Swiss Contributions to a Better Understanding of the Space Debris Environment

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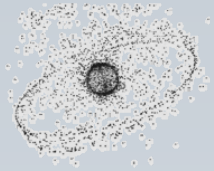
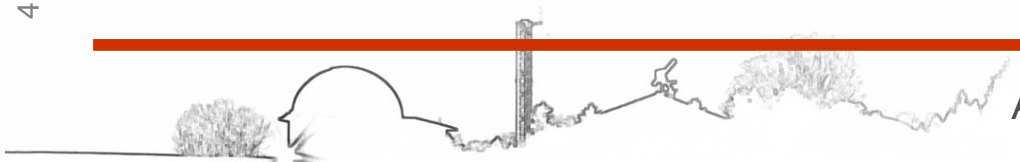
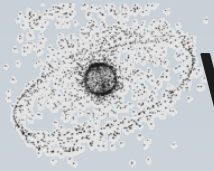


Outline

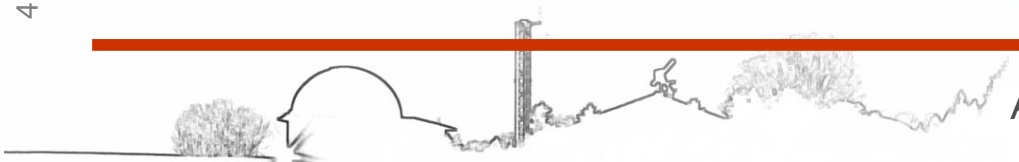
1. Why a Better Understanding
2. Swiss Space Debris Research
3. Scientific Highlights
4. International Collaboration
5. Summary

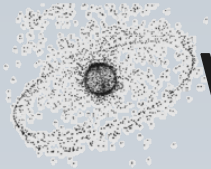




Why do we Need a Better Understanding?

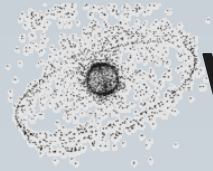
- Knowledge regarding the space debris environment required to
  - Assess threads (e.g. risk to spacecraft)
  - Design protection measures (e.g. shields)
  - Provide the scientific rationale to devise efficient mitigation/remediation measures enabling sustainable outer space activities





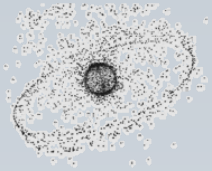
Why do we Need a Better Understanding?

- **Open Questions**
  - Population
    - how many?
    - size distribution?
    - orbit regions?
    - nature of objects?
    - sources, sinks?
  - Physics/Mechanisms
    - creation
    - evolution of orbits
- **Space debris research provides information on environment through**
  - Extending the catalogues of "known" space objects towards smaller sizes (deterministic population)
    → enable active collision avoidance (safety of operations)



Why do we Need a Better Understanding?

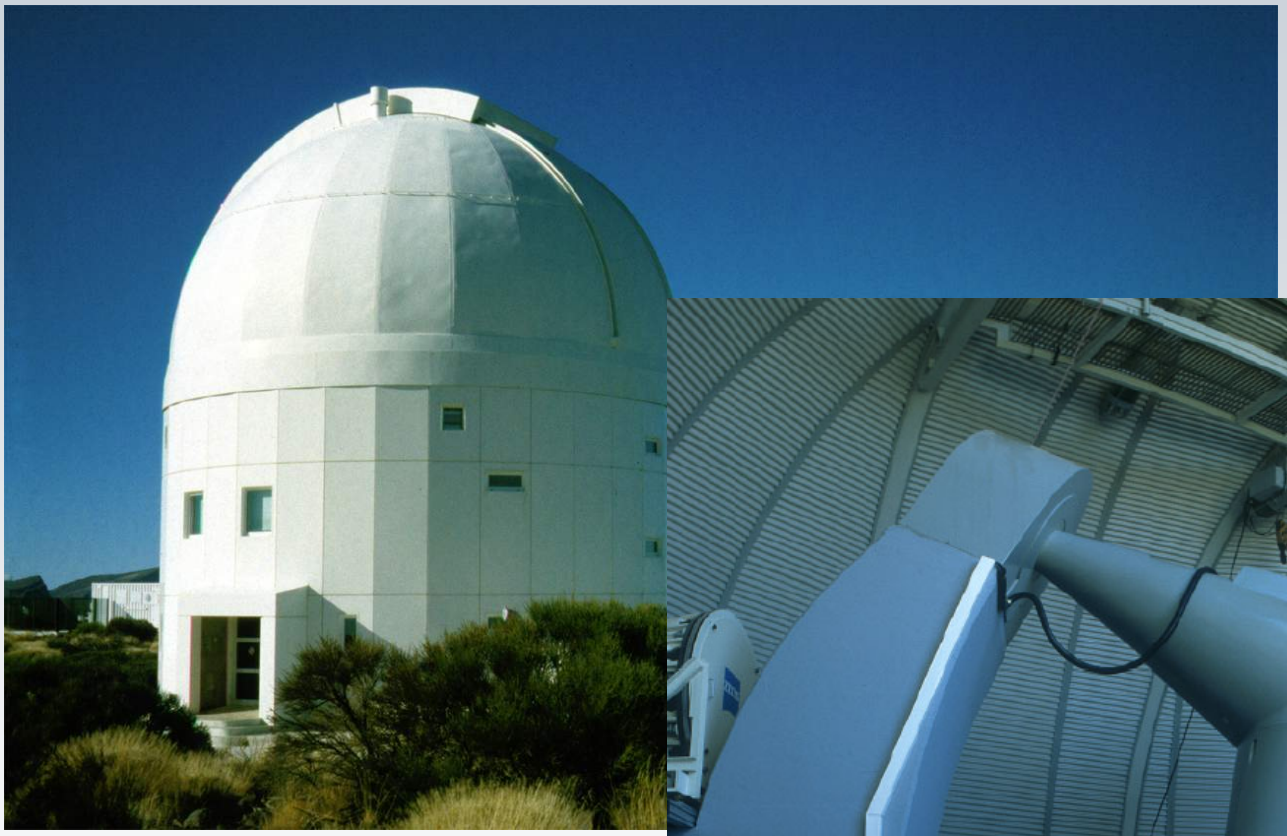
- Space debris research provides information on environment through (cont.)
  - Acquiring statistical orbit information on small-size objects in support of statistical environment models
    → statistical risk analysis (e.g. mission analysis, shielding, etc.)
    → input data for long-term evolution models
    → identification of debris sources
      - progenitors of debris clouds (breakup events)
      - disintegrations of spacecraft due to aging processes
  - Long-term monitoring of environment
    → identification of new sources
    → verification of evolution models
  - Characterizing objects
    → identification of (new) sources

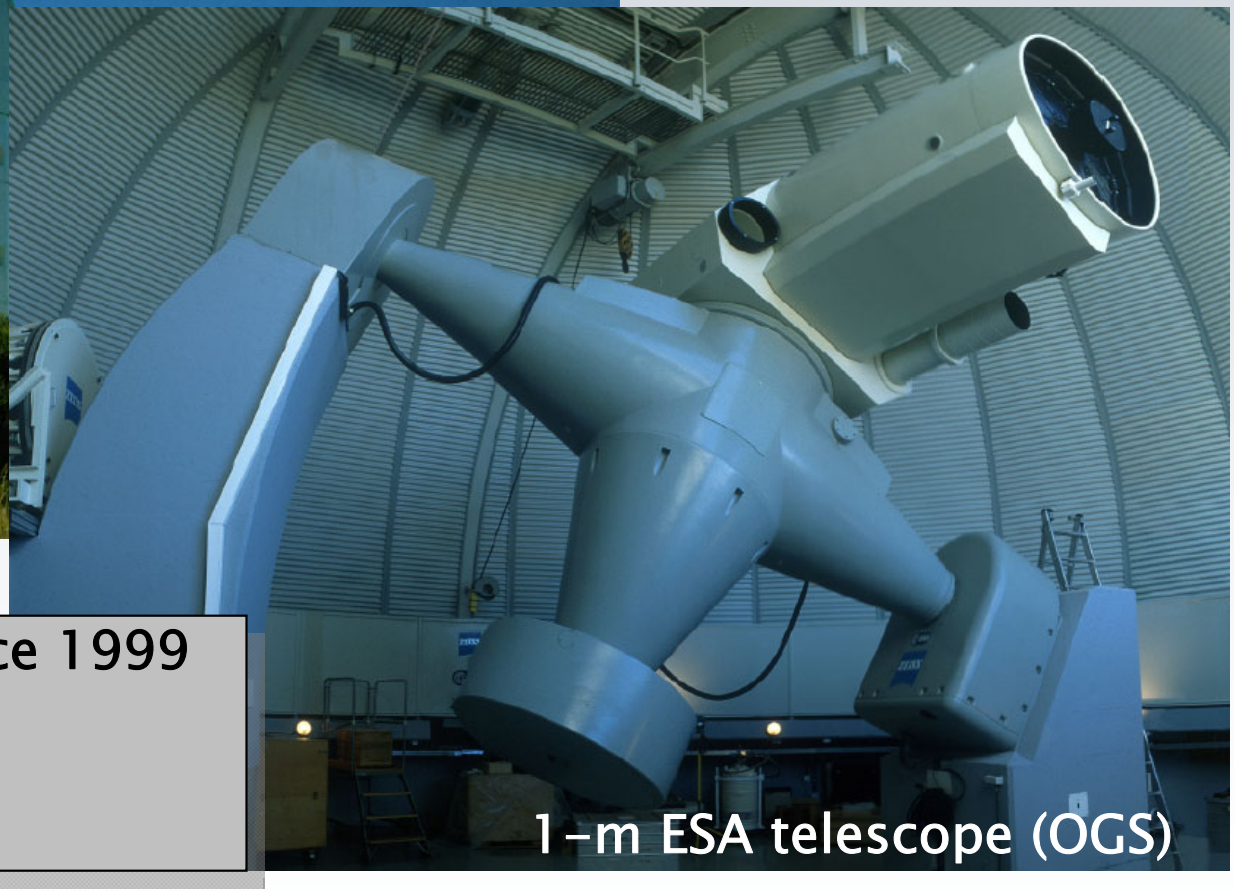


Swiss Space Debris Research

- Observation of artificial satellites at AIUB's Zimmerwald observatory since 45 years
- Essential contribution to the ESA space debris observation program trough
  - software development for the ESA space debris telescope
    - *planning, data acquisition, processing, 1992–*
  - observations programs (on behalf of ESA)
    - *Geostationary Orbit Objects Survey, 1998–*
    - *Geostationary Transfer Orbit Survey, 2001–*
    - *MEO Surveys*, 2008–
    - *Spectroscopic Measurements of GEO objects*, 2008–
- Space debris cataloguing and characterization with AIUB's sensors in Zimmerwald

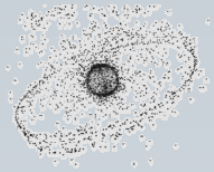
Surveys at the ESA 1-m Telescope, Tenerife





1-m ESA telescope (OGS)

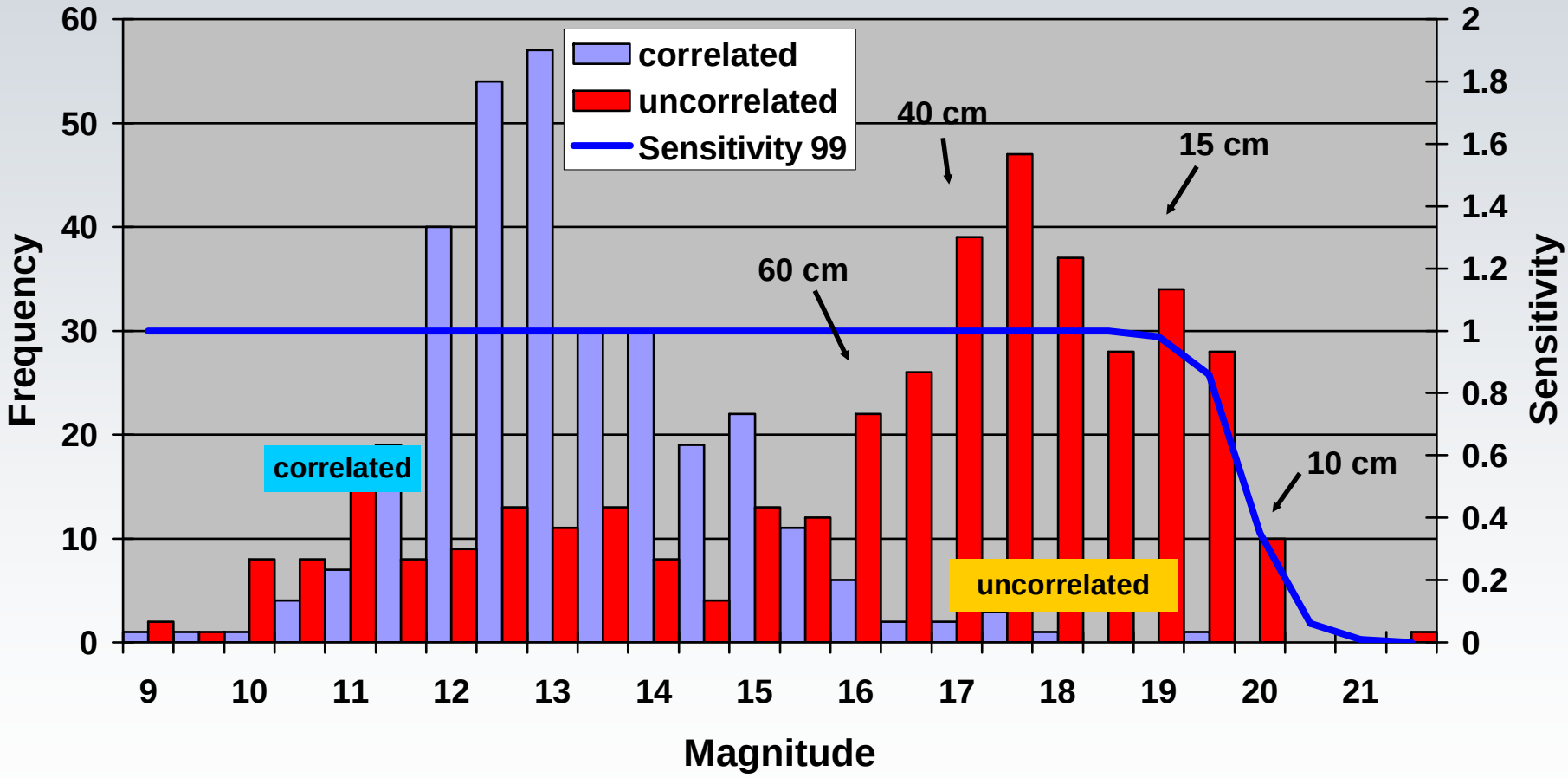
Continuous program since 1999
10-12 nights/month
operated by AIUB



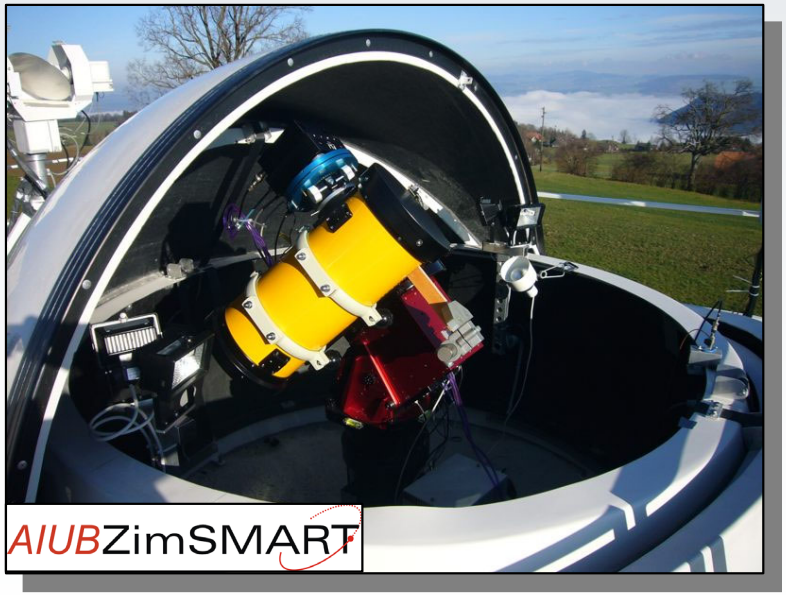
Key Scientific Results (several “firsts”)

- Longest and most sensitive observations of the GEO/GTO regime
  - Discovery of small-sized (dm) debris
    ➔ sensors with most significant contribution for objects < 0.4m in IADC GEO campaigns
  - >10 years of continuous monitoring
    ➔ clusters of debris in orbital element space discovered, evolution studied
  - Input data for ESA MASTER environment model: introduction of "artificial" breakup events in order to model the observed clusters of debris in the 0.2 to 1m size range
- Discovery of "new" (i.e. previously unknown) population of high area-to-mass (AMR) ratio objects
- First spectra of high area-to-mass (AMR) ratio objects

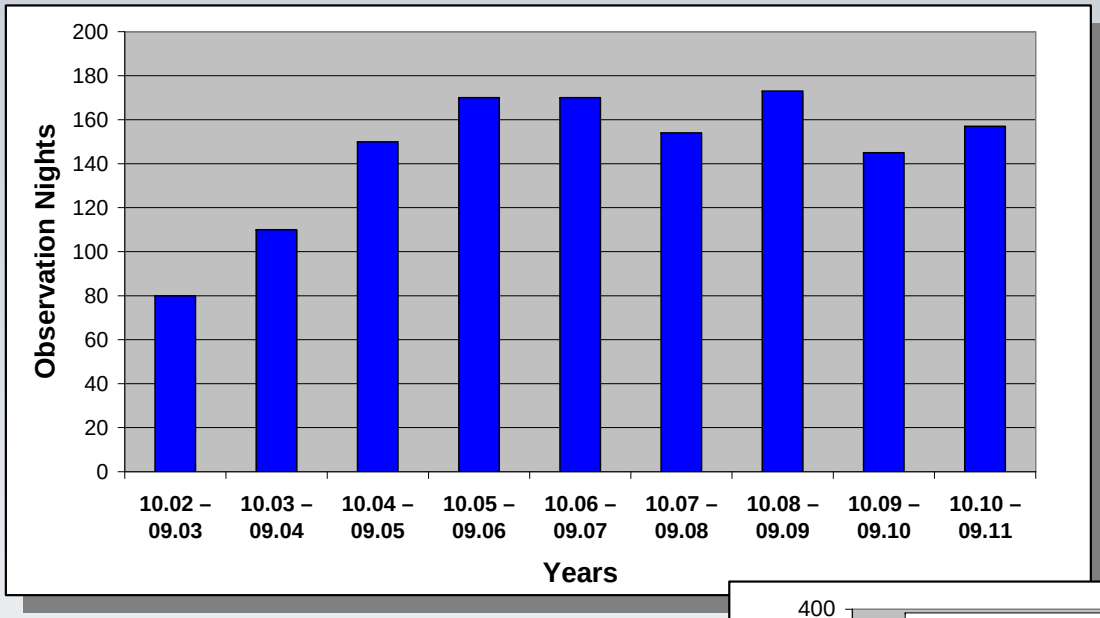
Small-Sized Fragments in GEO (example)



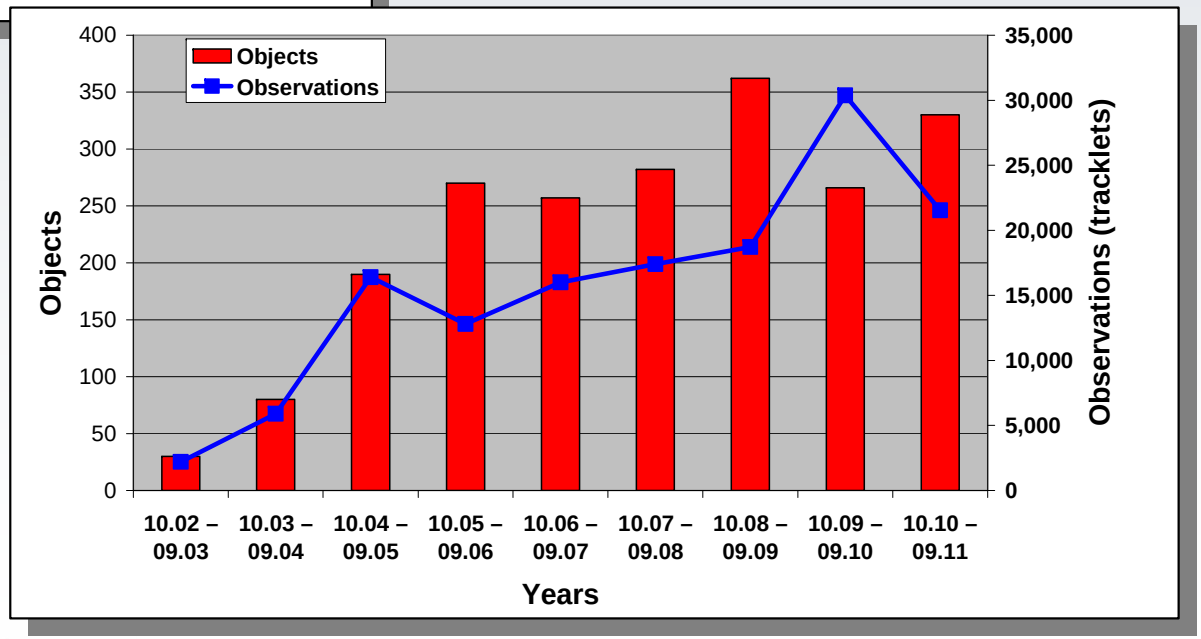
Contributing Swiss Sensors



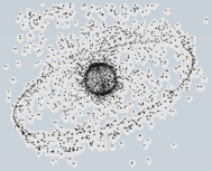
“Routine”, Continuous Operation



ZIMLAT
Observation Nights



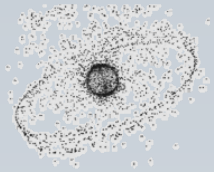
ZIMLAT
Observations / Objects



Catalogue of Small-Size Space Debris

- Build-up and maintenance of orbit catalogue of decimeter-sized debris in GEO (AIUB)
- Why?
  - Density/collision risk lower than in LEO
    BUT:
    No sinks → population constantly grows
  → Mitigation of debris is important
- Need to know nature and sources of debris

  Requires:
  - Orbit catalogue
  - Constant monitoring due to perturbations by non-gravitational forces

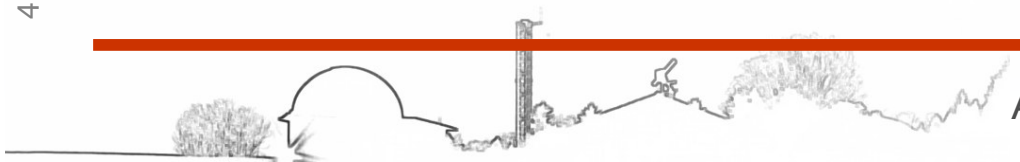


Networking is Essential

- Discover new objects: Obs. From Tenerife (OGS, AIUB)
- Secure orbits: obs. from OGS, Zimmerwald (AIUB)
- Maintain orbits: obs. from OGS, Zimmerwald, international partners, International Scientific Optical observation Network (ISON), …
  - Daily orbit maintenance at AIUB and Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM)

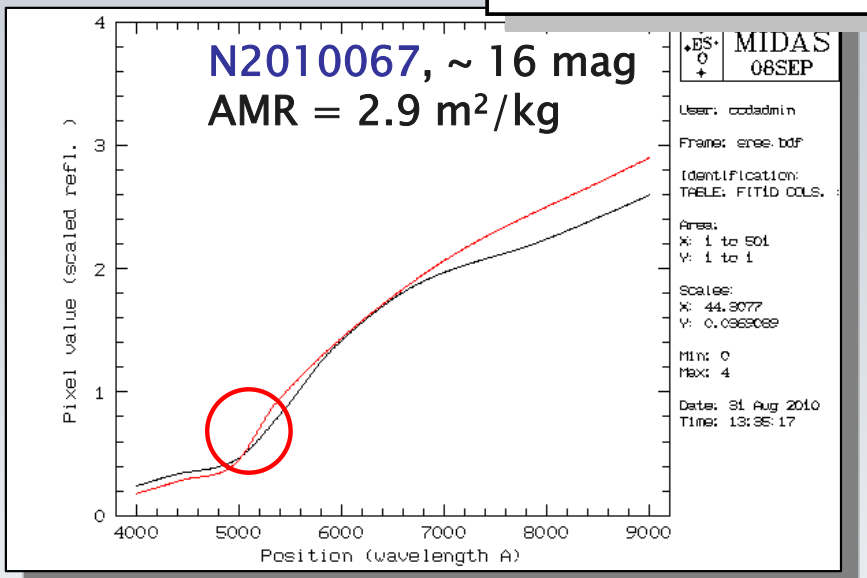
  → Orbit catalogue of high-altitude space debris

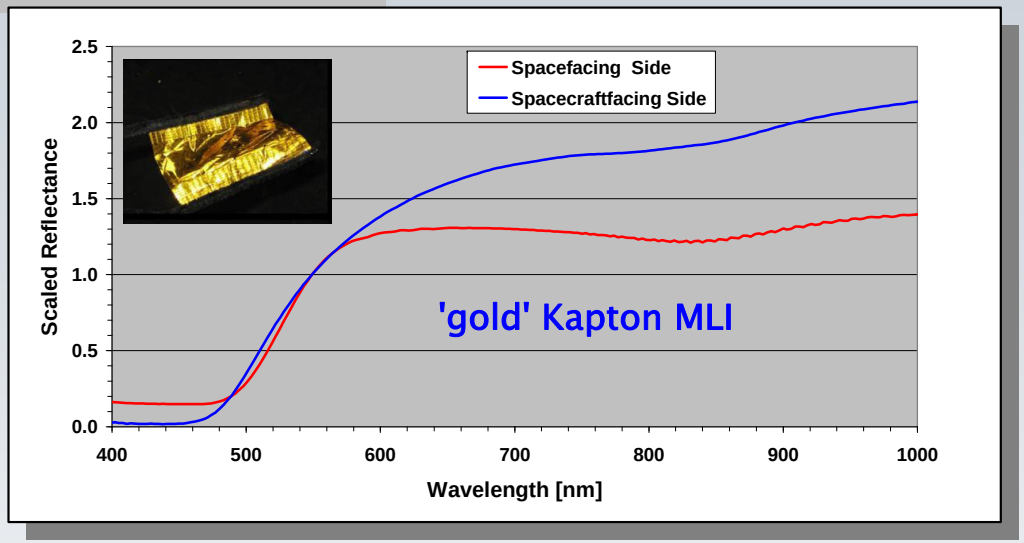
- Provide data:
  - To other partners (ESA, CNES, JAXA, NASA, Roscosmos…)
  - → to investigate physical properties of objects

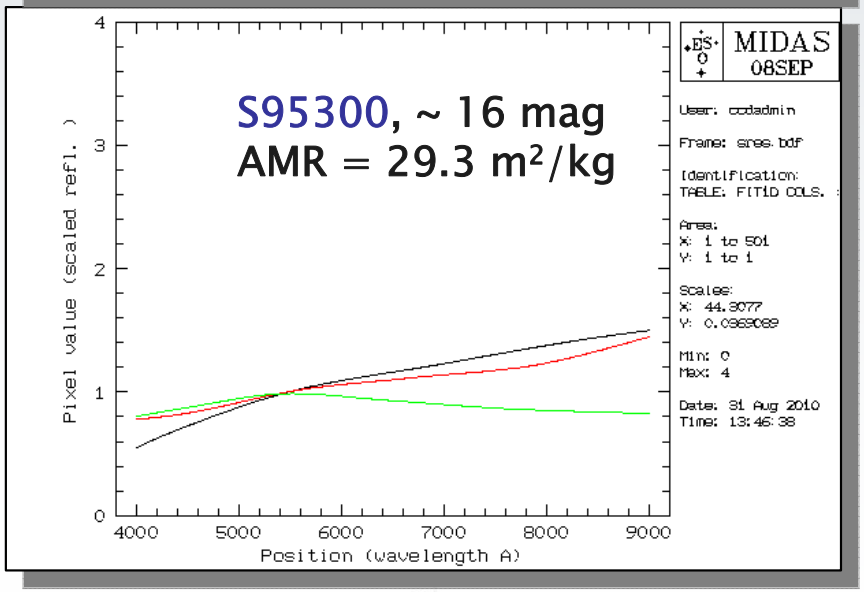


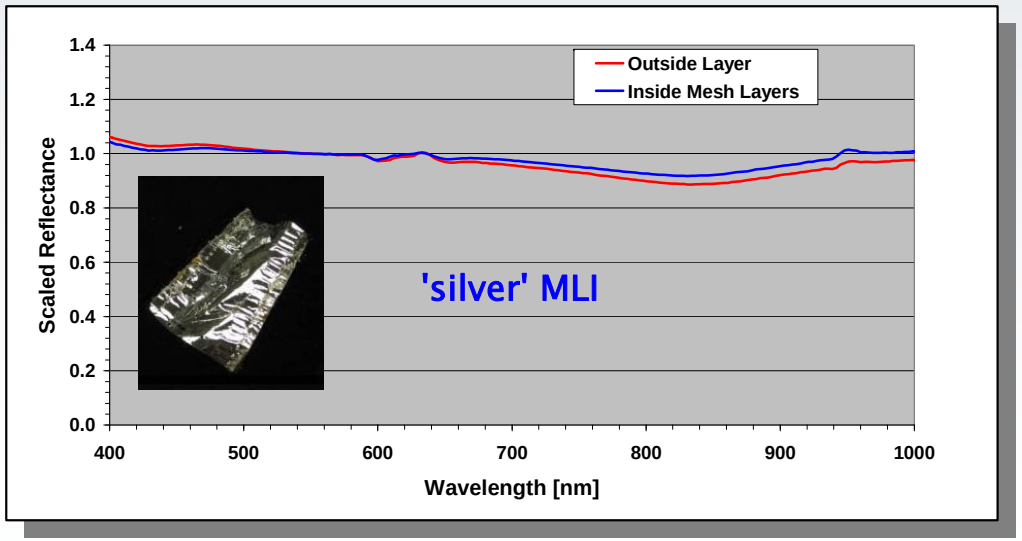
Characterization – Spektrophotometrie

Comparison with Lab Spectra

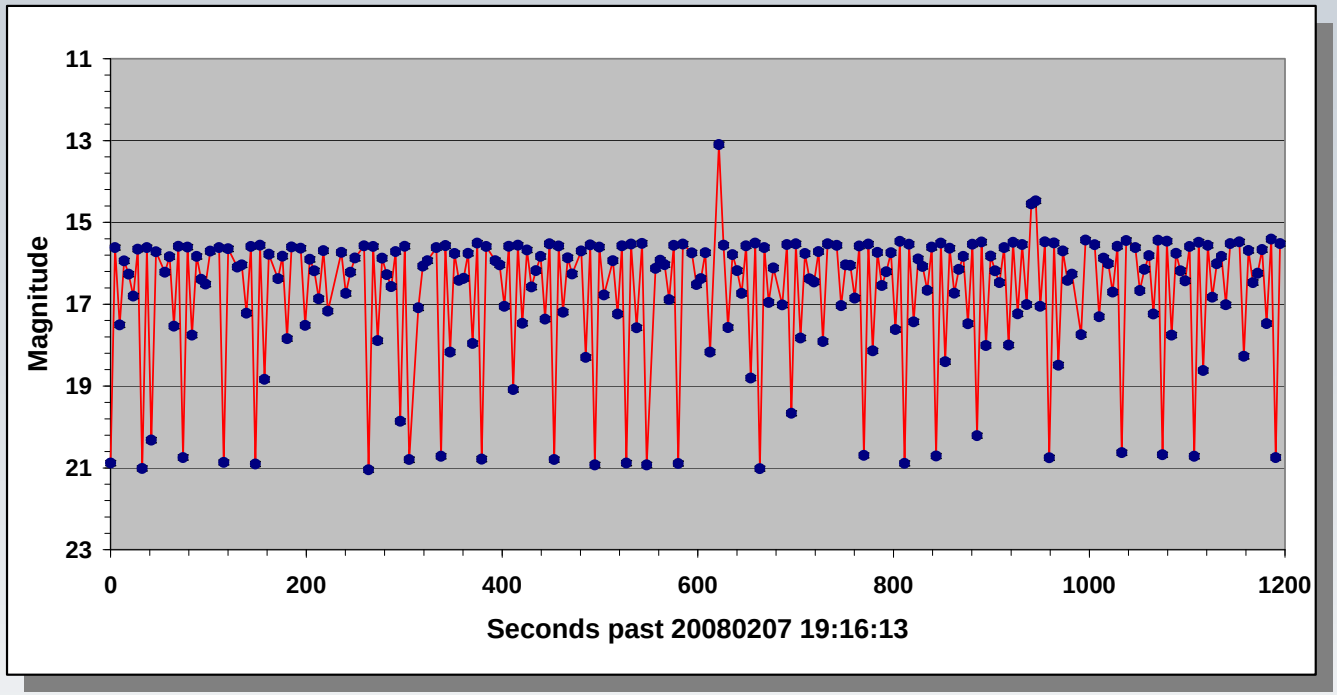


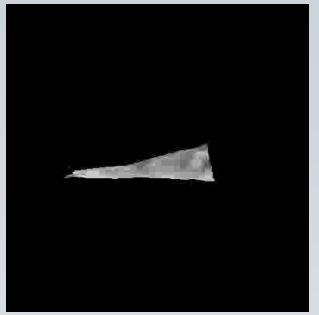


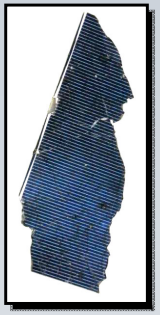


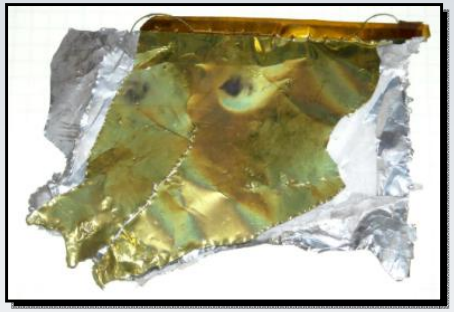


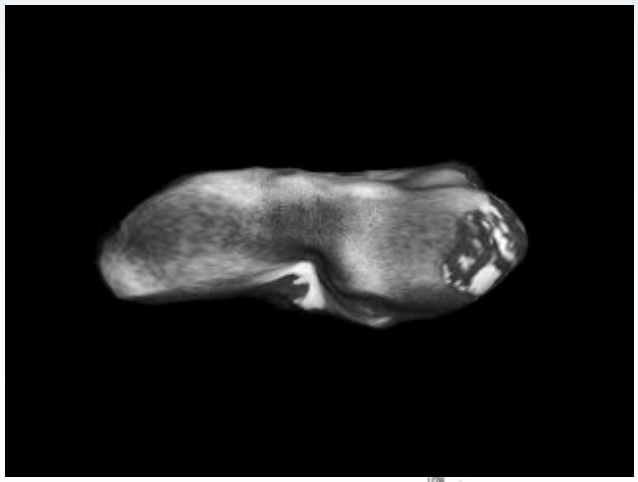
Characterization – Light Curves



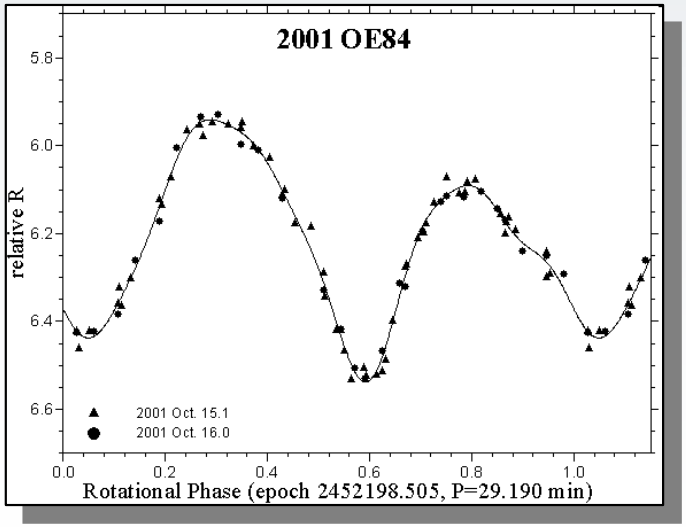






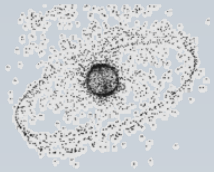


- **rotation period**
- **spin axis, shape**
- ZIMLAT



International Collaboration

- Active participation in the Inter-Agency Space Coordination Committee (IADC) by
  - exchanging information on space debris research
  - organizing cooperative observation campaigns
  - providing measurements
  - providing orbit predictions
  - author is WG-1 “measurements” chair
- Fostering international collaboration trough bi- and multilateral scientific cooperation
  - partner of Int. Scientific Optical Network ISON
  - scientific collaboration with Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM)
  - cooperative observations with ESA, BNSC, NASA, JAXA and other space agencies
  - operational support for ESA

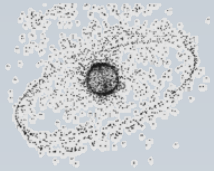


Summary

20 years of Space Debris Research in Switzerland

- **Optical survey techniques**
  - Algorithms (detection, survey scenarios)
- **Observations**
  - 14 years of space debris surveys at OGS for ESA
  - Operational, continuous, highly automated observation programs using the Zimmerwald sensors
- **Orbit Catalogues**
  - Orbit determination techniques/software
  - Build-up and maintenance of space debris catalogue (GEO/GTO)
  - International collaboration
- **Physical Characterization**
  - area-to-mass ratio from orbital evolution
  - sizes from photometry
  - shapes from light curves
  - materials from color photometry, spectra

→ Scientific basis for sustainable use of outer space



Thank you for your attention!

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