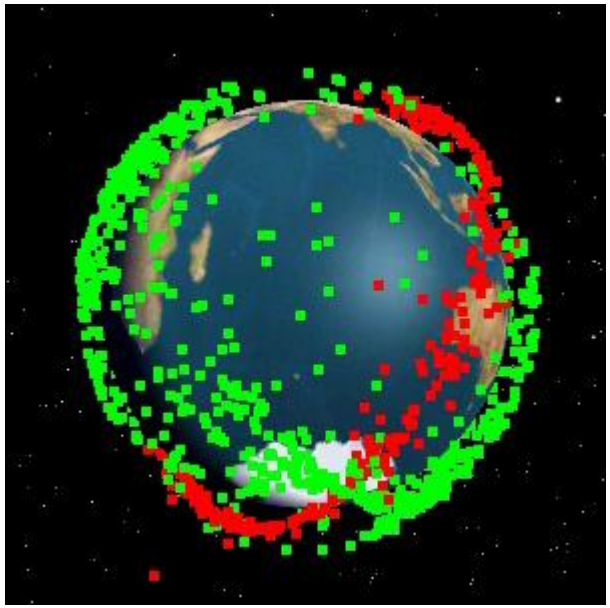
Collision between Iridium 33 and Cosmos 2251

Short-Term Development of Debris Clouds

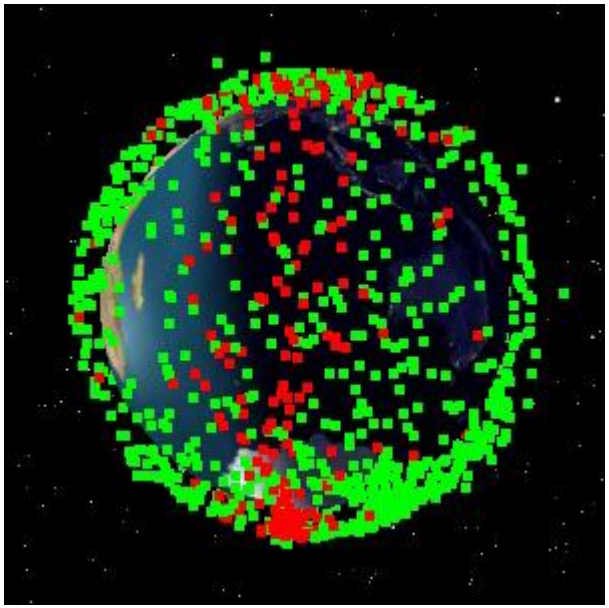
1 Month



1 Year



3 Years



➔ Homogeneous distribution after short time

Assumed Collisions:

Cosmos 1934 / Cosmos 926 (1991) – Cerise / Ariane Fragment (1996) – NOAA 7 / NCO (1997) – Cosmos 539 / NCO (2002) – Thor Burner 2A / CZ-4 Debris (2005) – UARS / NCO (2007) – Iridium 33 / Cosmos 2251 (2010) – …

NCO: Non-catalogued object

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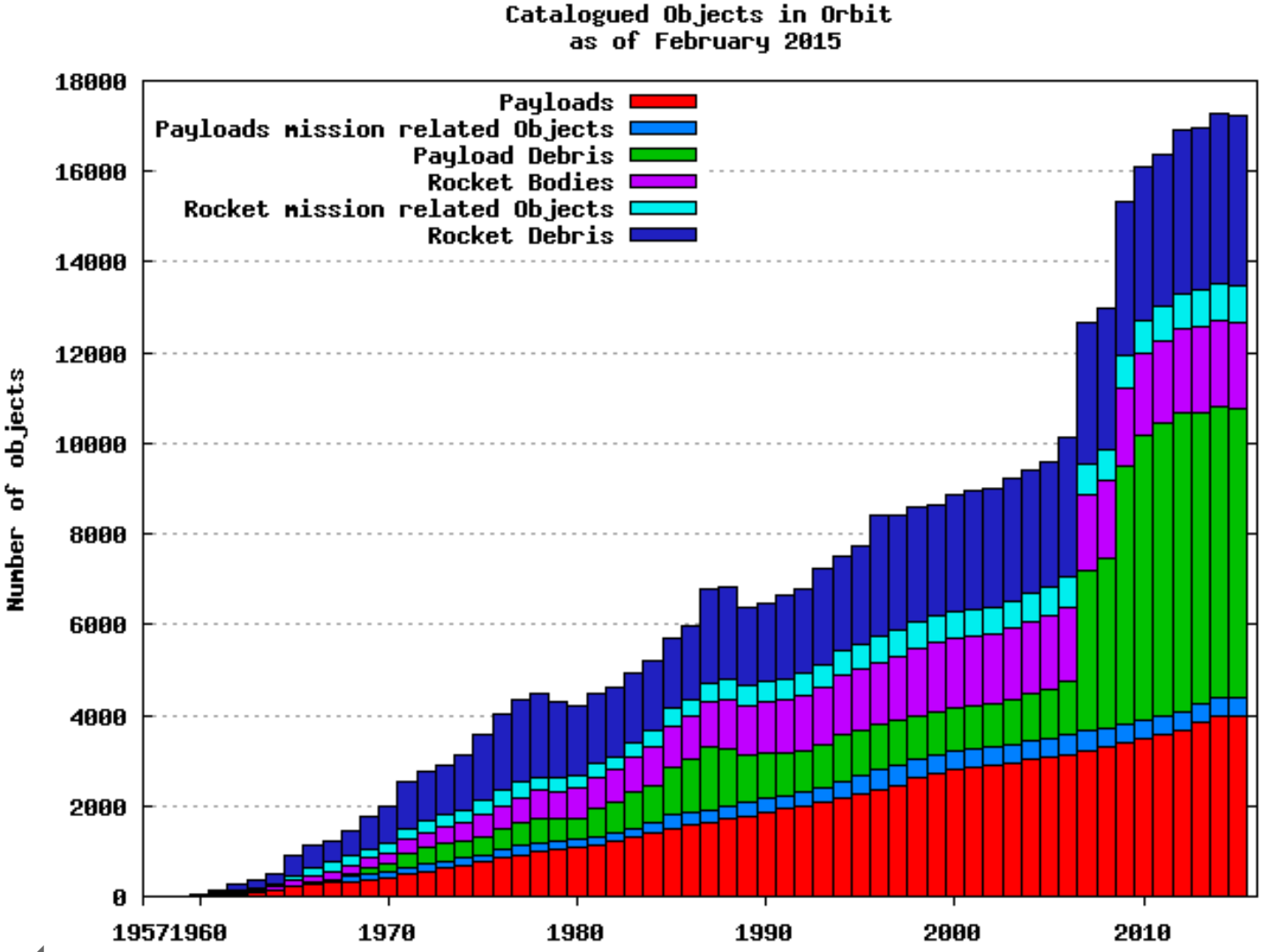
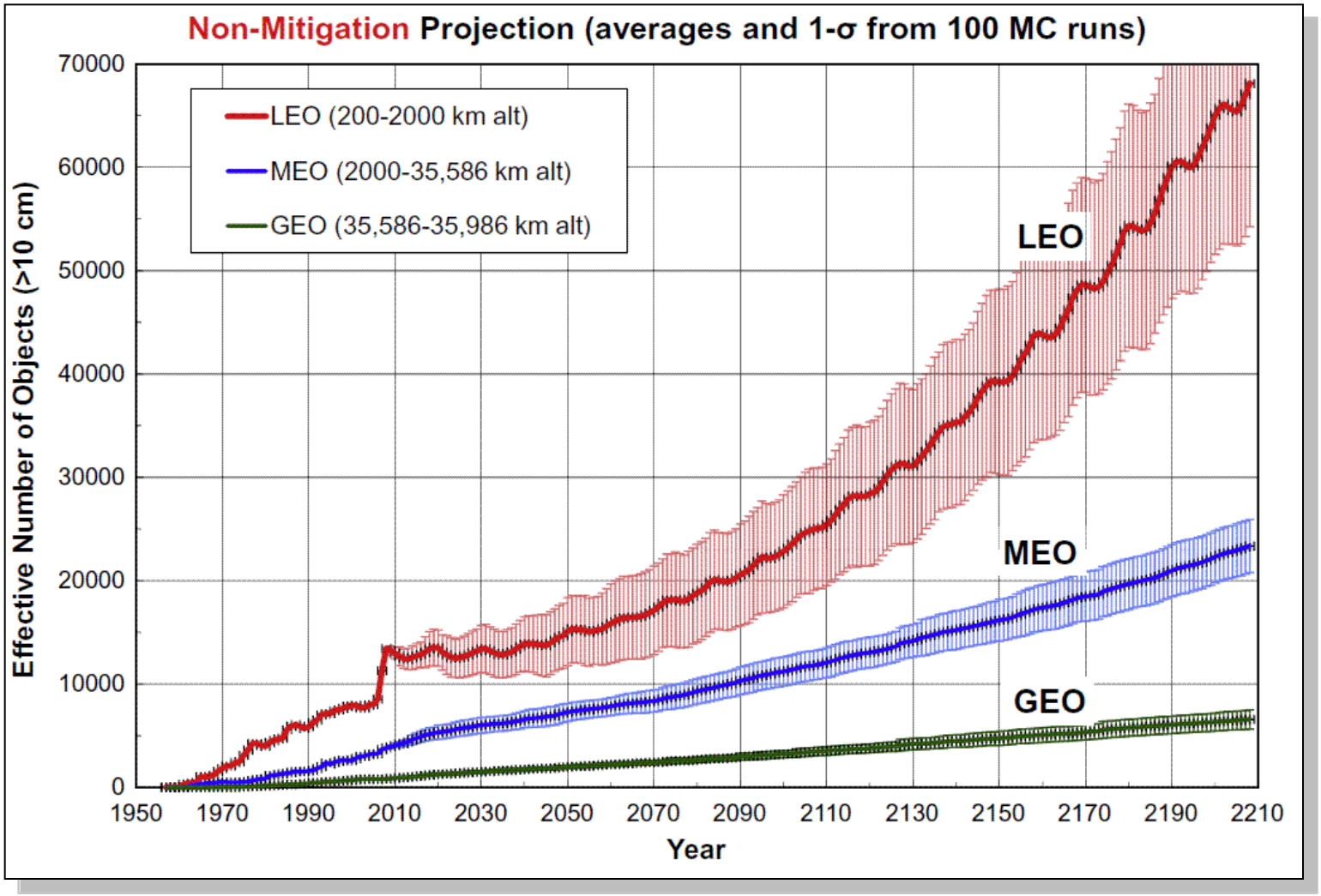
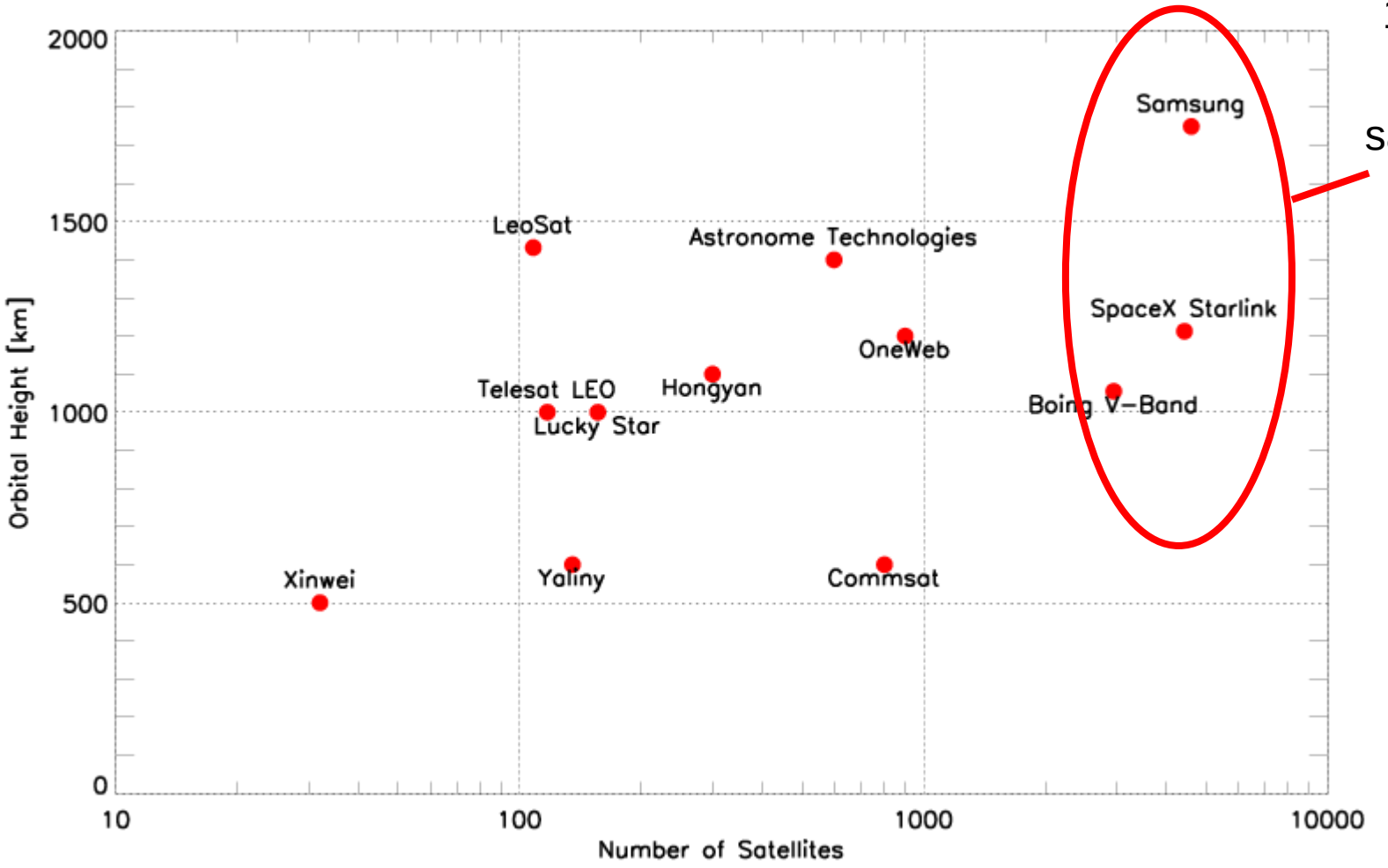
Evolution of Population (Publicly Available Data)



A Possible Future

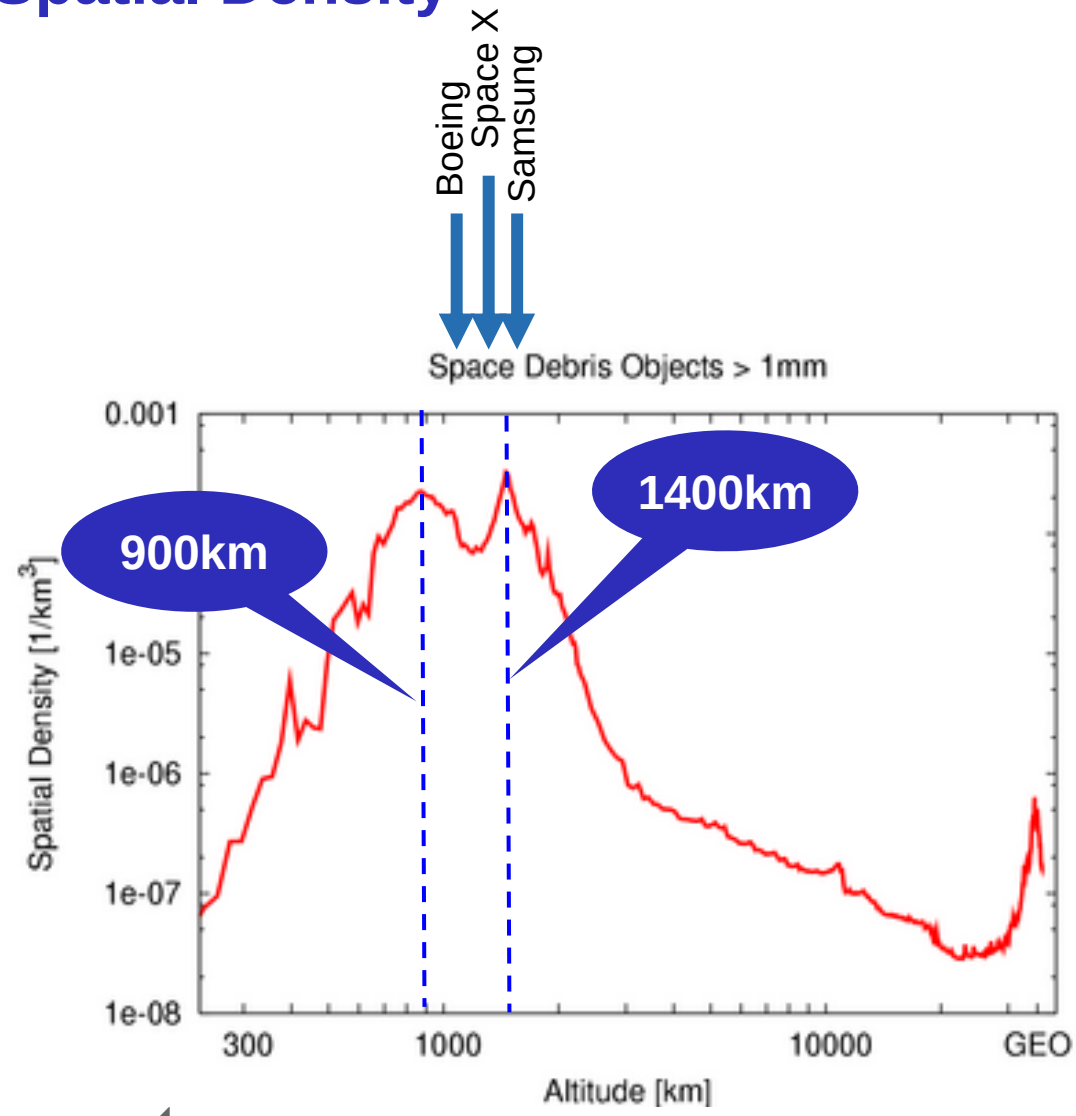


New Players: The Mega-Constellations



12.000 new satellites

Spatial Density



Critical Orbits:

- Sun-synchronous (Earth observation)
- 1400km (low perturbances)
- Geostationary Orbits

→ Protection of favourable orbits strongly necessary!

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Why Do We Care

- **S/C Owners/Operators**
  - Safety of flight
  - Prevent collisions (traffic management, collision avoidance maneuvers)
  - Contingency: cause?
- **S/C designers**
  - Risk analysis
  - Shielding (shields, passive shielding)
  - → spacecraft reliability
- **Mission analysts, launch campaigns**
  - Risk analysis, trajectory optimization, orbit selection
  - Launch conjunction analysis
- **Governments, Space Agencies, Scientists**
  - Protecting vital space services
  - Long term sustainable use of space
  - Evolution

Space Surveillance And Tracking

First Steps:

- Detection, tracking and cataloguing
- International exchange of (raw) data
- Provision of free catalogues with all objects to spacecraft operators

Next Steps:

- Holistic SSA Approach
- Prevent proliferation of space debris (e. g. 25-year guideline)
- Perform collision avoidance (e. g. laser nudging)
- Support active debris removal
- International binding agreements

First Step: Cataloguing

Requirements:

- Extension to smaller sizes (ideally below lethal threshold, i. e. 1-2cm)
- Completeness
- Extremly high accuracy need for “just in time collision avoidance”

Challenges:

- New Space Fence: 200.000-300.000 new objects expected
- Improved algorithms and tracking techniques
- Object identification, object correlation, …
- Better physics models
- Better characteristics of objects for e. g. orbit propagation
- …

SMARTnet™

Small Robotic Telescope Network

Optical Network for Monitoring Geostationary Orbits

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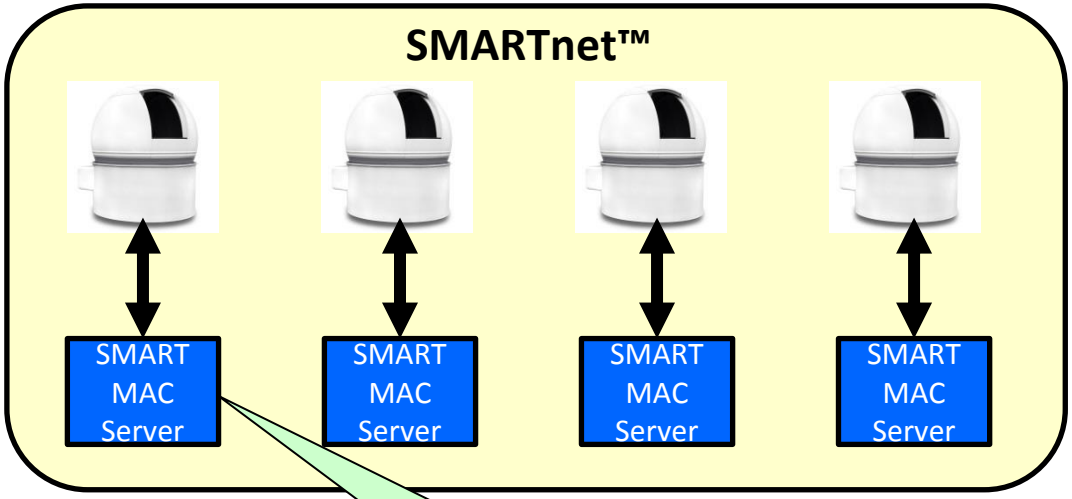
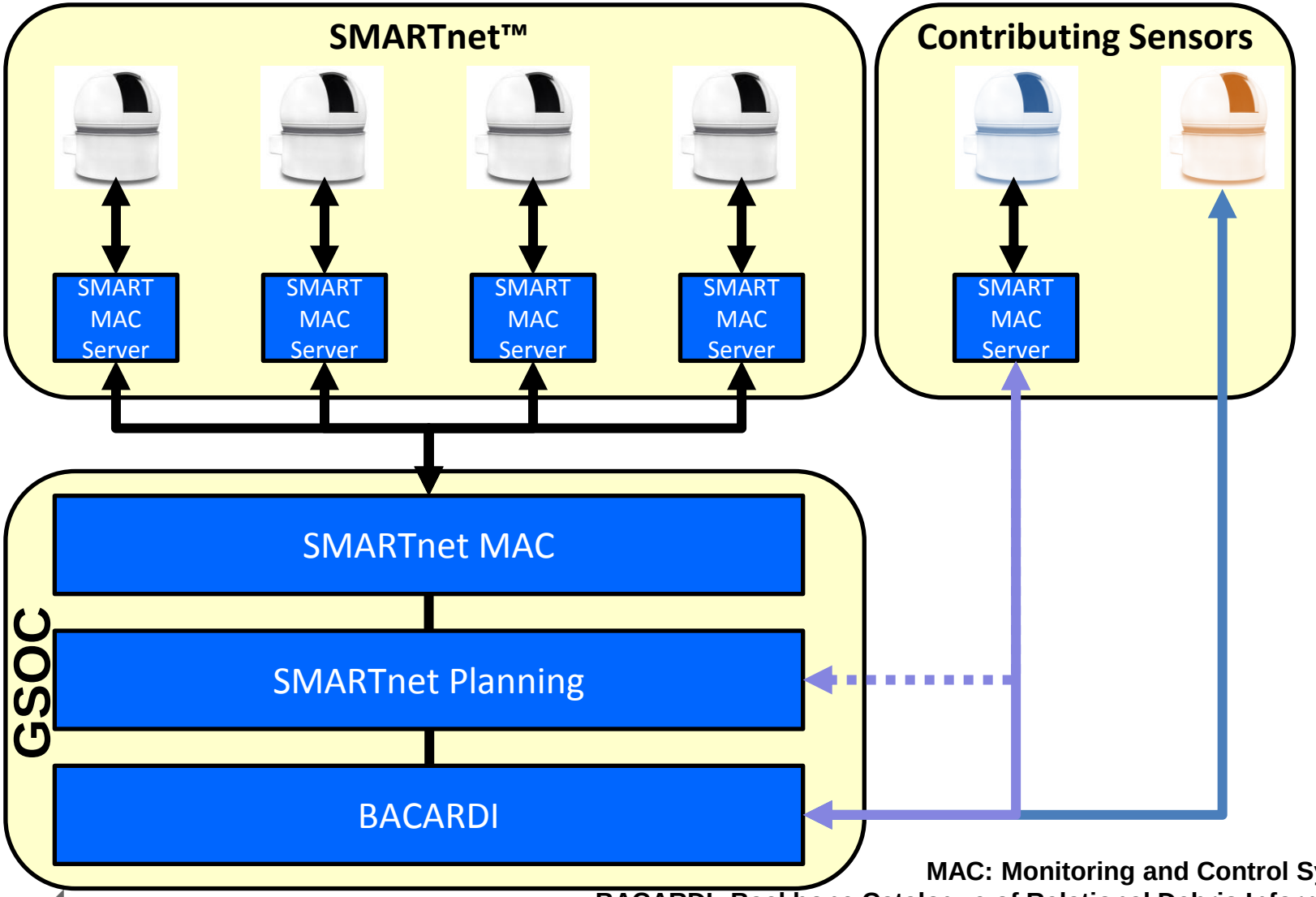
SMARTnet™ Sensor Network



- (almost) autonomous operations
- redundancy concept: 2 of 3 are alive (two computer, one internet connection)
- pre-processing (30GB → 1MB)
- UPS, WebCam, weather monitoring

MAC: Monitoring and Control System
BACARDI: Backbone Catalogue of Relational Debris Information

SMARTnet™ Sensor Network



MAC: Monitoring and Control System
BACARDI: Backbone Catalogue of Relational Debris Information

SMARTnet™ Conditions and Terms (Excerpt)

Partners bring to SMARTnet™

- Sensor, e. g. telescope with minimum aperture size of 20cm
- Year-round operational system
- Tracklets (e. g. pairs of RA/DEC of objects; ITAR free: NO object identification

Partners get from SMARTnet™

- All tracklets for free produced within SMARTnet™ of all contributing sensors
- Free exchange platform
- Support if desired

Do with data

- Develop products (e. g. sell them)
- Research
- Operate satellites safely (in GEO)

RA - DEC: Right Ascension – Declination
Tracklet: Time sequence of measured object positions belonging to the same object

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SMARTnet™ Overview

Zimmerwald: Operational

Partners
(April 2018)

- 1 established partner (US, several sensors)

APPLIED DEFENSE SOLUTIONS

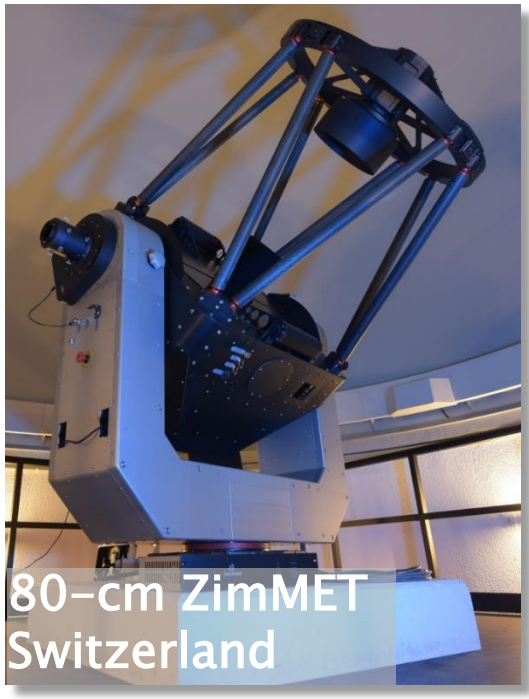
- negotiation with several potential partners

South America: Survey 2018

Sutherland: Operational

Australia: 2018

SMARTnet™ Station: Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald



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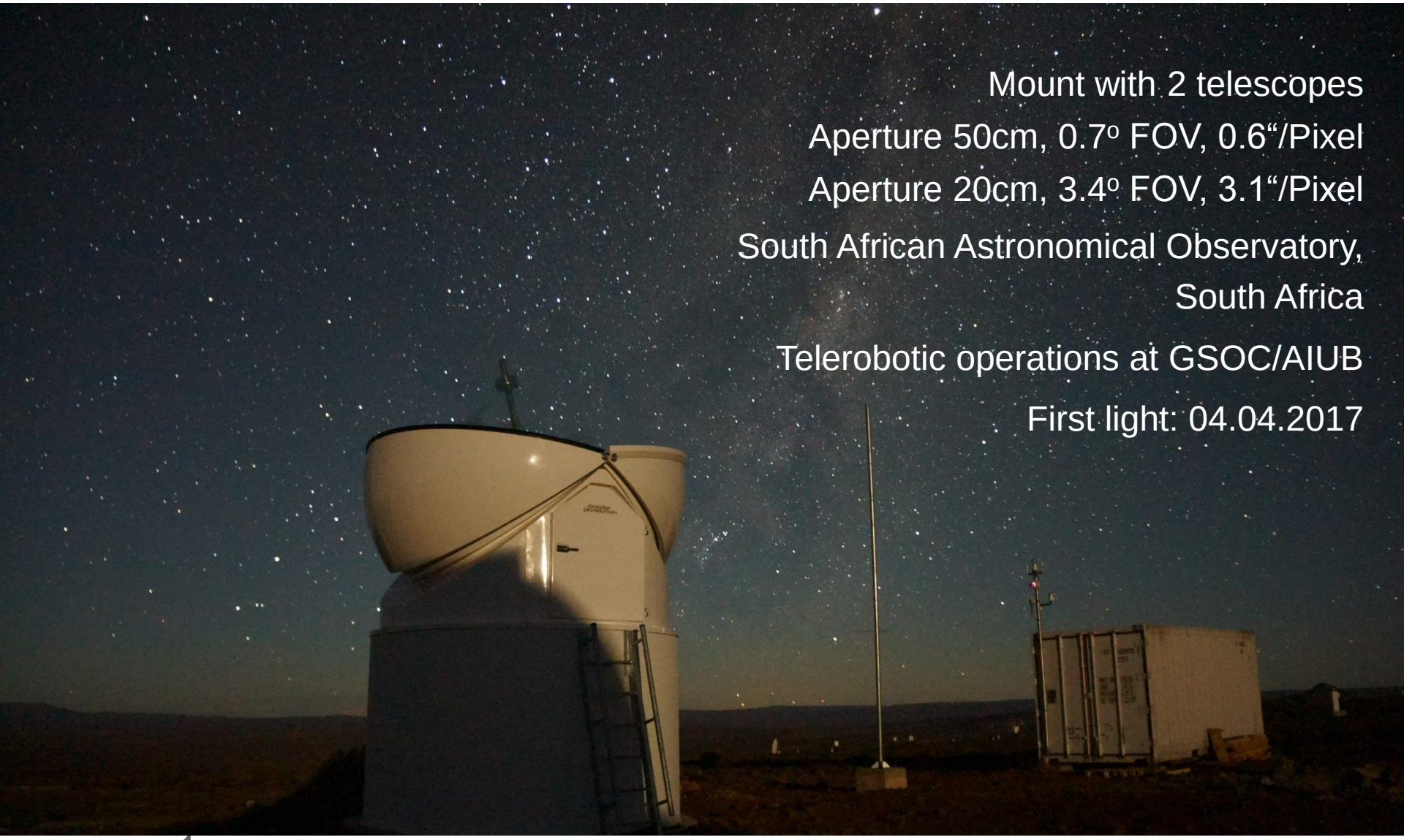
SMARTnet™ Station: SMART-01-SUTH



Mount with 2 telescopes

Aperture 50cm, 0.7° FOV, 0.6“/Pixel

Aperture 20cm, 3.4° FOV, 3.1“/Pixel

South African Astronomical Observatory, South Africa

Telerobotic operations at GSOC/AIUB

First light: 04.04.2017

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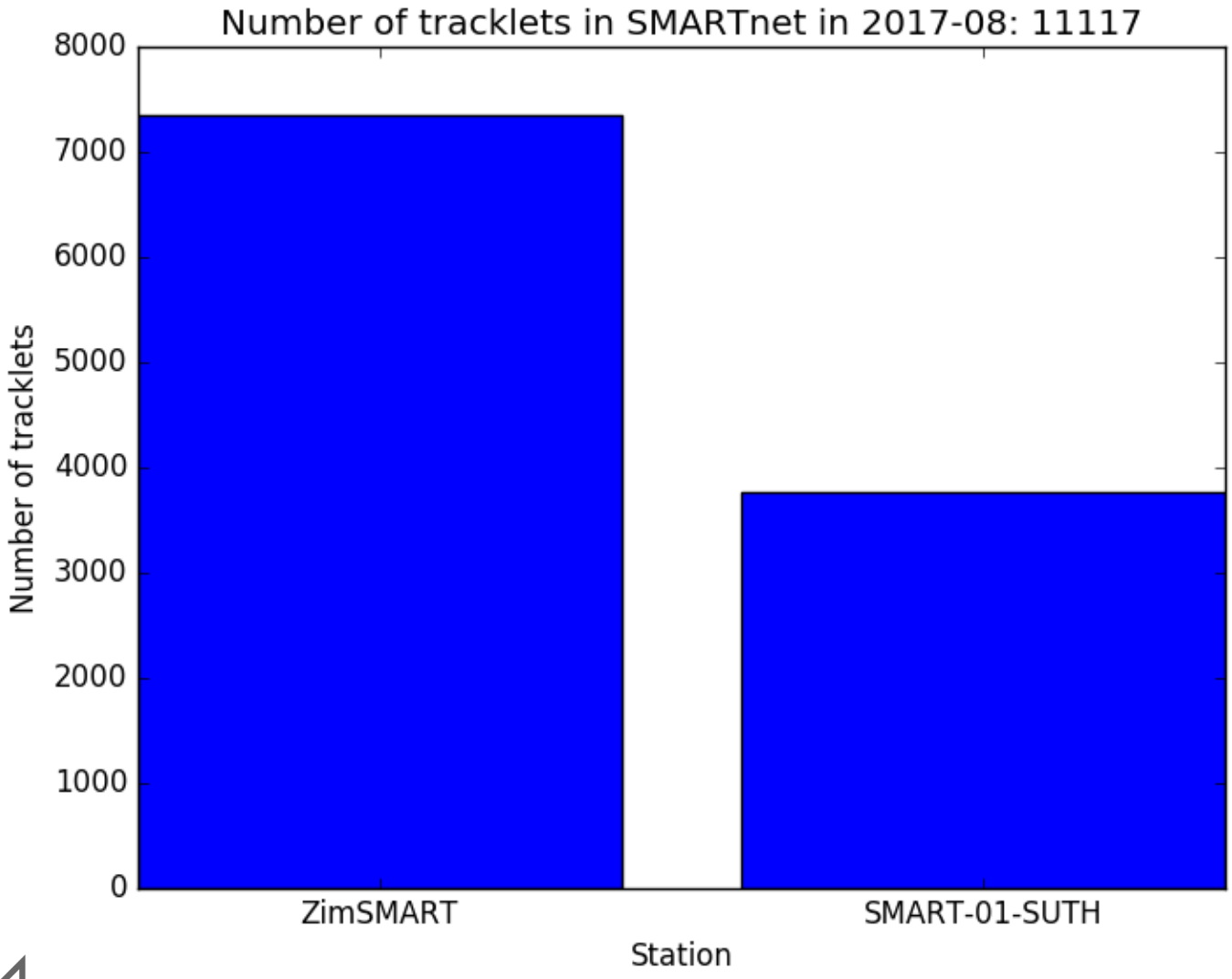
SMARTnet™: Monthly Bulletin Example – Tracklets I



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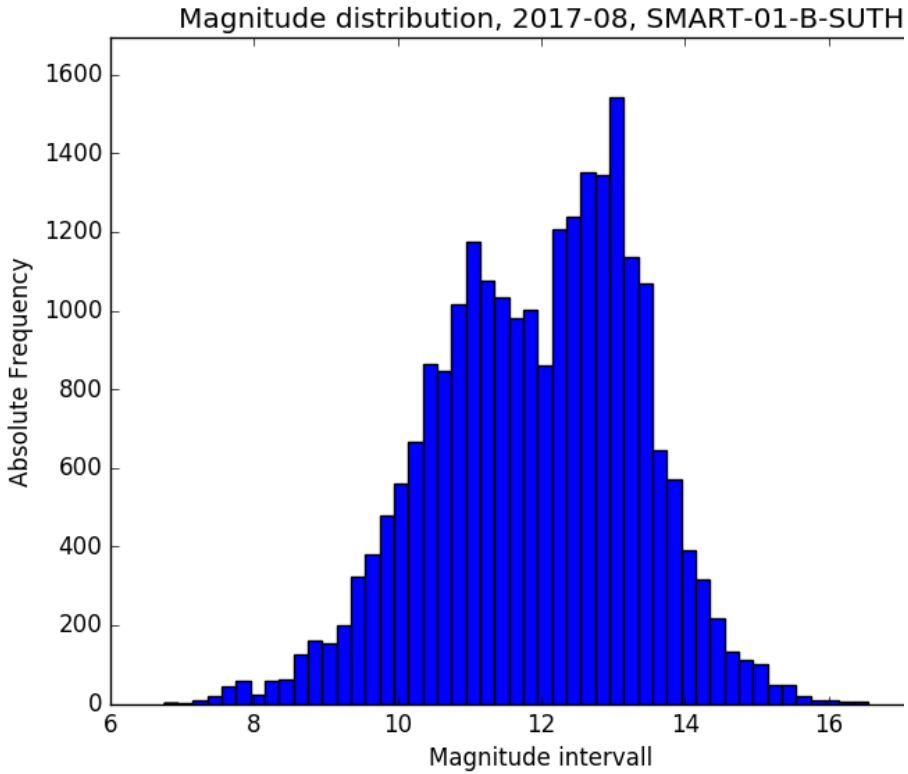
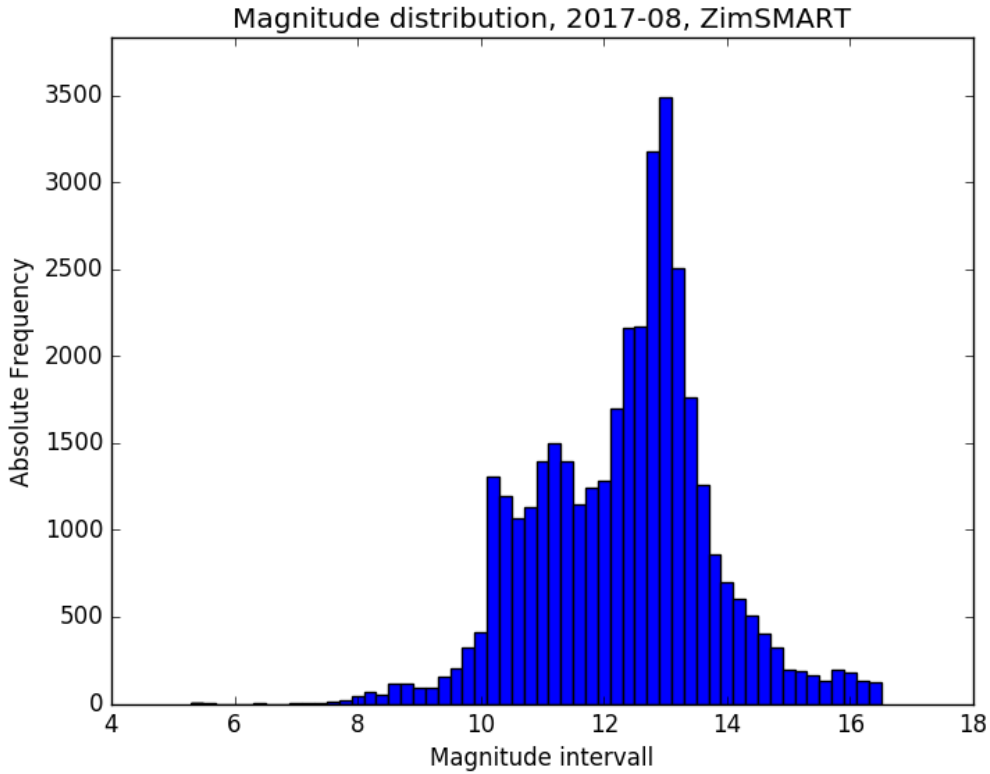
SMARTnet™: Monthly Bulletin Example – Tracklets II

20 cm SMART-01 at Sutherland



20 cm SMART-01 at Zimmerwald



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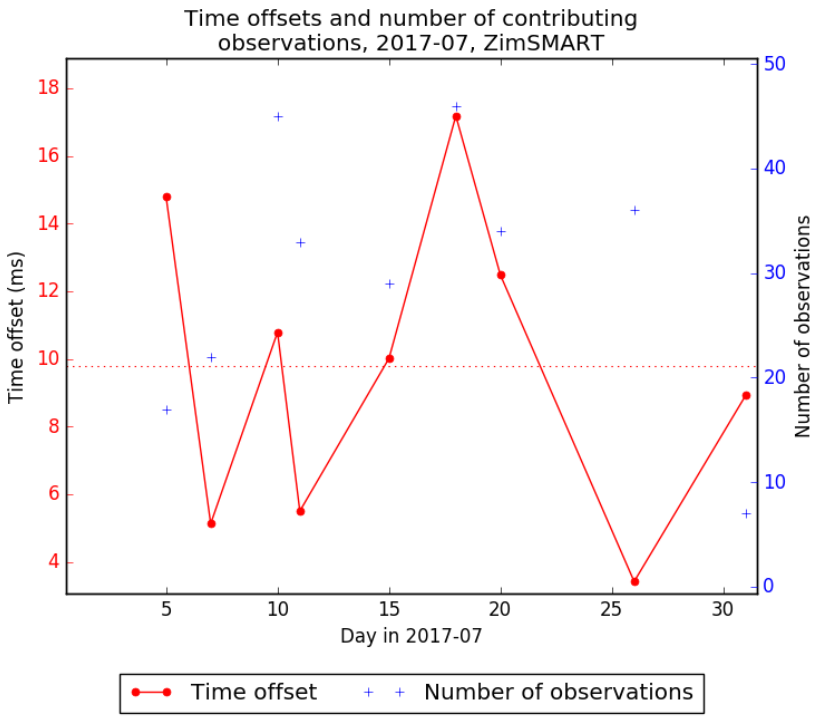
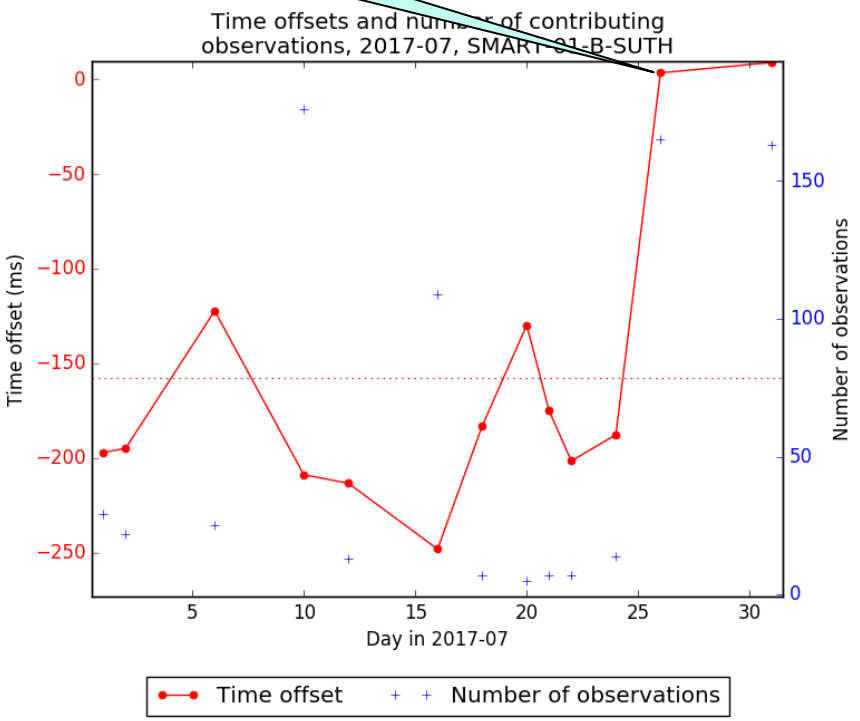
SMARTnet™: Monthly Bulletin Example – Calibration

Time Calibration





20 cm SMART-01 at Zimmerwald

20 cm SMART-01 at Sutherland

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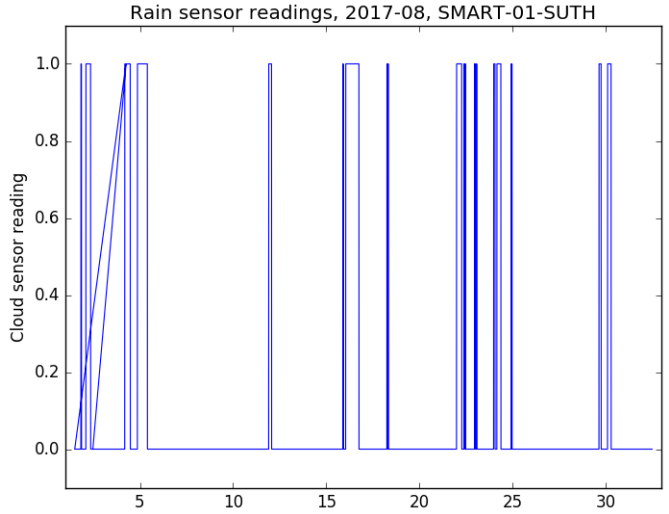
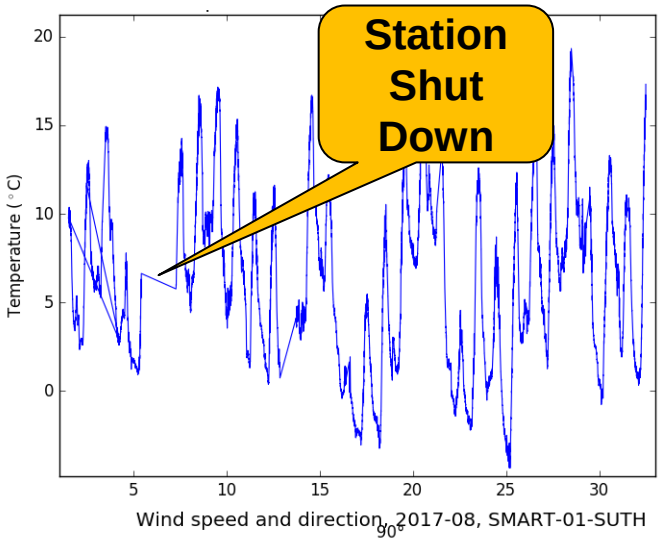
SMARTnet™: Monthly Bulletin Example – Weather Information

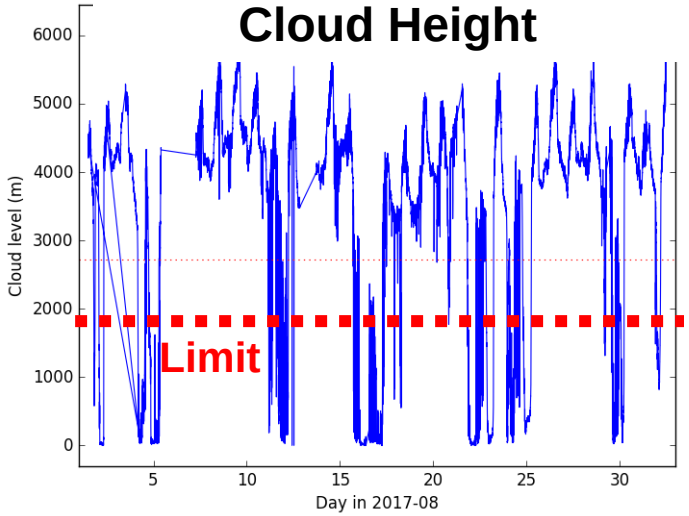
Rain



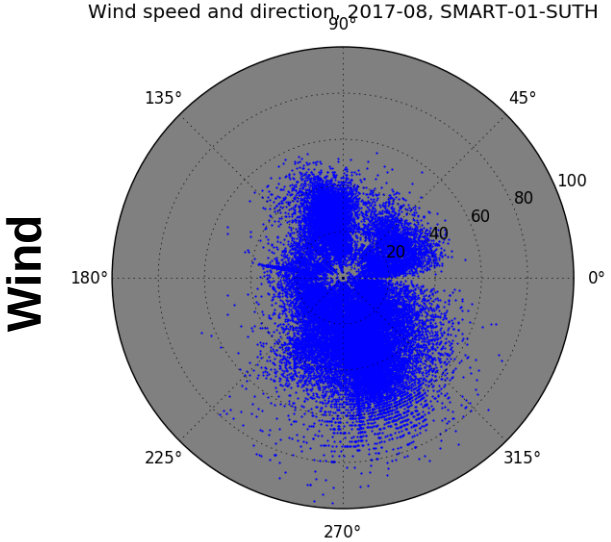
Temperature



Cloud Height



Wind



Space Debris Research

Population

- How many?
- Size distribution?
- Orbit regions?
- Nature of objects?
- Sources, sinks?

Physics / Mechanisms

- Creation of new debris
- Evolution of orbits
- Long-term evolution
- …

Challenges

Correlation
- Tracklet-tracklet association
- Tracklet-orbit association

Orbit
- Initial orbit determination
- Orbit Propagation
- Uncertainty propagation
- Maneuver estimation

Data Fusion
- Radar, Optical, Laser

Observation
- Optimized observation strategy
- Survey / follow-up
- Multiple station concept

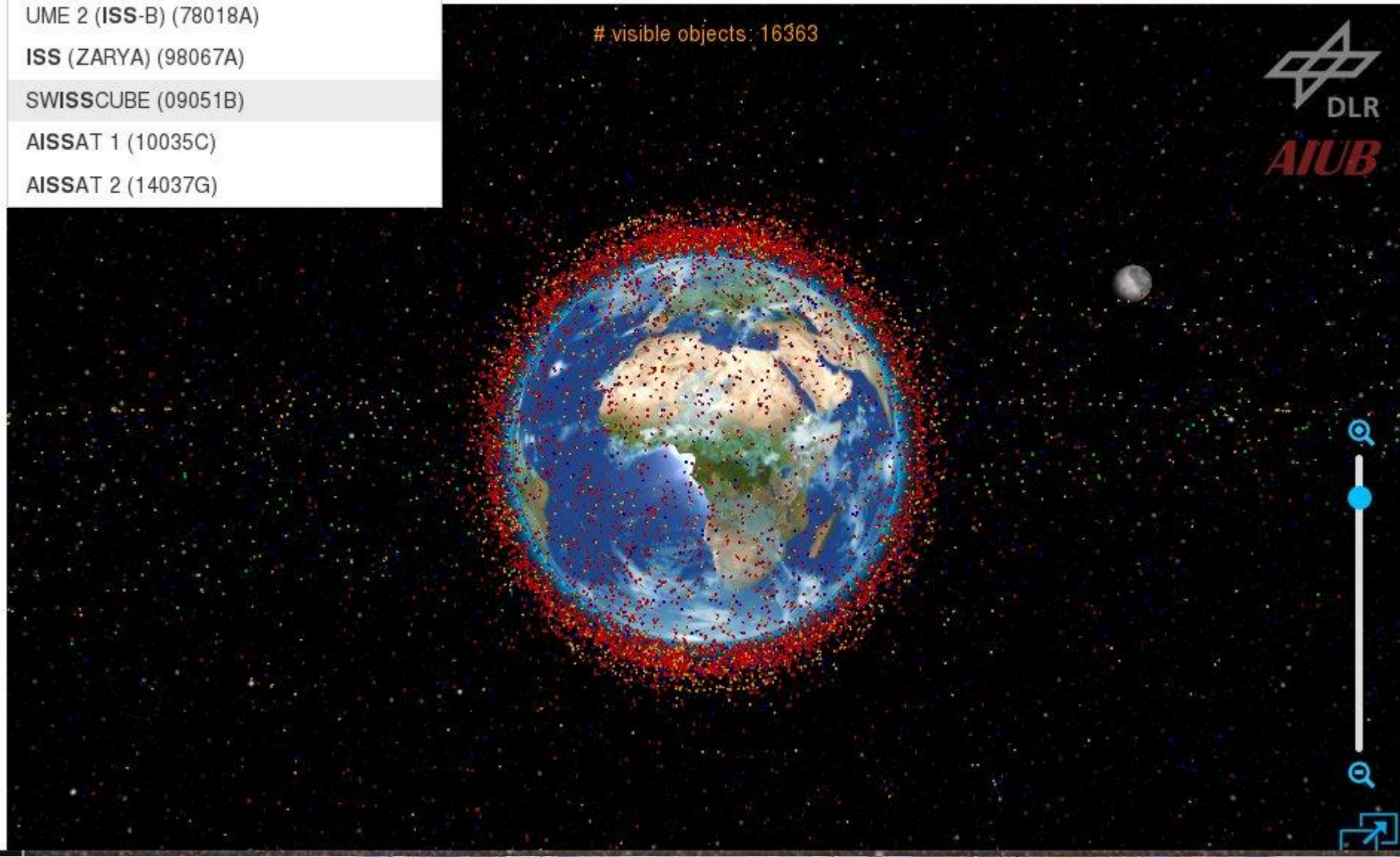
Physical Characterization
- Size, shape, area-to-mass-ratio, material

BACARDI:
Backbone Catalogue of
Relational Debris Information

Bacardi Viewer

SWISSCUBE (09051B)

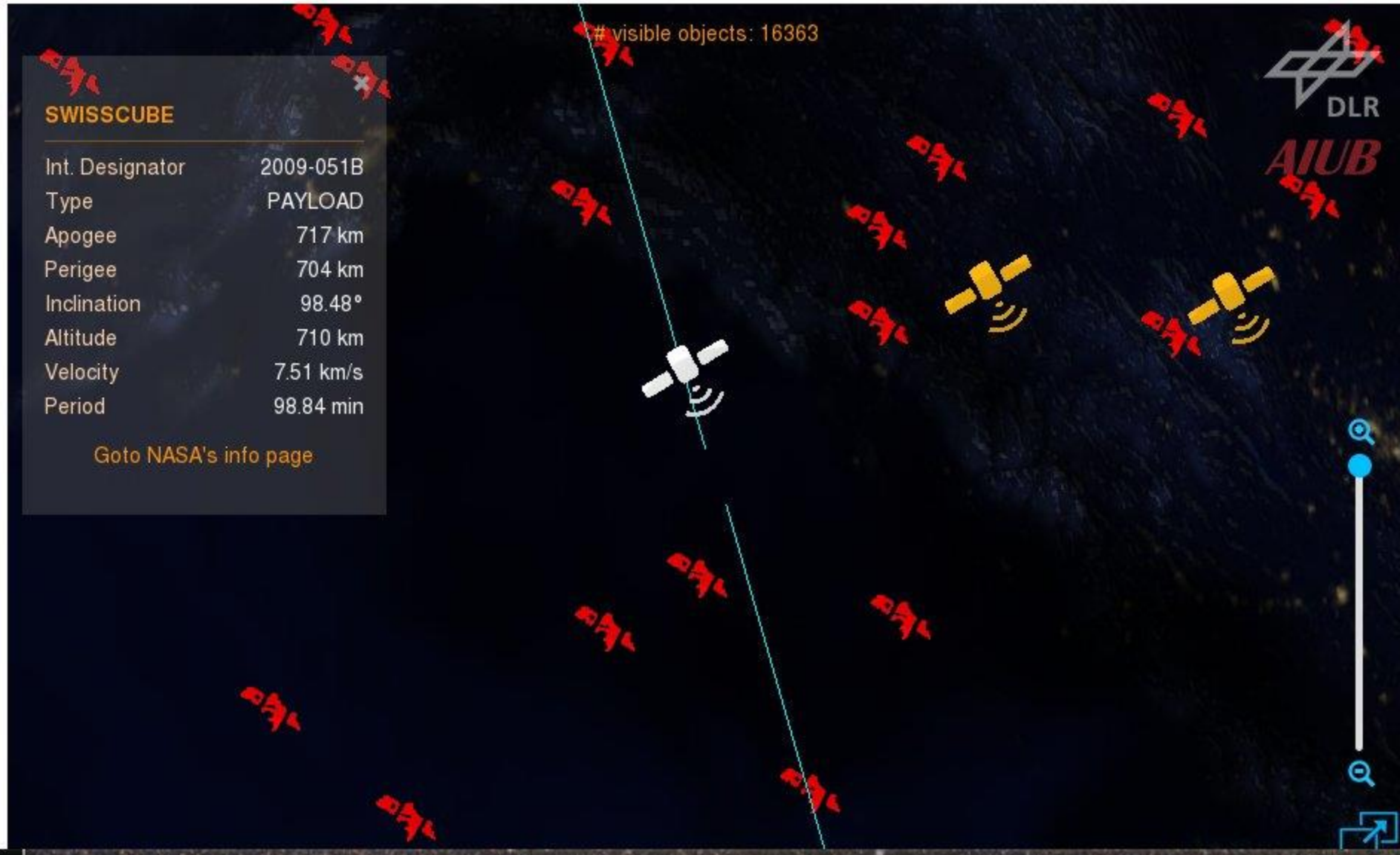
- UME 1 (**ISS** 1) (76019A)
- UME 2 (**ISS**-B) (78018A)
- **ISS** (ZARYA) (98067A)
- SW**ISS**CUBE (09051B)
- **AISS**AT 1 (10035C)
- **AISS**AT 2 (14037G)

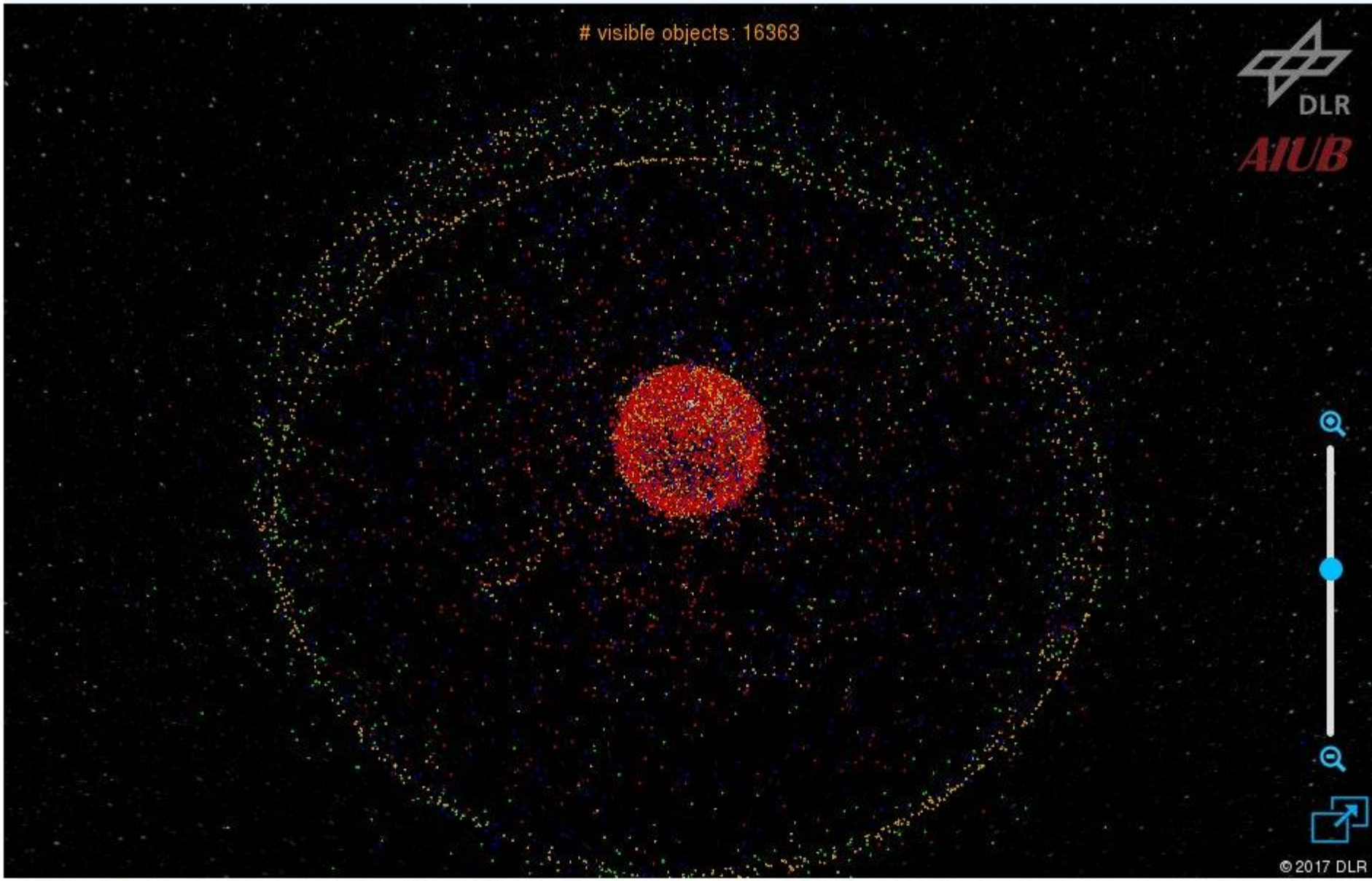


Bacardi Viewer

Search

Show Filters

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min-max (1990-2010)
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Payload/Satellites
Rocket Bodies
Debris
SMARTnet™
visible objects: 16363
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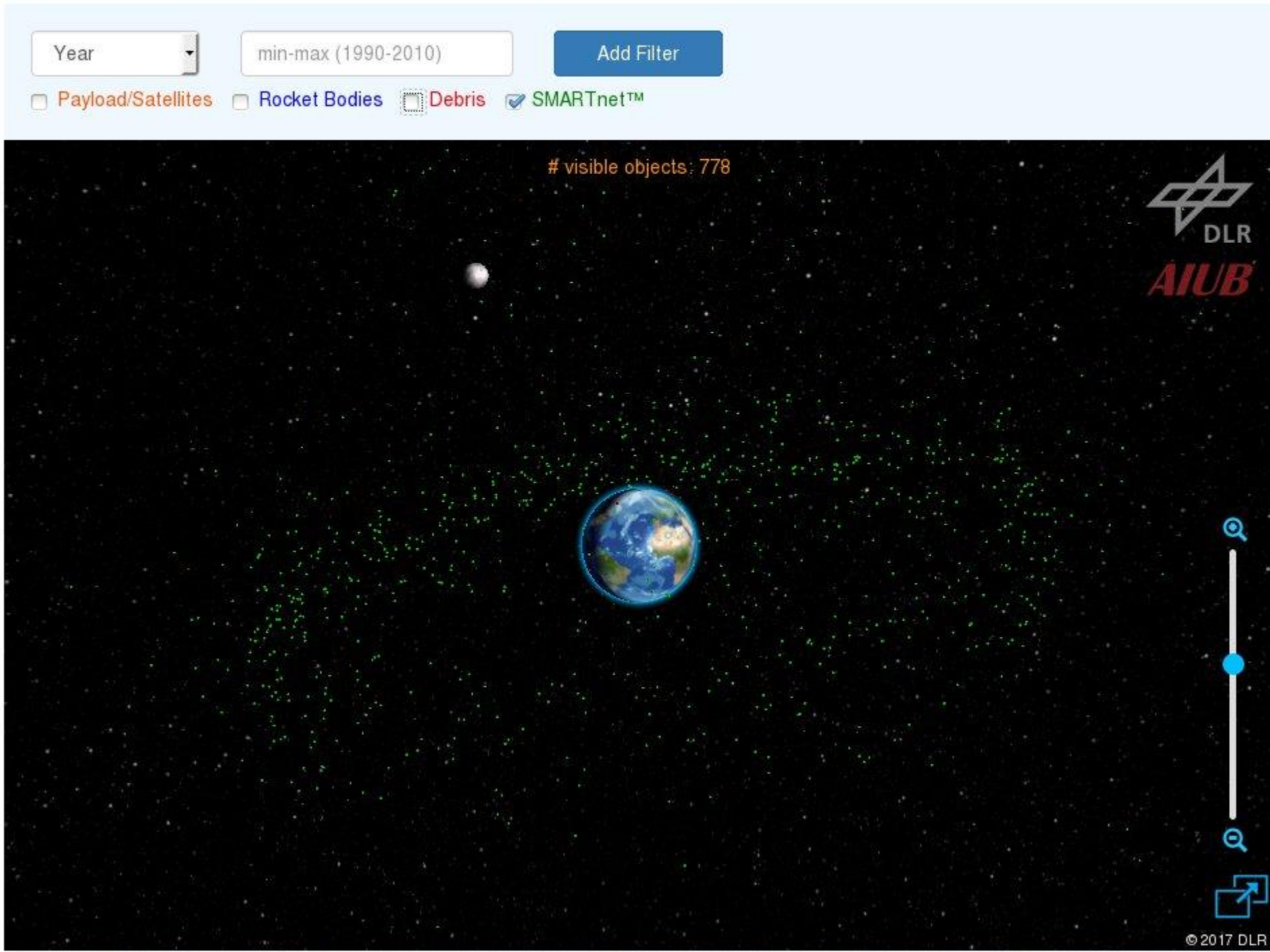
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min-max (1990-2010)
Add Filter
Payload/Satellites
Rocket Bodies
Debris
SMARTnet™
visible objects: 778
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Conclusion

- **Near-Earth space becomes more and more congested**
- **Hollistic approach is required**
  - Need to include data from trusted sources: government, commercial, academia, …
  - Exchange of sensor raw data, observations: verification, traceability, transparence
  - Data sharing standards / mechanisms required
  - Development of algorithms to cope with massive data volumes (multi-sensor, data fusion, …)
- **Change of paradigms needed**
  - Hiding in space is not anymore an option (during peace times)
  - Abandon classification
- **“Open source SSA“:**
  - SMARTnet™ as example of a civil, non-commercial sensor network

Thank you for your attention

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