IADC Observation Campaigns

43rd Session of
UNCOPUOS S&T SC

IADC Organization

- Membership: space agencies of China, ESA, France, Germany, India, Italy, Japan, Russia, Ukraine, the United Kingdom, and the United States

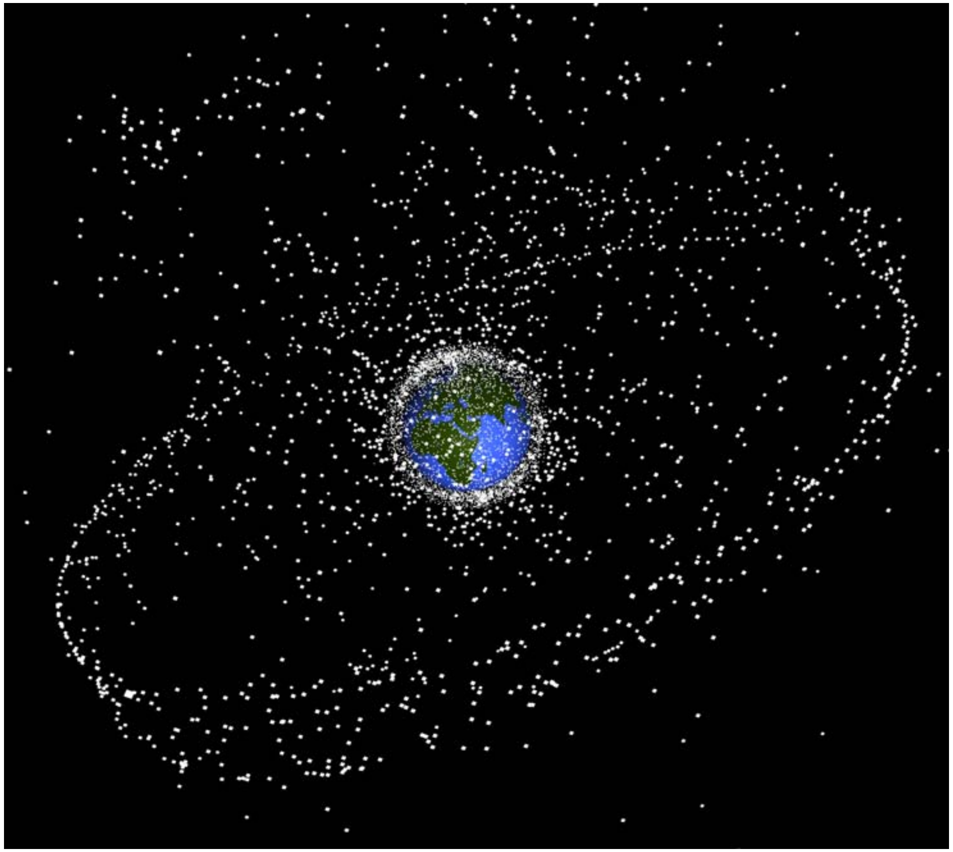
- Organization structure:
  - Steering group
  - **WG-1: measurements**
  - WG-2: environment & database
  - WG-3: protection
  - WG-4: mitigation

- Scope of activities defined in IADC Terms of Reference (see IADC Web-site: **http://www.iadc-online.org)**

IADC WG-1 (Measurements)

- Scope and objectives of WG-1 activities:
  - Ground- and space-based measurements and related techniques, e.g. **radar**, **optical** and infrared
  - Detectors and collectors for small-size particulates onboard space vehicles; analysis of spacecraft surfaces exposed to the space environment
  - Review of space debris research efforts in the area of measurement techniques
  - Identification, evaluation and recommendation of new opportunities for cooperation
- Coordinated measurement campaigns:
  - Geostationary environment (GEO): 1999, 2002, 2003
  - Low-Earth orbit environment (LEO): 1996, 1999, 2000, 2003, 2004

The Space Debris Environment



- Low-Earth Orbit (LEO): 0 < H < 2000km
- Objects in LEO (*):
  - d>1m: ~2,300
  - d>10cm: ~10,000
  - d>1cm: ~190,000
- Objects outside LEO (*):
  - d>1m: ~2,000
  - d>10cm: ~8,000
  - d>1cm: ~290,000

(*) According to the MASTER-2001 model of ESA

Observing Space Debris in LEO

- Radars are the preferred sensor type for LEO observations

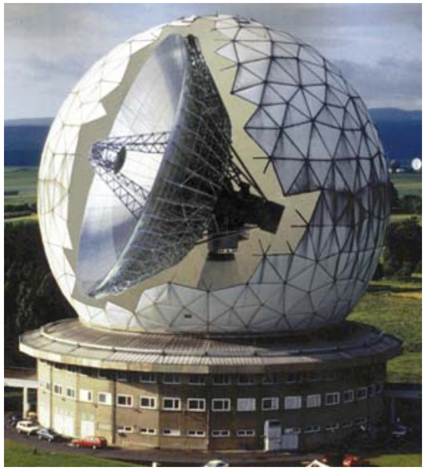
- Advantages:
  - day/night and all-weather capability due to active illumination of the target
  - good detection effectiveness (depending on radar frequency, emitted power, antenna gain, ...)
  - insensitive to high field-of-view crossing speeds
  - simplified (bulk) data processing capabilities

- Disadvantages:
  - sensitivity decreases with 1/(range-to-target)^4
  - debris size estimation may be ambiguous

Participating Radars (1)

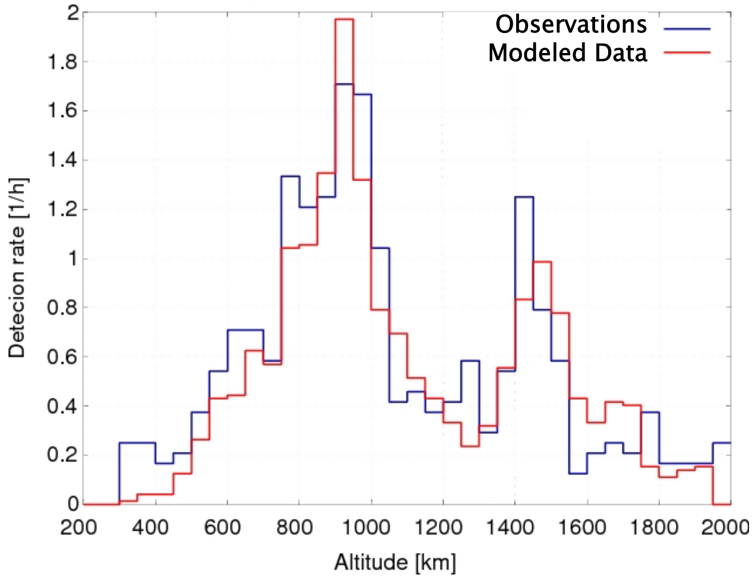
- Goldstone (USA, left): bi-static mode with 34m transmitter and 70m receiver antenna, 500m apart; detection limit: ~2mm
- Haystack LRIR and HAX (USA, center): mono-static mode with 36m and 12m antenna; detection limit: ~5mm and ~3cm
- Cobra Dane (USA, right): phased array of 29m diameter with 96 sub-arrays; detection limit: ~5cm

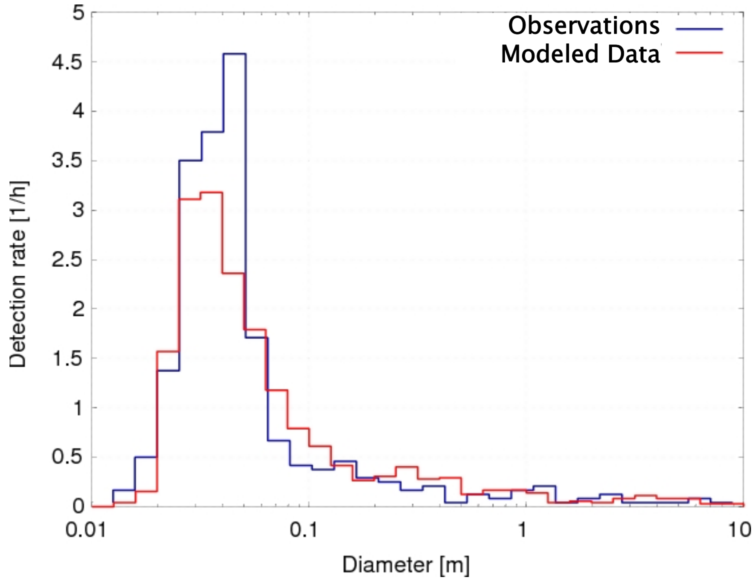
Participating Radars (2)



- TIRA (D, left): mono-static mode with 34m transmitter and receiver antenna, detection limit: ~2cm
- TIRA/Effelsberg (D, center): bi-static mode with 34m TIRA transmitter and 100m Effelsberg receiver antenna; detection limit: ~9mm
- EISCAT (FIN/N/S, right): mono-static, ionosphere research radar with 32m antenna; detection limit: ~2cm

Sample Results of a LEO Campaign





- Strategy: Earth-fixed radar beam park; mono- or bi-static
- Performance drivers: antenna diameter, radar frequency, emitted power, system noise level
- Data products: range, angles, Doppler-inclination, size (RCS)

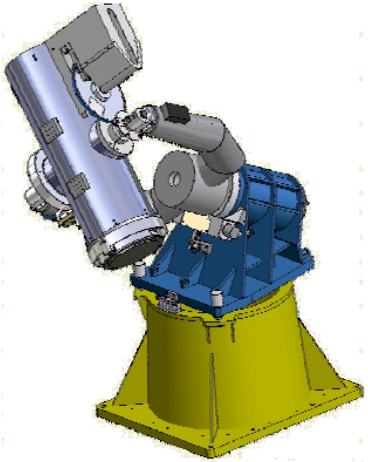
Observing Space Debris in GEO

- Telescopes are the preferred sensors for GEO observations

- Advantages:
  - target is illuminated by the Sun
  - sensitivity decreases only with $1/(\text{range-to-target})^2$

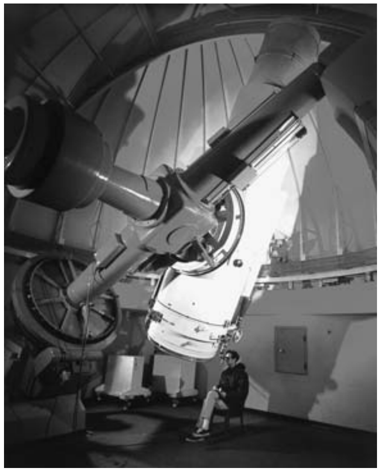
- Disadvantages:
  - observability depends on weather conditions, target illumination, and moon phase
  - observation processing more complex than for radar
  - field-of-view crossing speeds must be limited
  - a single sensor only sees a fraction of the GEO ring

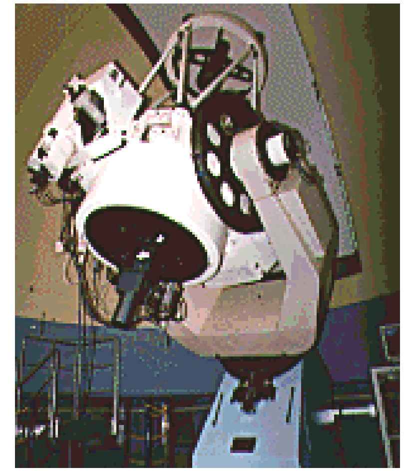
Participating Telescopes (1)



- ESA SD telescope (ESA, left): 1.0m aperture; 4 x 2k x 2k CCD mosaic; limiting mag.: ~20 (2 sec) → ~15cm objects in GEO
- TAROT telescope (F, center): 25cm aperture; 2k x 2k CCD; limiting mag.: ~17 (10 sec) → ~ 50cm objects in GEO
- CAT telescope (I, right): 40cm aperture; 1k x 1k CCD; limiting mag.: ~17 (20 sec) → ~ 50cm objects in GEO

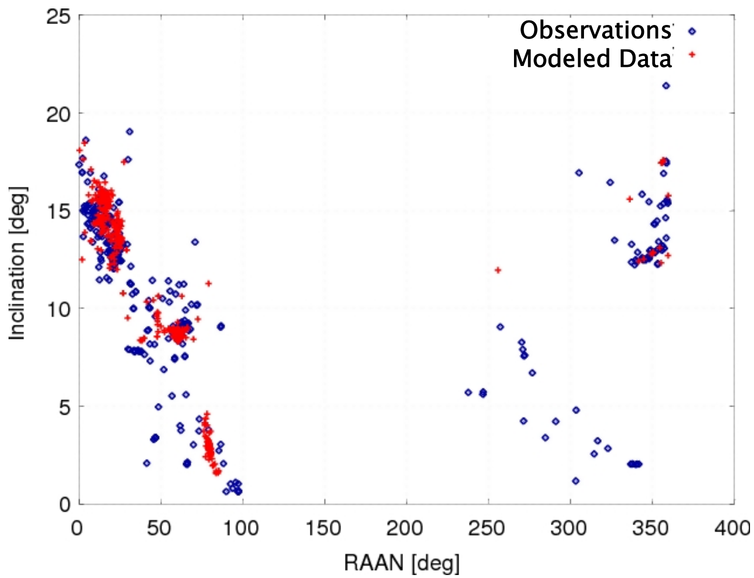
Participating Telescopes (2)

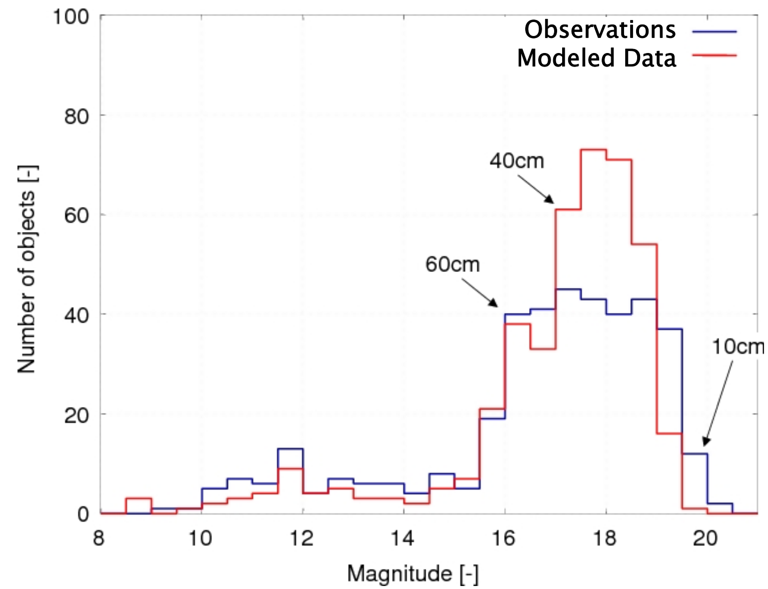




- MODEST telescope (USA, left): 61cm aperture; 2k x 2k CCD; limiting mag.: ~18 (5 sec) → ~30cm objects in GEO
- PIMS telescopes (UK, center): 40cm aperture; 1k x 1k CCD; limiting mag.: ~17.5 (3 sec) → ~35cm objects in GEO
- Bisei telescope (J, right): 0.5/1.0m aperture; 2/10 x 2k x 4k CCD mosaic; limiting mag.: ~18 → ~30cm objects in GEO

Sample Results of a GEO Campaign





- Strategy: Earth-fixed stare and/or sidereal tracking mode
- Performance drivers: aperture diameter, characteristics of the CCD (pixel resolution, quantum efficiency, read-out time, S/N)
- Data products: angular positions (α,δ), visual magnitude

Conclusions

- Since its formation in 1993 IADC has coordinated several international observation campaigns for the Low-Earth Orbit (LEO) and for the Geostationary Orbit (GEO) regions

- Predominantly, radar techniques are applied for LEO surveys, and optical techniques are used for GEO surveys

- Campaign results are …
  - reported to IADC in standardized formats
  - important to calibrate debris environment models
  - useful to compare sensor performances
  - suited to identify populations below the detection size thresholds of operational surveillance systems

- IADC might extend future campaigns beyond LEO and GEO