Space Debris – An overview

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SA Council for Space Affairs

Outline

- The space debris issue
- Approaches to dealing with the debris issue
  - Scientific & technical aspects
  - International and national regulatory frameworks
  - Multilateral & political initiatives to address the issue
- What can APRSAF do about the debris issue?

Evolution of space activities

In the past 50 years, space has underpinned global peace and prosperity.

Beneficiaries: States

Actors: Few, States

Engagement: Pluralism

Beneficiaries: Citizens

Actors: Many, State & Non-State

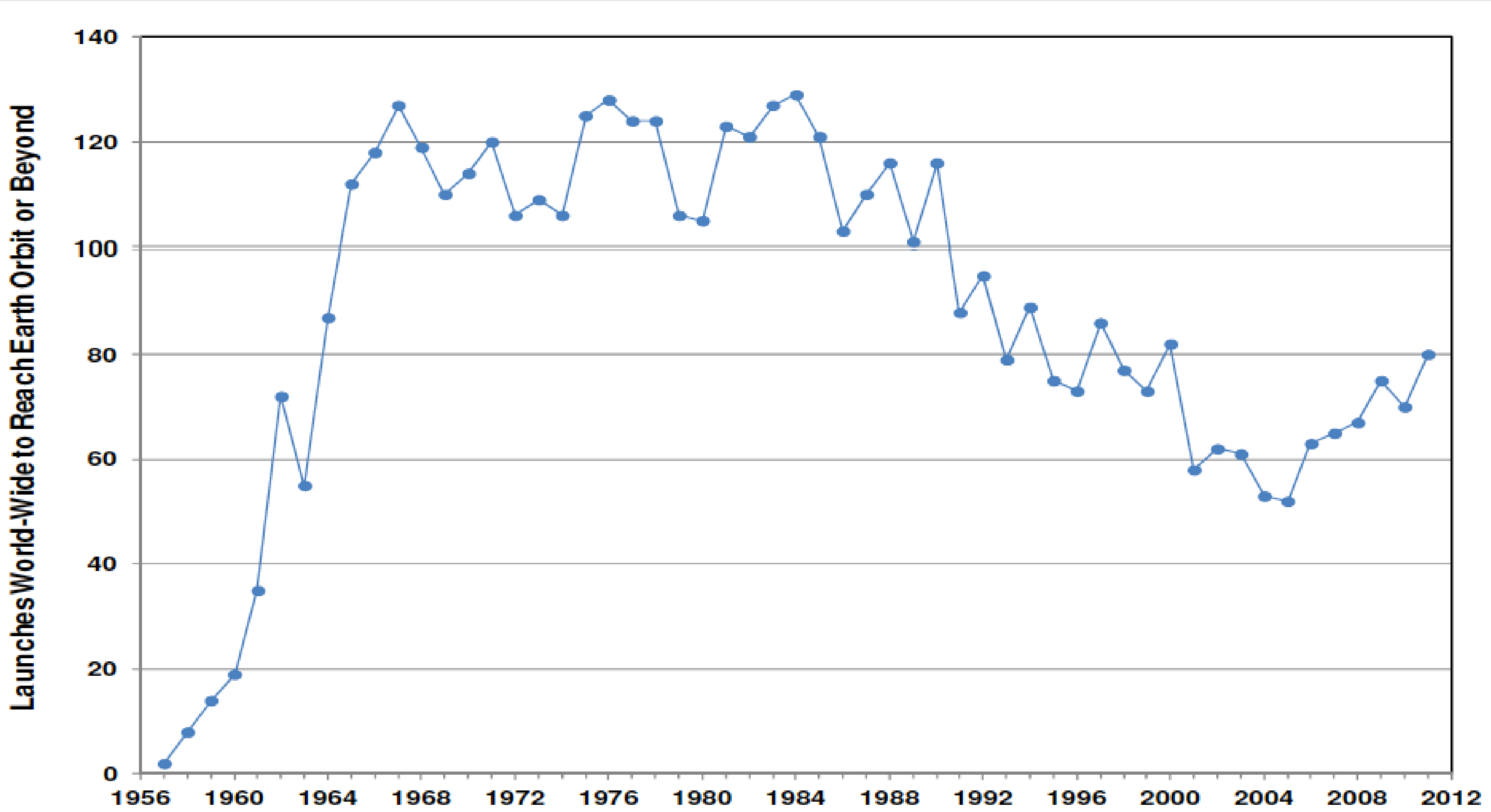
Engagement: Mutualism

Space is becoming more crowded, more hazardous ➔ Ensuring safe operations more complex.
Our generation must act now to preserve the space environment for future generations.

The space debris situation

Launch Activity 1957 - 2012

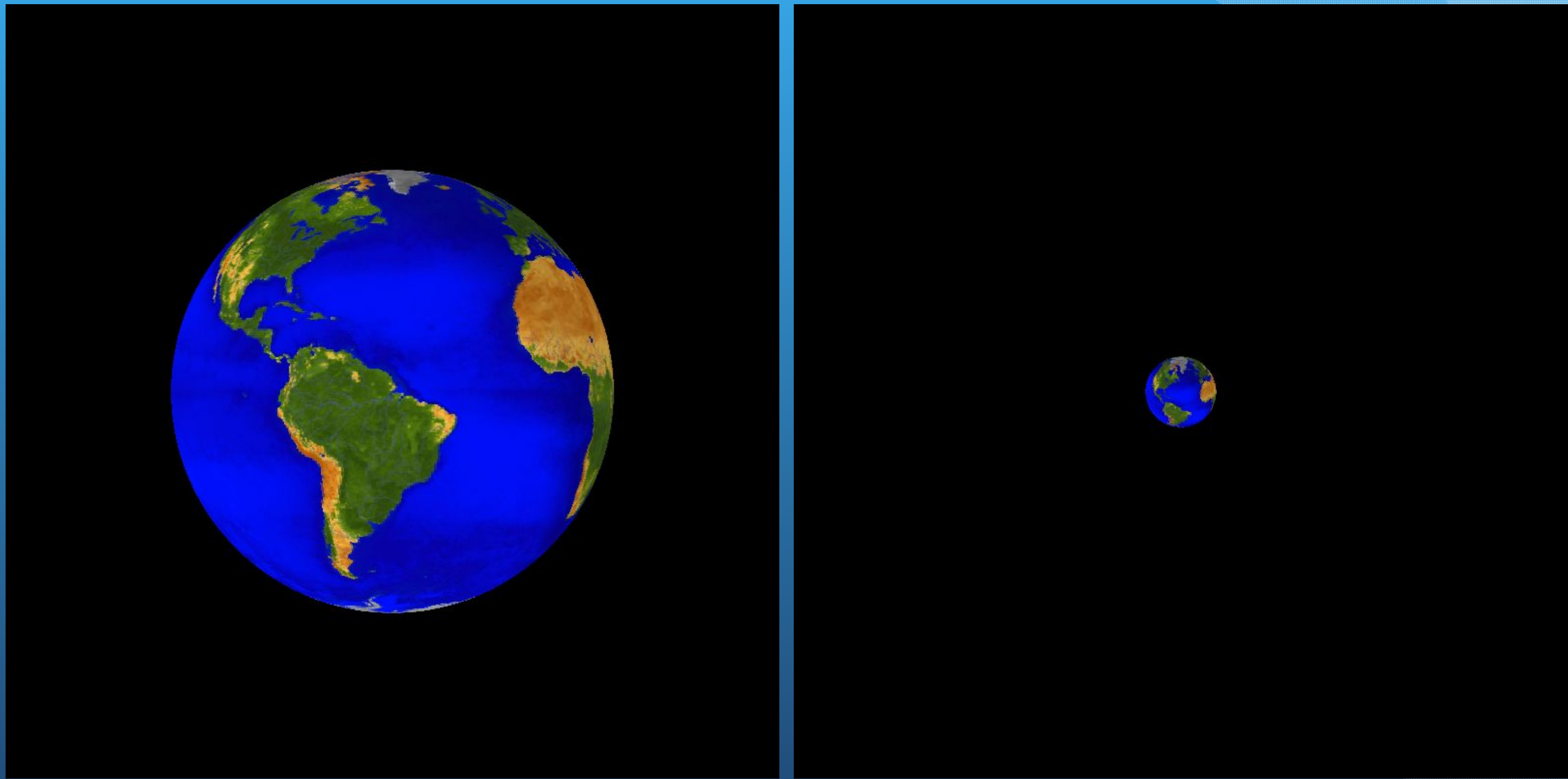
A total of 80 space launches reached Earth orbit or beyond during 2011, the most since the year 2000.



Nicholas Johnson, NASA

Crowding of the Earth's orbital environment

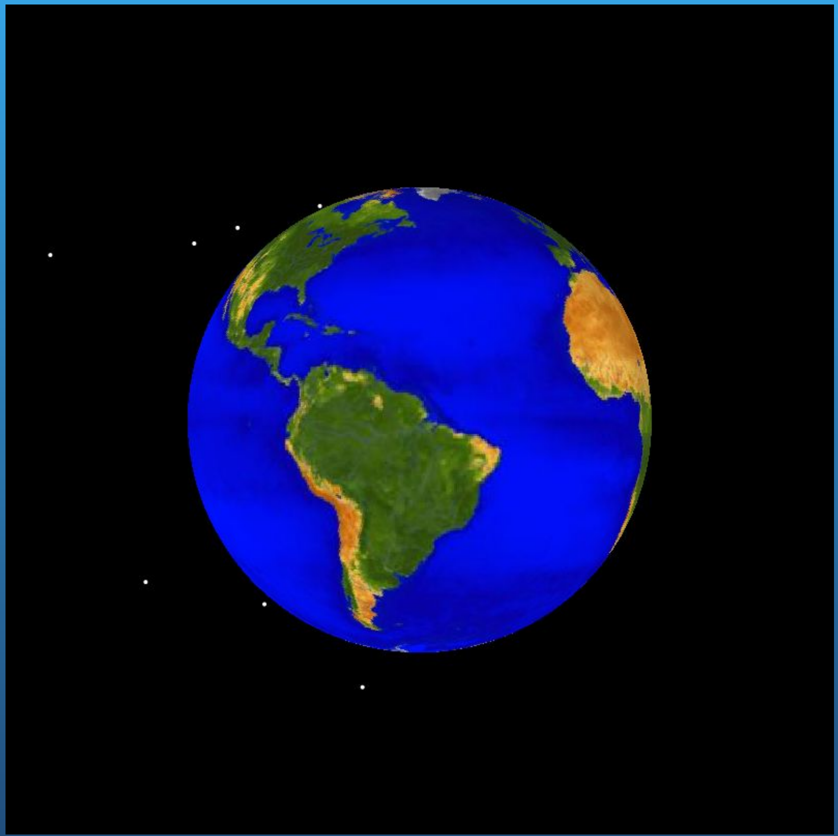
Before 1957

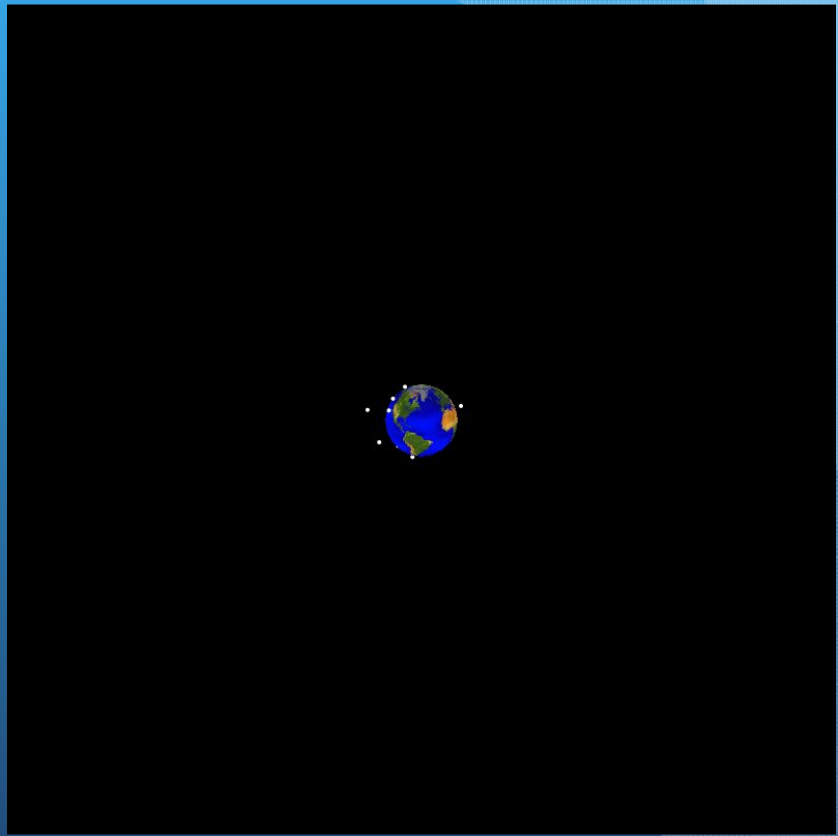


White dots represent catalogued objects (>10 cm in diameter)

Crowding of the Earth’s orbital environment

1960

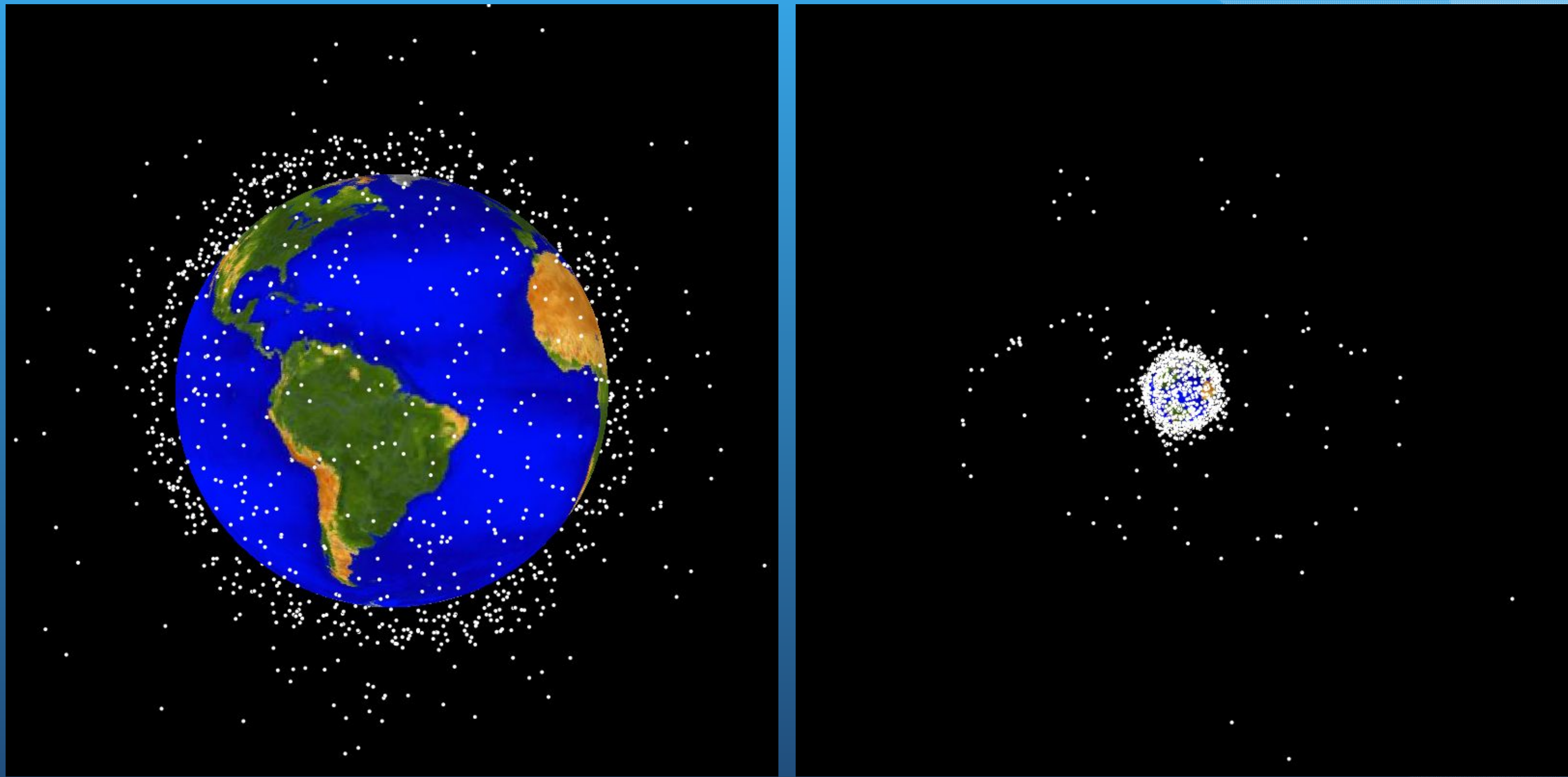




White dots represent catalogued objects (>10 cm in diameter)

Crowding of the Earth's orbital environment

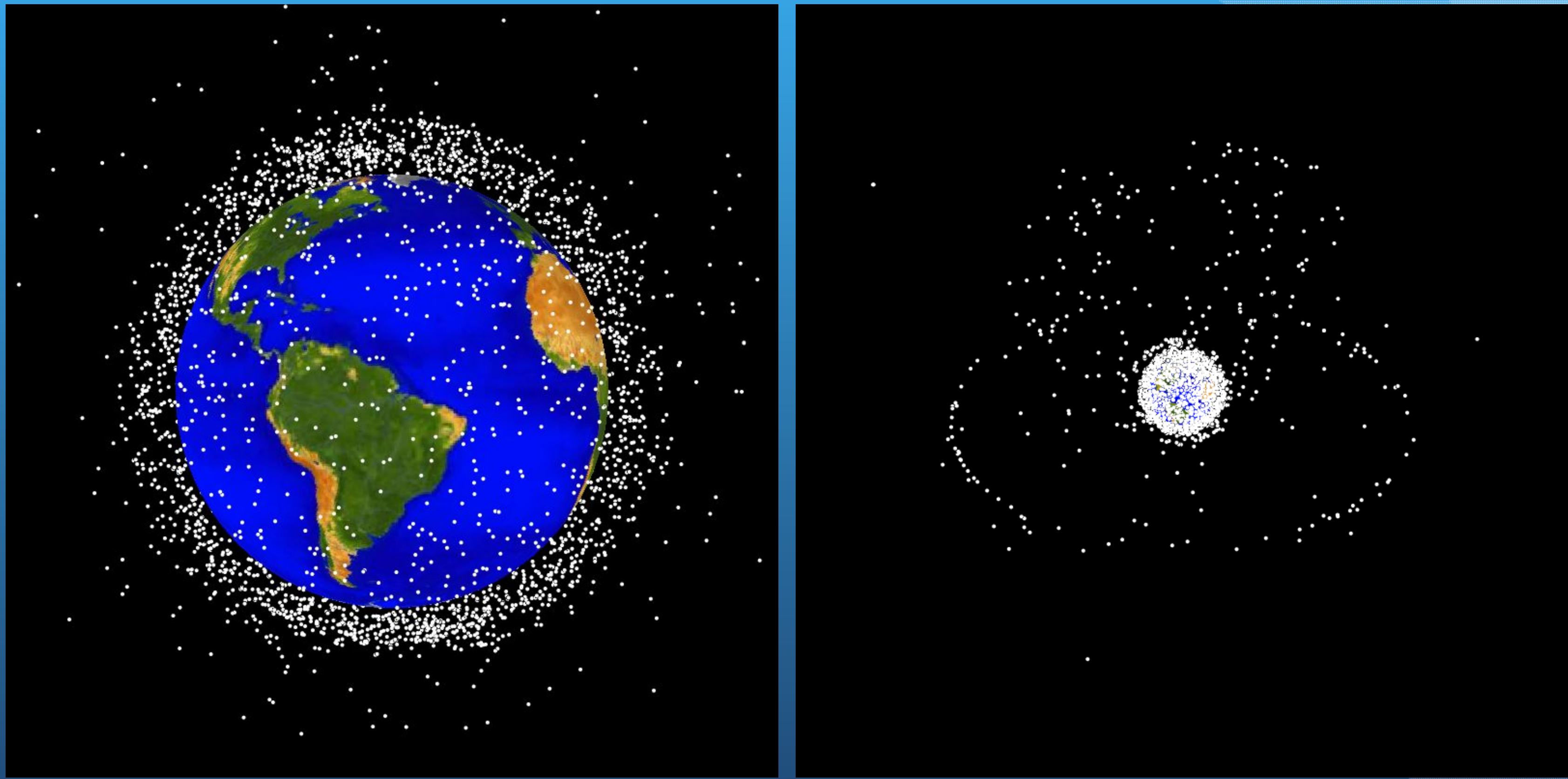
1970



White dots represent catalogued objects (>10 cm in diameter)

Crowding of the Earth's orbital environment

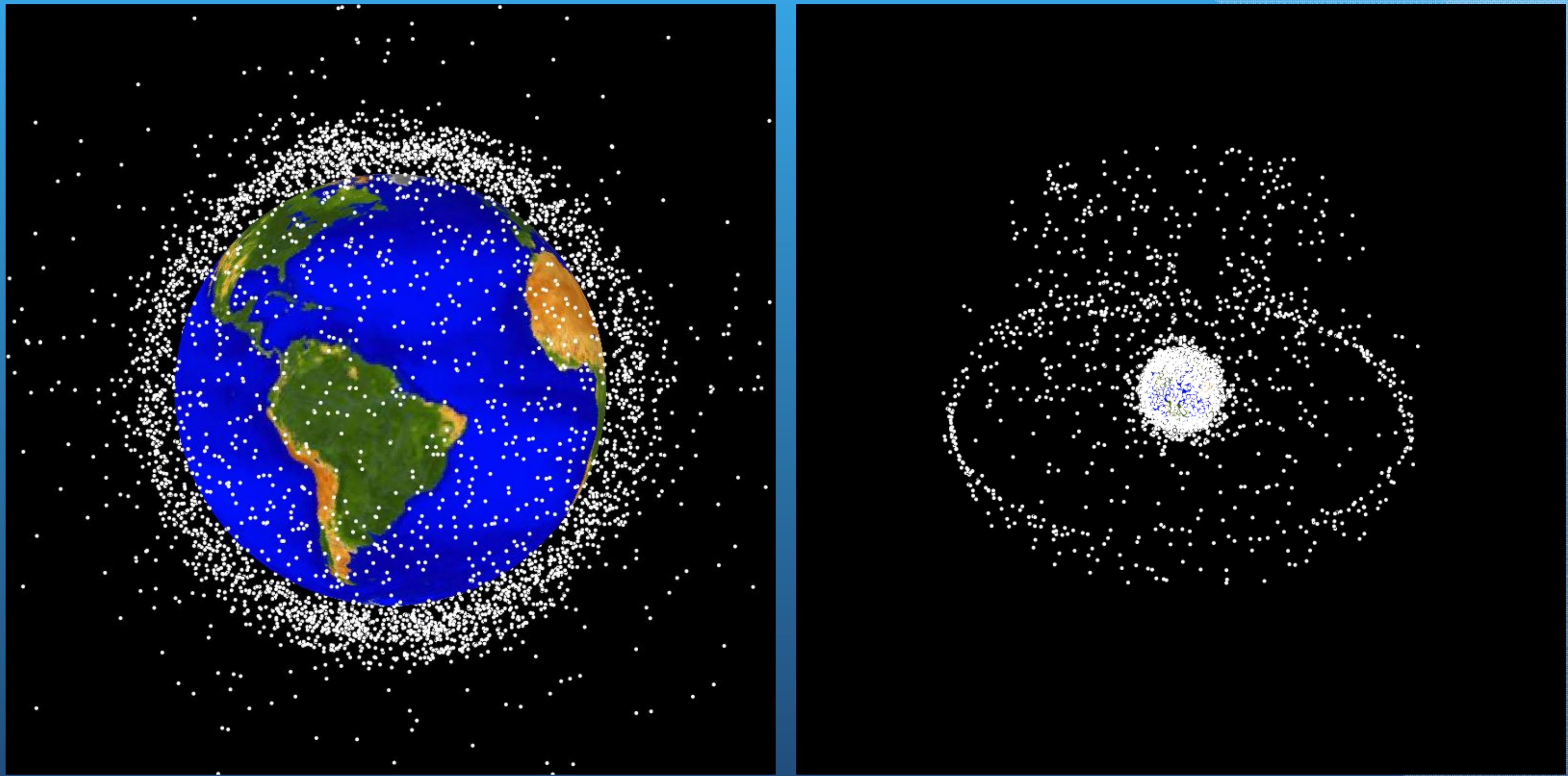
1980



White dots represent catalogued objects (>10 cm in diameter)

Crowding of the Earth's orbital environment

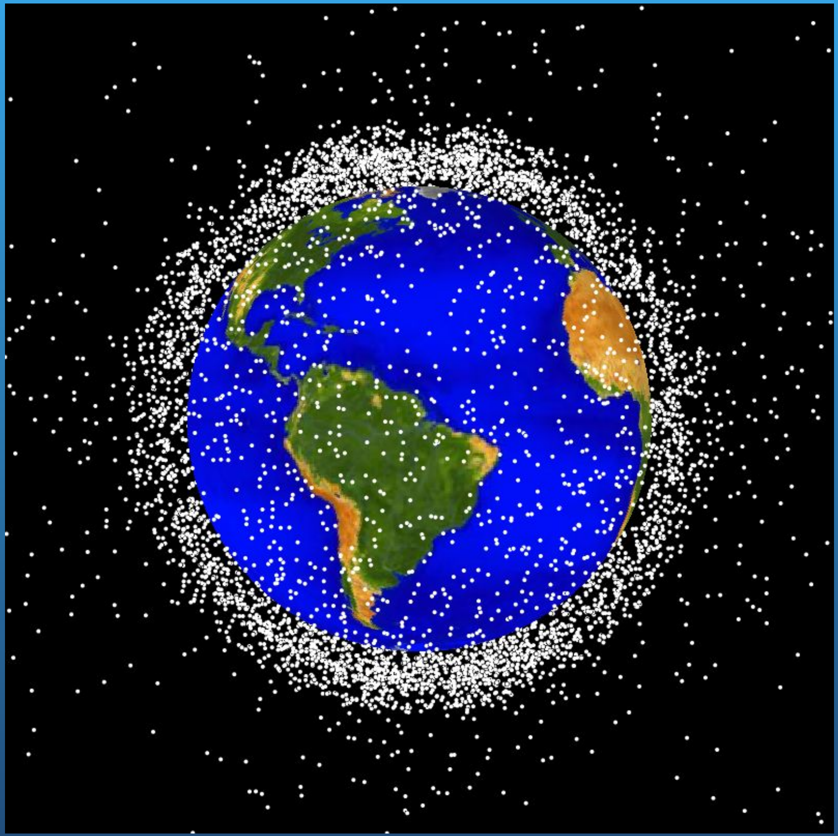
1990

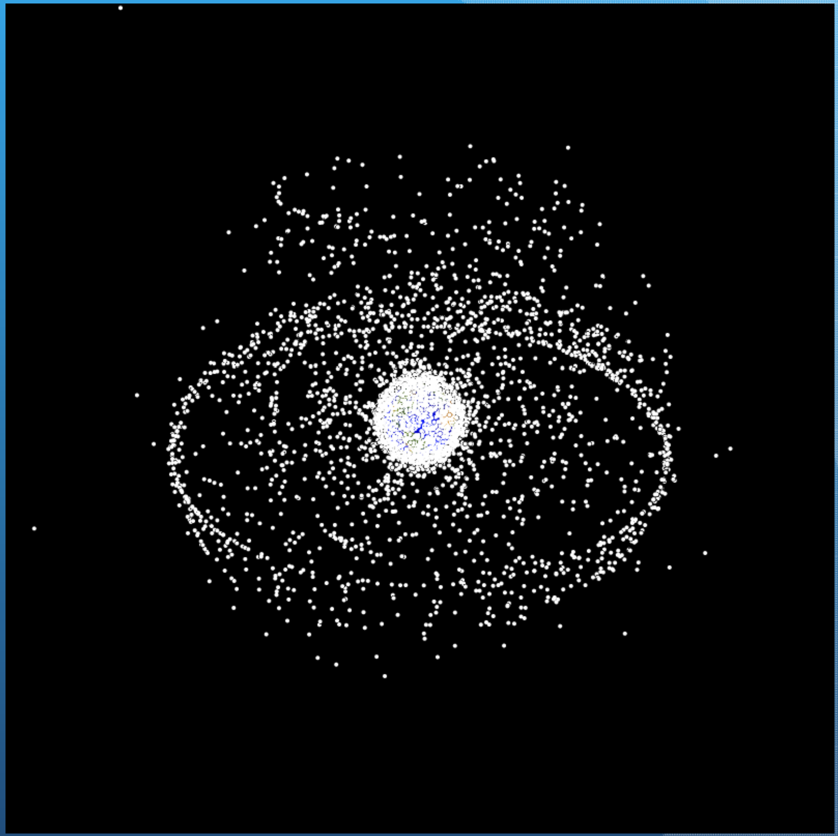


White dots represent catalogued objects (>10 cm in diameter)

Crowding of the Earth's orbital environment

2000

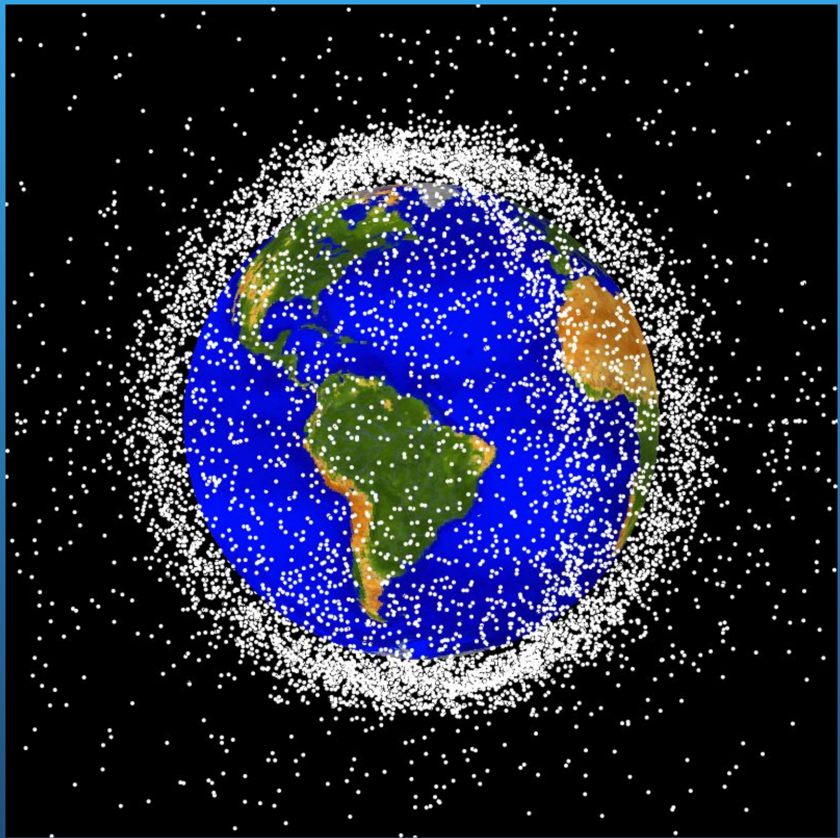


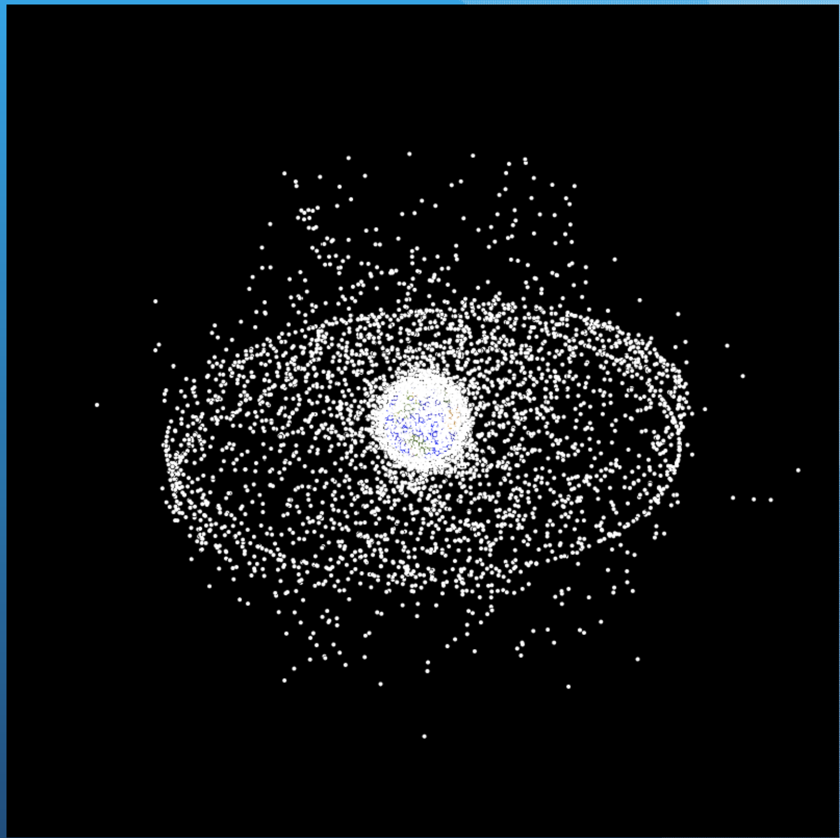


White dots represent catalogued objects (>10 cm in diameter)

Crowding of the Earth's orbital environment

2010



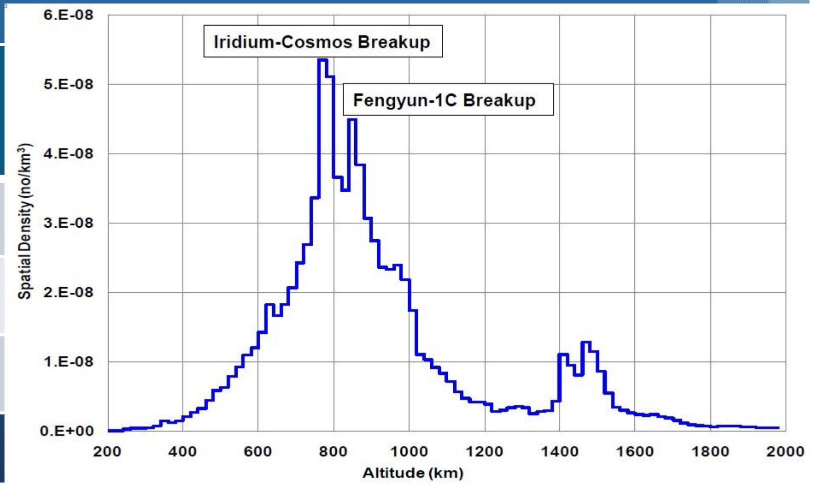


White dots represent catalogued objects (>10 cm in diameter)

The concern

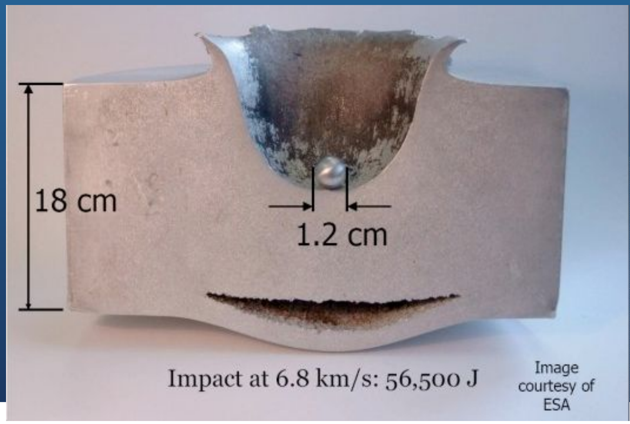
- The growing population of space objects in orbit may in time make activities in regions of near-Earth space hazardous and extremely expensive
- U.S. now tracks about 22,000 objects in Earth orbit
  - ~ 1,000 working satellites
  - ~ 21,000 debris pieces > 10 cm

Orbit	Operational Satellites
LEO	~ 450
MEO	~ 55
GEO	~ 400



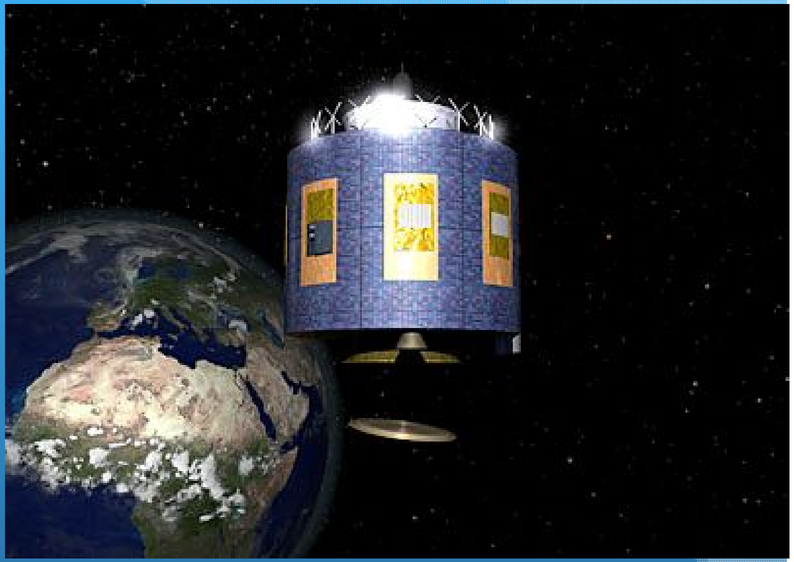
But that's not all…

- Objects smaller than 10 cm are not consistently trackable
  - There may be as many as 500,000 objects of 1-10 cm size
  - Perhaps as many as 10s to 100s of millions < 1 cm
- No active collision avoidance is possible for such objects
- These objects can cripple or destroy spacecraft and endanger astronauts
- Total mass ~ 6300 tons



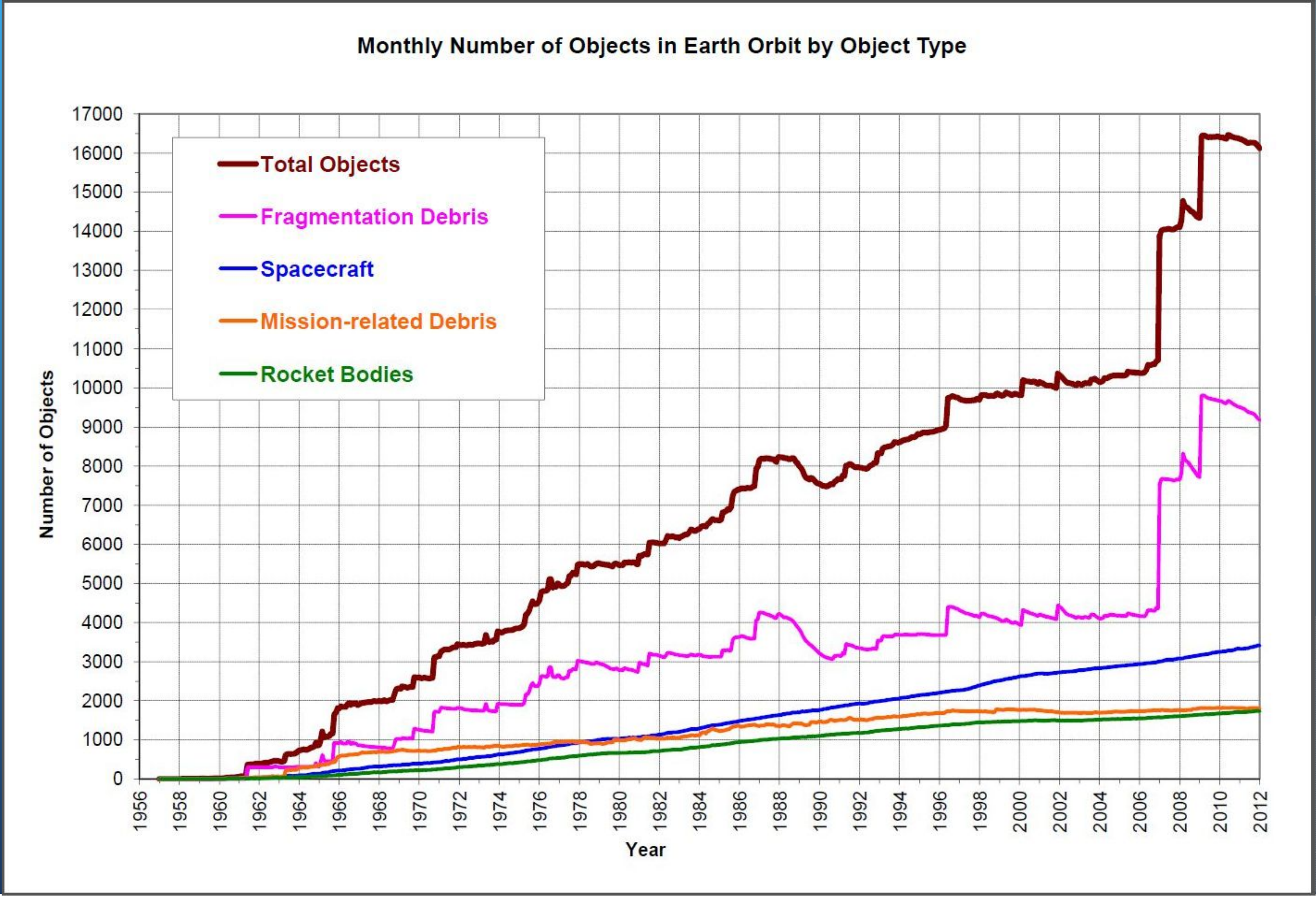
Sources of debris

- Defunct spacecraft
- Mission debris
- Rocket bodies
- Fragmentation debris
  - Explosions
  - Degradation
- Collisions
- Deliberate debris creation
  - ASAT tests

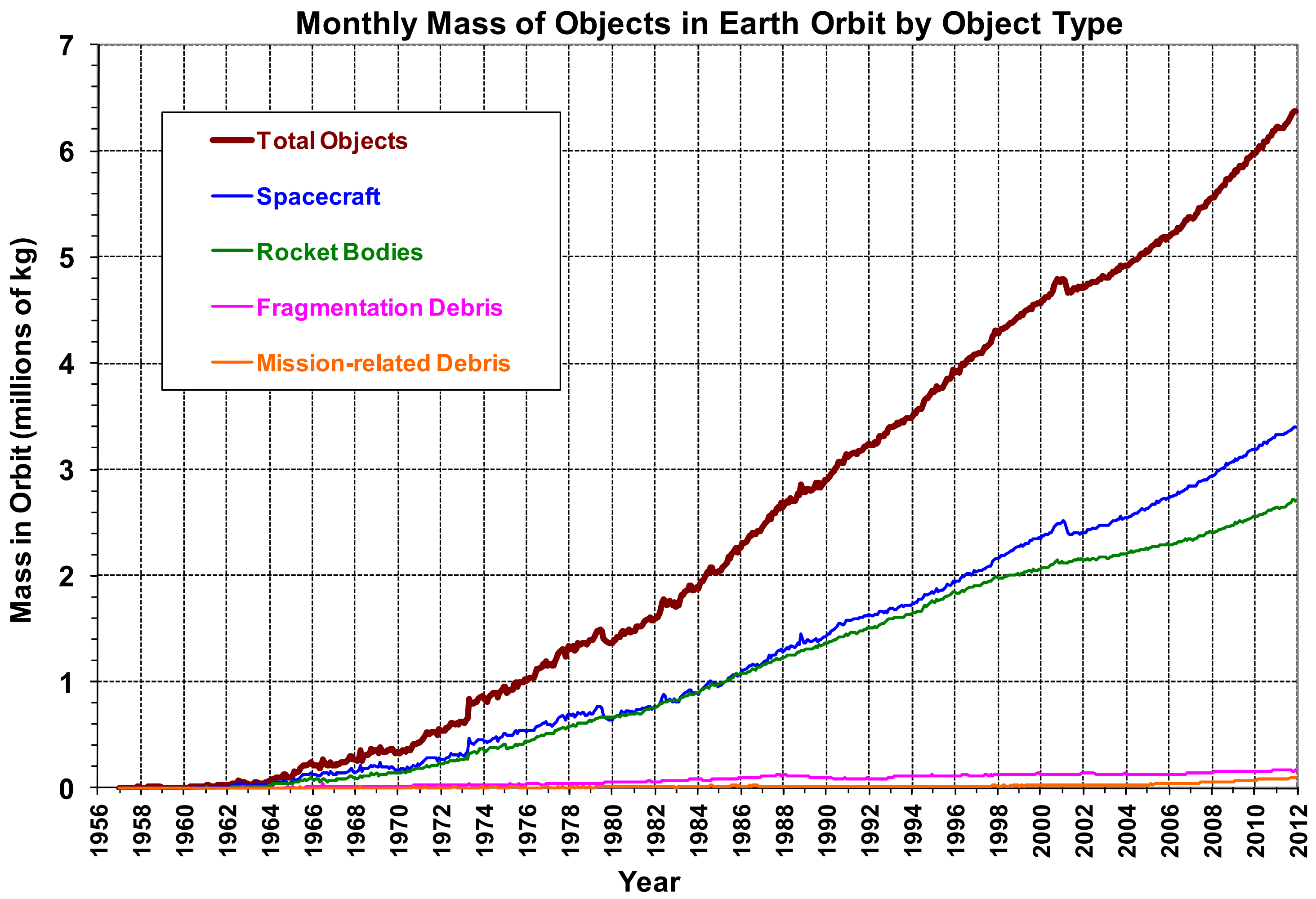


Images: ESA

Trackable debris population



Growth of the debris environment



Space Shuttle vulnerabilities

Window Replacement

EVA Suit Penetration

Radiator Penetration

RCC Panel Penetration

Tile Penetration

Cabin Penetration

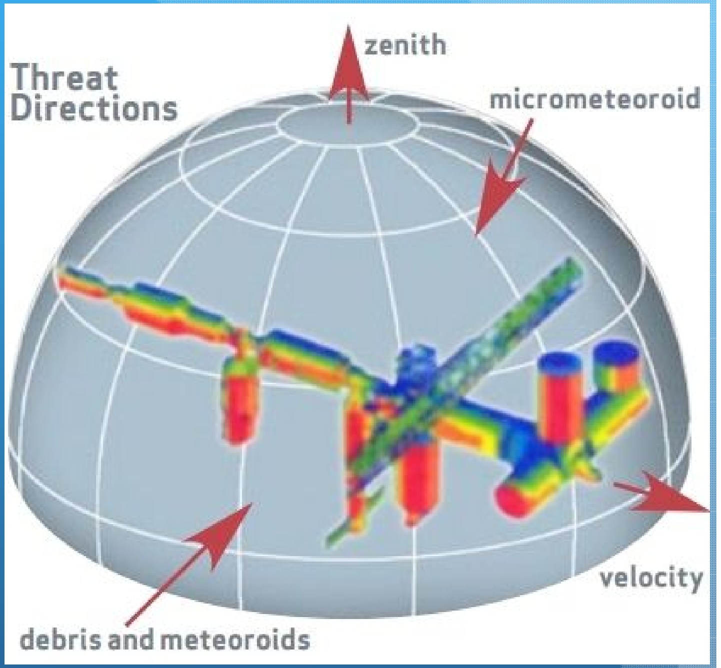
0.001 0.01 0.1 1 10 100 1000

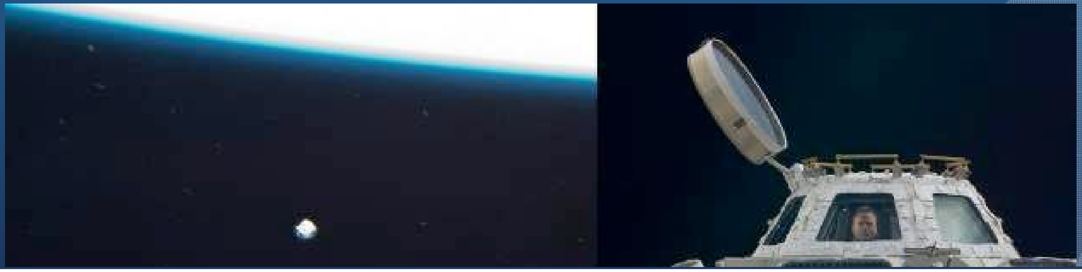
Debris Diameter in Centimeters

NASA OD Program Office

International Space Station vulnerabilities

- Passive shielding
  - Most shielded spacecraft ever flown
  - Total shielding mass ≈ 23,400 kg
  - Launch cost ($10k/lb) ≈ $515 million
- Collision avoidance manoeuvres
  - 16 manoeuvres since 1999
  - 5 since 2011
- Risk tolerances
  - <24% probability of penetration (10 yr)
  - <5% probability of catastrophic failure (10 yr)

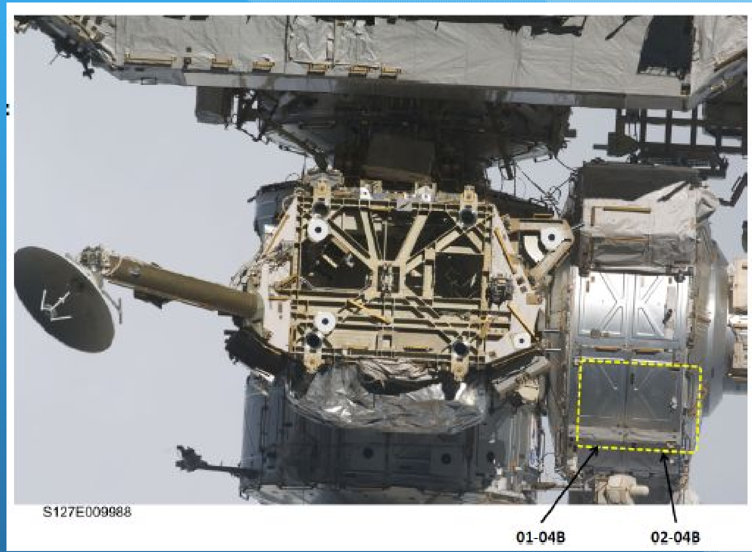




10 June 2012 MMOD hit on ISS Cupola

Small particle impacts on ISS

- Two debris shields from an airlock returned to Earth after nearly 9 years in orbit

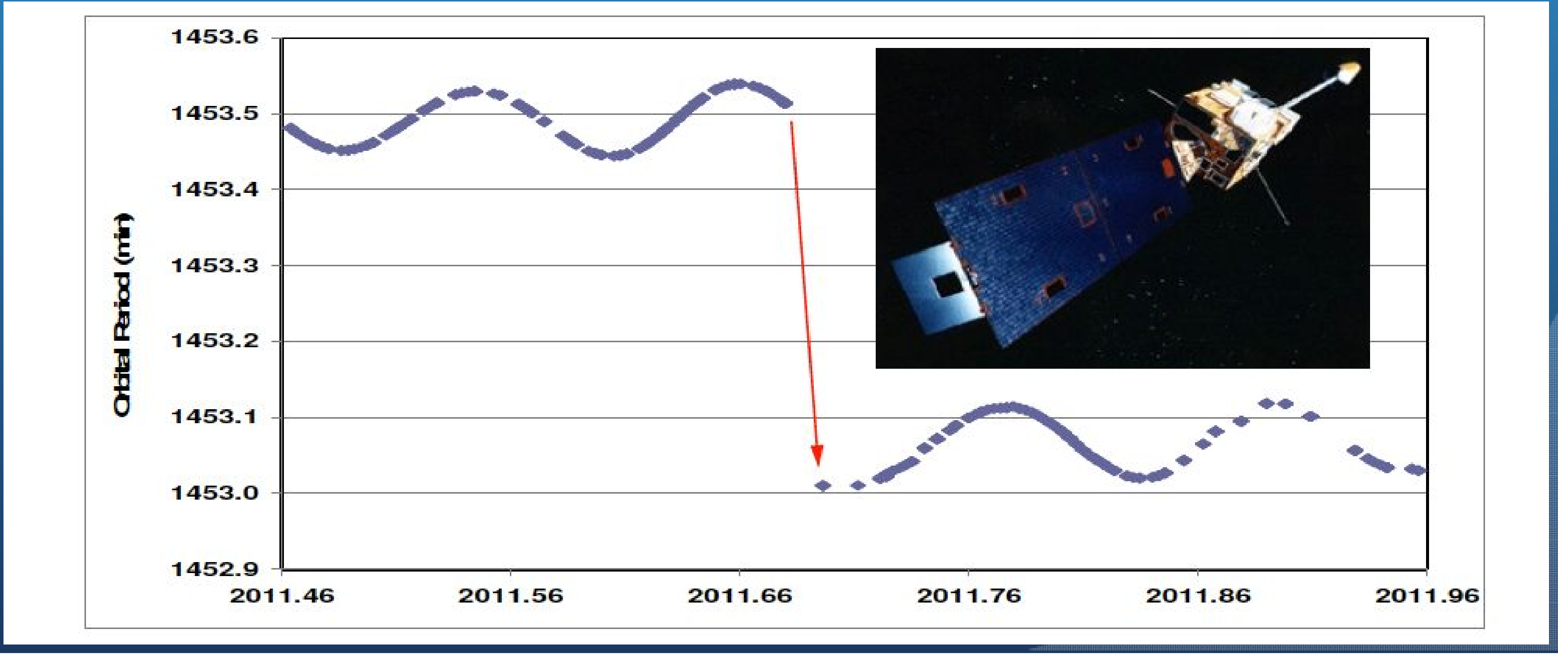


- Analysis at JSC showed
  - 58 craters with diameter > 0.3mm
    - Largest crater had a diameter of 1.8 mm and nearly penetrated the shield
    - Six craters contained residues of silica, teflon, or both
    - Might be evidence of secondary debris from impacts on the ISS solar arrays

Courtesy Nicholas Johnson, NASA

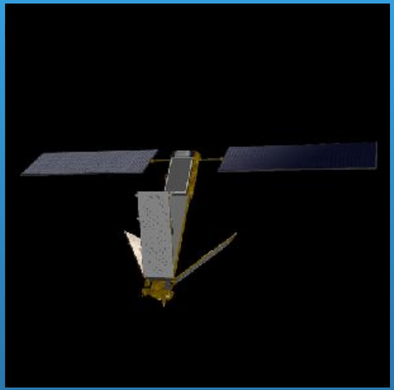
GOES 10 Anomaly

- On 5 Sept 2011, nearly 2 years after GOES 10 had been decommissioned and placed in a disposal orbit above GEO, its perigee decreased abruptly by 20 km.
- Collision with a small object is a possible explanation

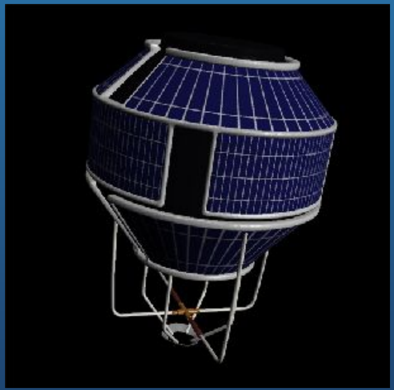


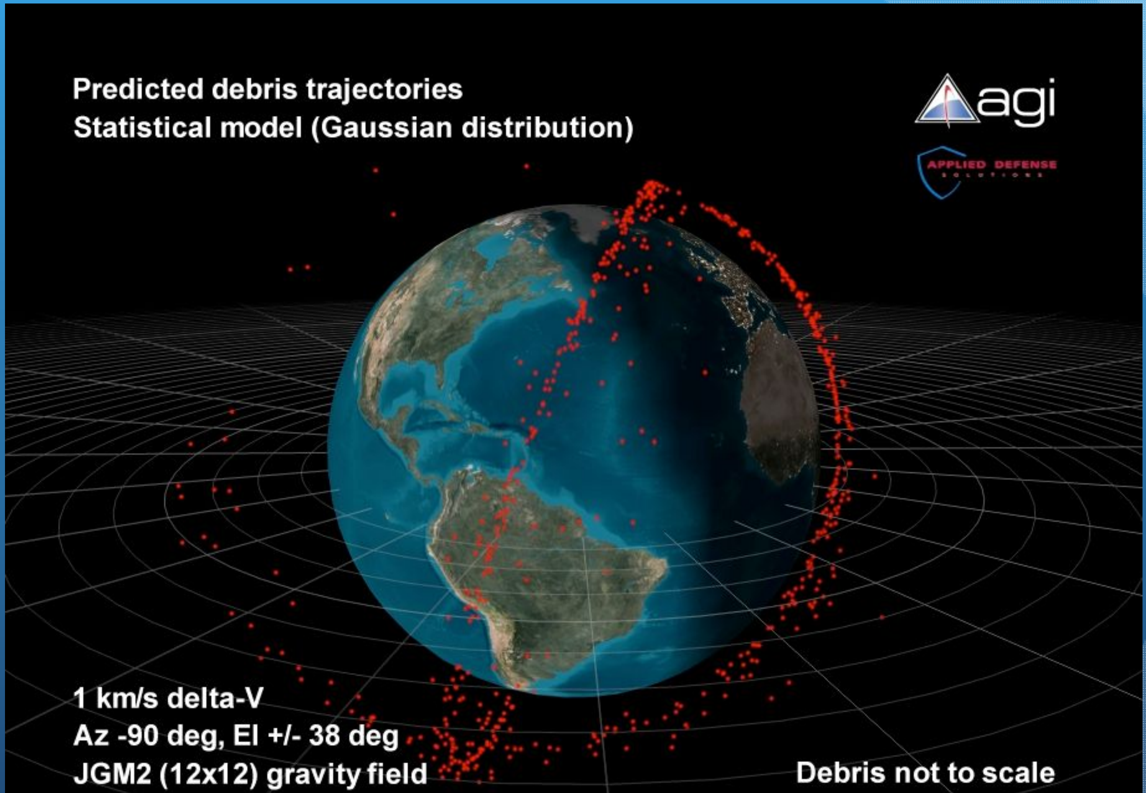
Cosmos – Iridium collision: 10 Feb 2009

Iridium



Cosmos 2251

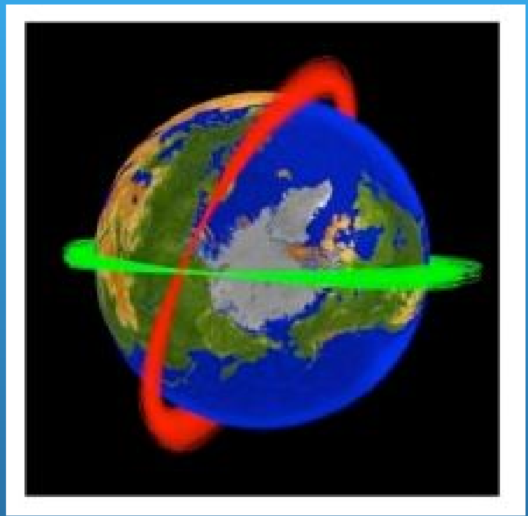




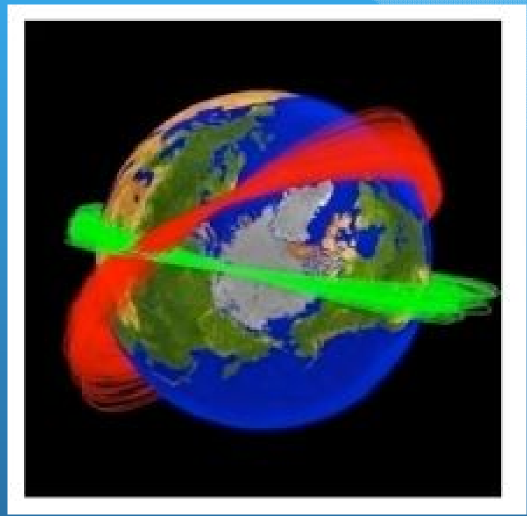
1500 trackable objects

We do not have in place the capacity and systems to prevent another similar collision!

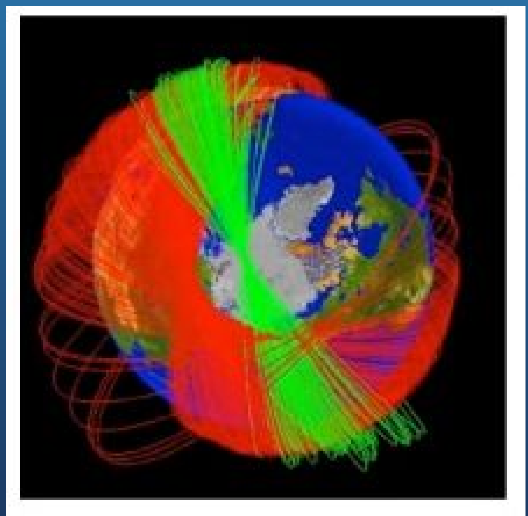
Spread of debris orbital planes



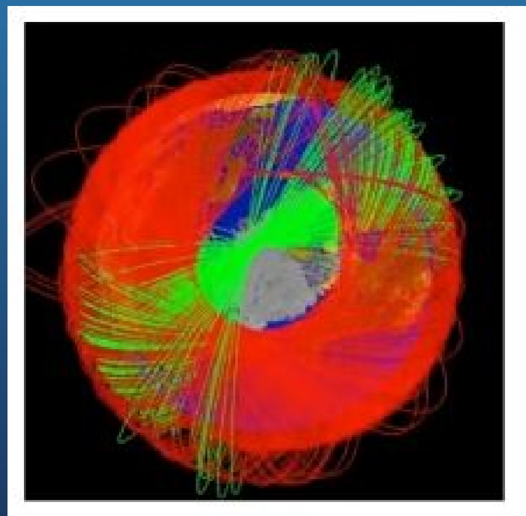
7 days



30 days



6 Months



1 Year

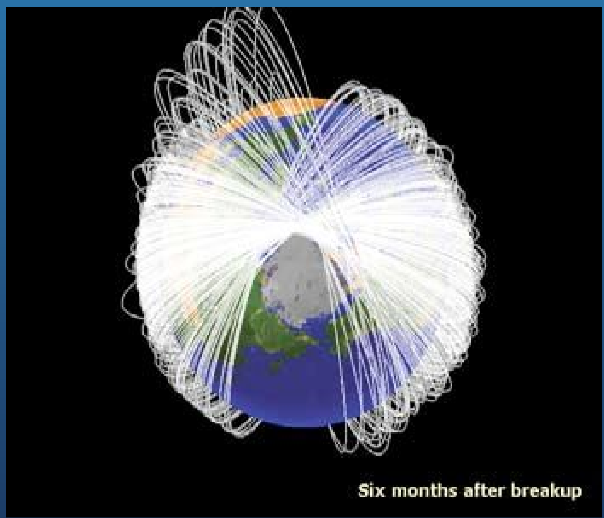
Destruction of FY-1C: 11 Jan 2007

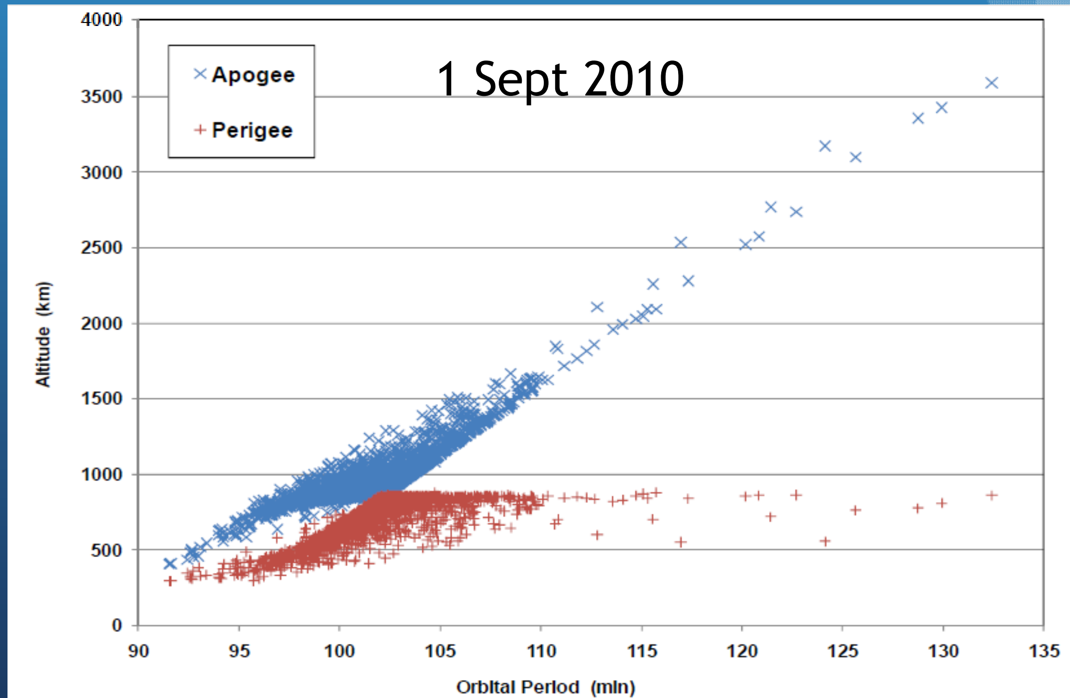
- Direct ascent kinetic destruction of inactive Chinese Feng Yun 1C (FY-1C) weather satellite.
- The satellite was in a polar orbit, at an altitude of 865 km, and was struck when it passed over the Xichang Space Centre in Sichuan province.
- 2377 trackable fragments created > 10 cm
  - Perhaps ~150,000 too small to track
- Instantaneous 23% increase in the trackable debris population

Similar tests were conducted by the USSR and USA in the 1970s and 1980s

Destruction of FY-1C: 11 Jan 2007

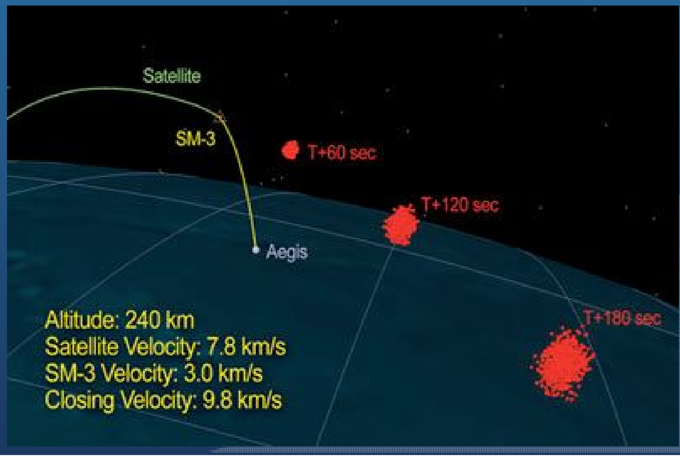
- Debris dispersed in range 200 km to 3500 km orbits.
- 2/3 of all active or inactive satellites in Earth orbit pass through this orbital region, including the ISS





Destruction of USA-193: Feb 2008

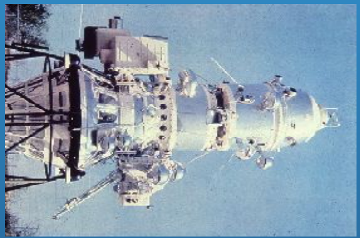
- The ailing US national security satellite USA 193 was expected to re-enter some time in 2008, with hydrazine fuel in its tanks.
- The US government decided to destroy the satellite shortly prior to re-entry at an altitude of 250km.
- The debris fell from orbit within 8 months of the event.



Space debris - reentry

SOME EXAMPLES

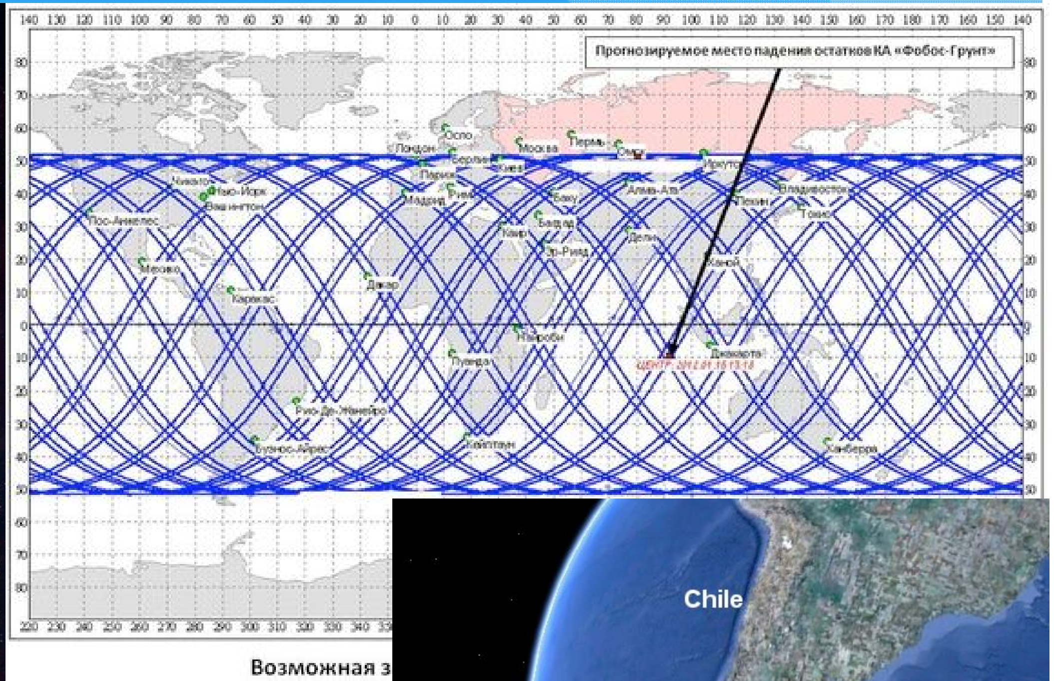
- On January 24, 1978 the Soviet military satellite Cosmos 954 crashed in Northwest Canada.
- It had a nuclear reactor on board.

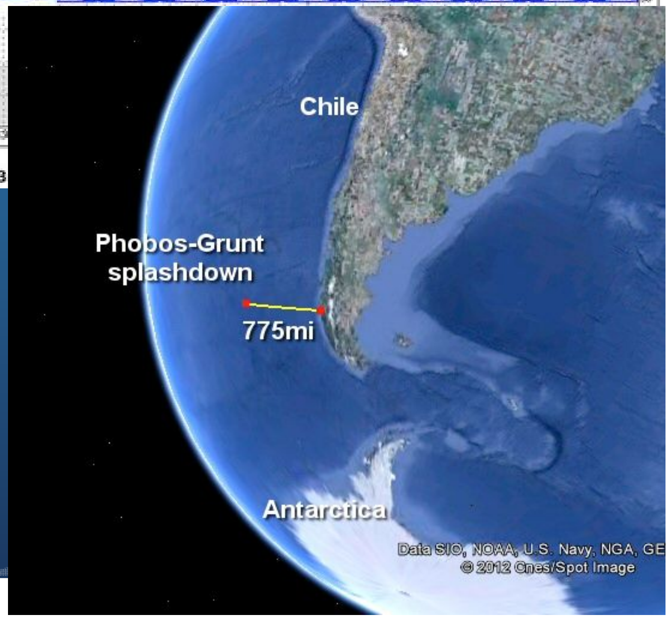


- Radioactive debris scattered over 800 km area of Canada.

On April 27, 2000 a USA Delta II 2nd stage reentered over South Africa. The propellant tank landed 37 km NE of Cape Town.
A pressurisation sphere and rocket nozzle were also recovered.

Phobos-Grunt reentry – 15 Jan 2012





Mass: 13,200kg
(with fuel)

SPECIAL EDITION

POLICE VIEW OF MIGRANTS — Page 3

The Sydney Morning Herald

Skylab's dying sweep across the Indian Ocean and into Western Australia

3 AM NEWS

SKYLAB HITS WEST AUST

By BEN SANDILANDS, in Sydney, RICHARD MACEY, in Canberra, and MIKE STEKETEE, in Washington

The dying US spaceship Skylab crashed to earth in a huge ball of flame near the West Australian town of Esperance at 2.38 am today, Sydney time.

Skylab

As far as was known, there was no damage to life or property.

It was not known if the wreckage fell into the sea or on to land near the remote coastal town.

"It was beautiful. There was a huge glow which lit up the sky," said Constable P. Giles, of Esperance police.

"We heard the rumbling followed by an explosion. It shook the windows and the sky was lit up like an exploding sky rocket.

"It must have been the metal parts breaking up, everyone is outside watching it."

TV camera catches image on tape

Oil traces

Flights grounded

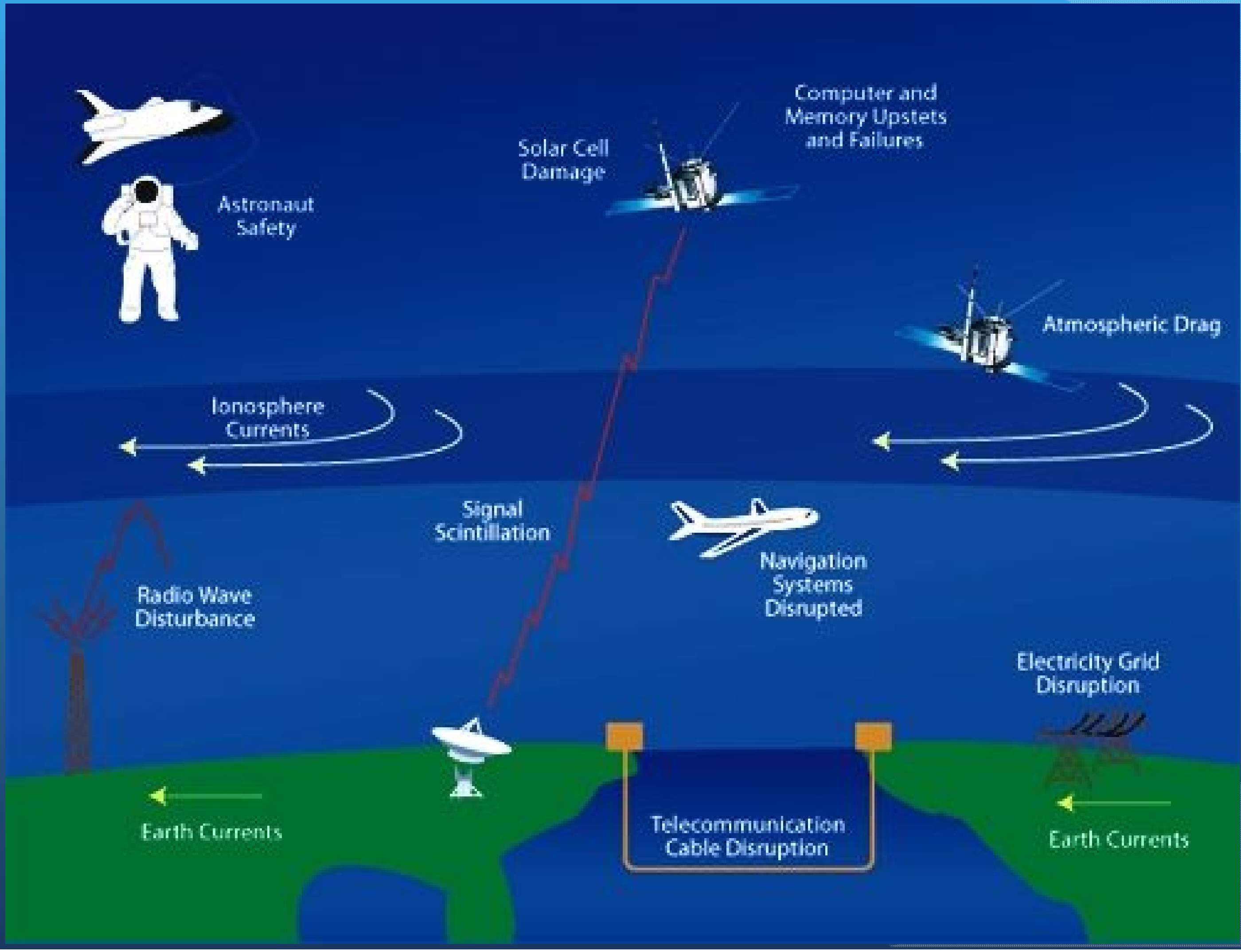
Union clash looms over PM's threat to use new law

Telecom technicians and public service unions ...

Tomorrow

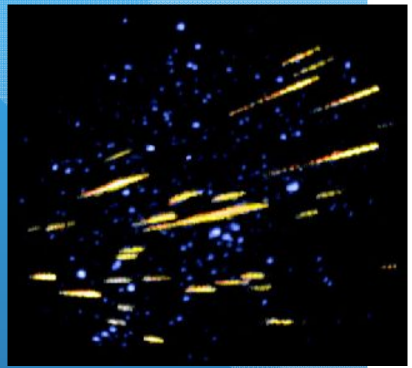
Natural hazards that can result in space debris

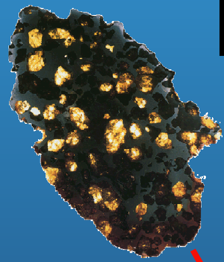
Space weather effects



Meteor impacts

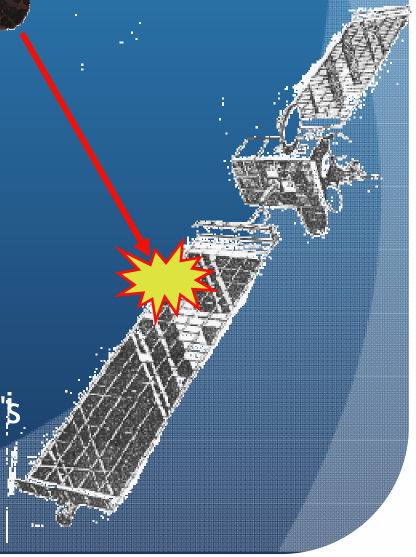
- Approx 100 tons of material enters the Earth's atmosphere each day (dust, meteors)
- Meteor showers occur when Earth crosses the orbit of a comet





EXAMPLE OF A METEOR STRIKE

- In August 1993 ESA Comsat Olypmpus-1 ($850 M) was lost due to a meteoroid hit in the Perseid Shower
  - Associated with comet Swift-Tuttle
  - Over 350 meteors per hour at peak
- The meteoroid vaporized when it struck the solar array, generating a small cloud of electrically charged gas (plasma) which acted like a wire, allowing electrical charge on the array to move into the spacecraft's attitude control electronics.
- OLYMPUS tumbled wildly. By the time operators regained control, the satellite's attitude-control fuel was exhausted, and its useful life was over. By month's end, the satellite was moved to a "graveyard orbit" and shut down.

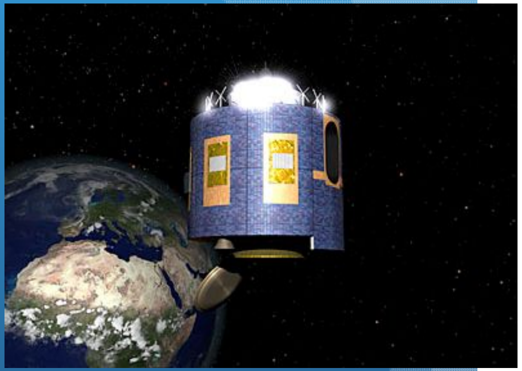


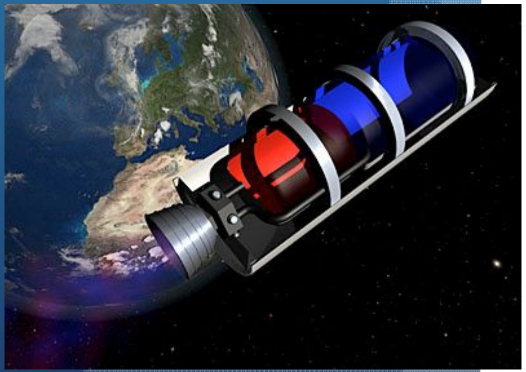
Approaches to dealing with the debris issue

Scientific and Technical Aspects

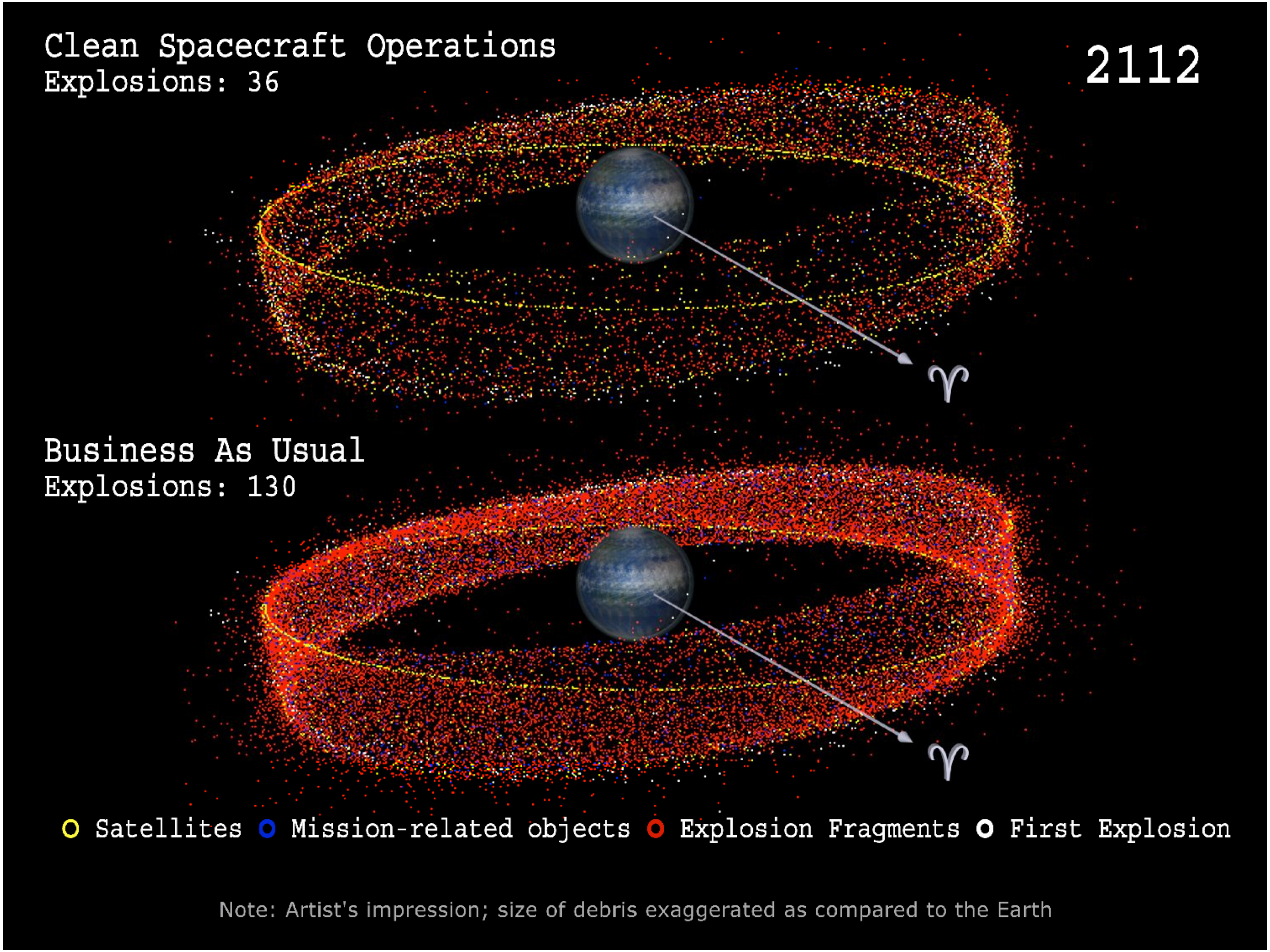
Space debris mitigation measures

- Voluntary measures have been adopted by the leading space agencies to reduce introduction and proliferation of debris.
- **IADC Debris Mitigation Guidelines (adopted by UN)**
  - No intentional production of debris
  - Designing to minimise space debris production during normal operations & fragmentation due to strikes
  - Employ launchers that do not pollute the LEO environment
  - End of service disposal
    - Intentional de-orbiting & breakup for LEO s/c
    - Transfer to graveyard orbit for GEO s/c (235 km higher)
  - Active passivation of the spacecraft
    - Draining of all power, fuel and energy sources





IMPLEMENTATION OF SDMGs WILL RETARD BUT NOT STOP OR REVERSE DEBRIS GROWTH


Clean Spacecraft Operations
Explosions: 36
2112
Business As Usual
Explosions: 130
Satellites
Mission-related objects
Explosion Fragments
First Explosion
Note: Artist's impression; size of debris exaggerated as compared to the Earth

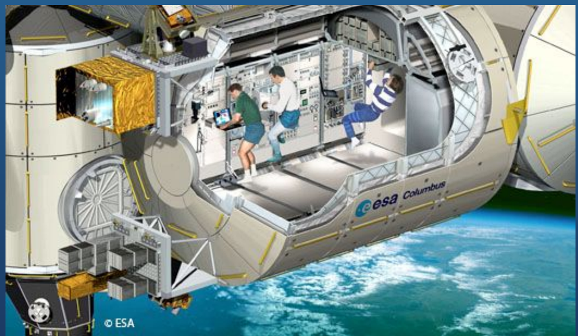
Dealing with meteoroid/space debris risk

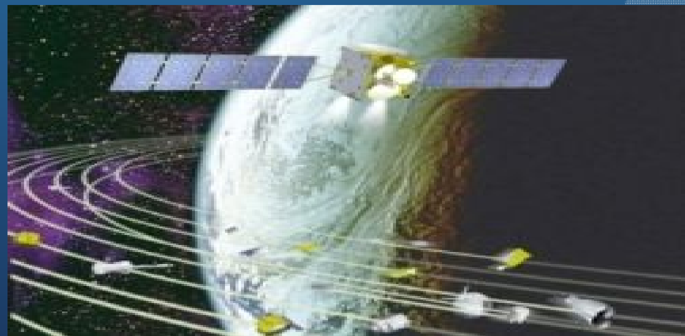
NON-TRACKABLE PROBABILISTIC RISK MODELS “TAKE THE HIT”	TRACKABLE PREDICTABLE EVENTS “GET OUT OF THE WAY”

MMOD <1 cm
Passive shielding

1 cm < MMOD < 10 cm
Passive shielding

MMOD > 10 cm
Collision avoidance manoeuvre





Space Situational Awareness (SSA)

- Aims towards a full knowledge of the dynamic near-Earth space environment

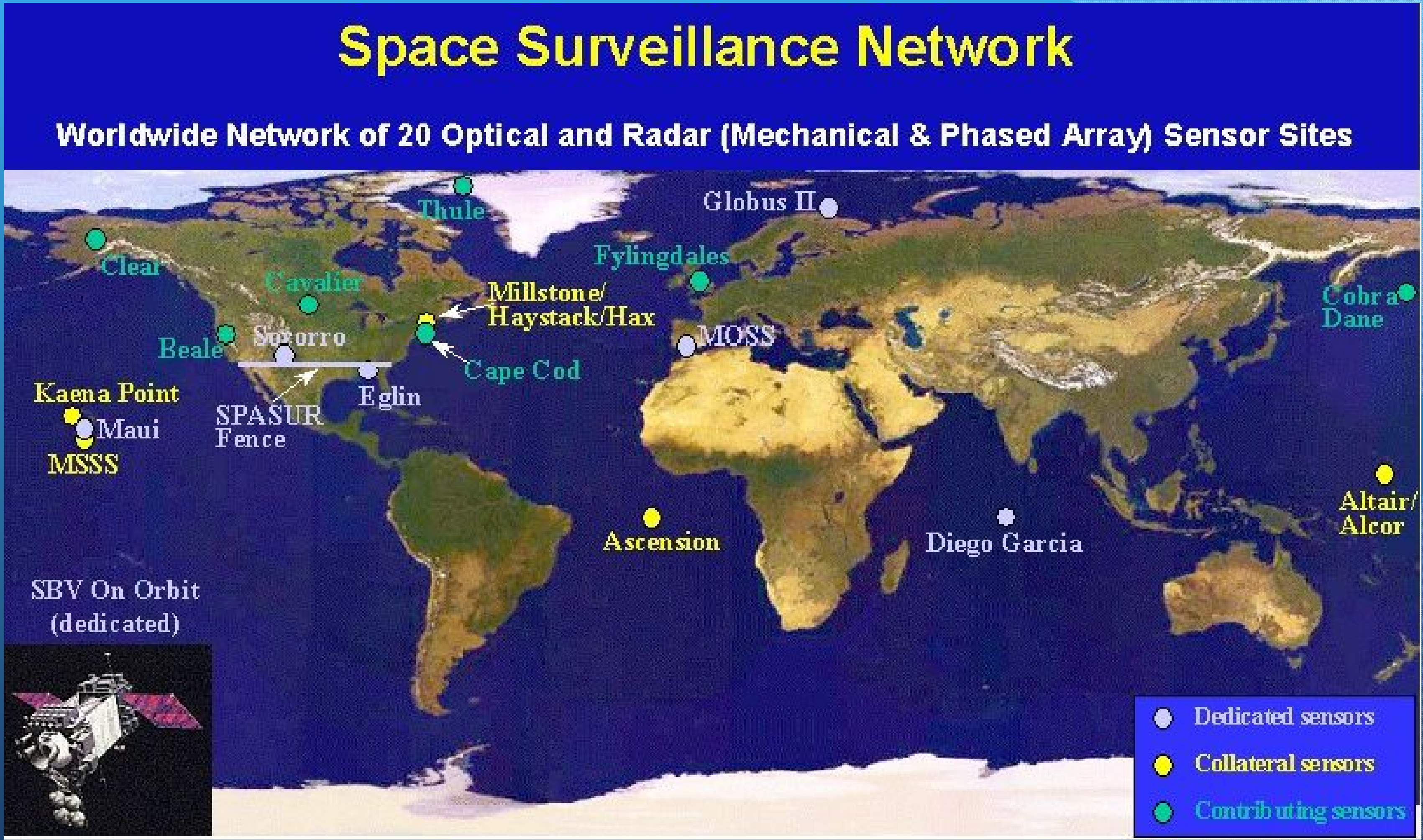
- Three main pillars of SSA
  - Space weather
  - Space debris
  - NEOs

- Makes use of a variety of optical and radar techniques

- Requires coordinated, multisite networks of sensors
  - On Earth (& in space)

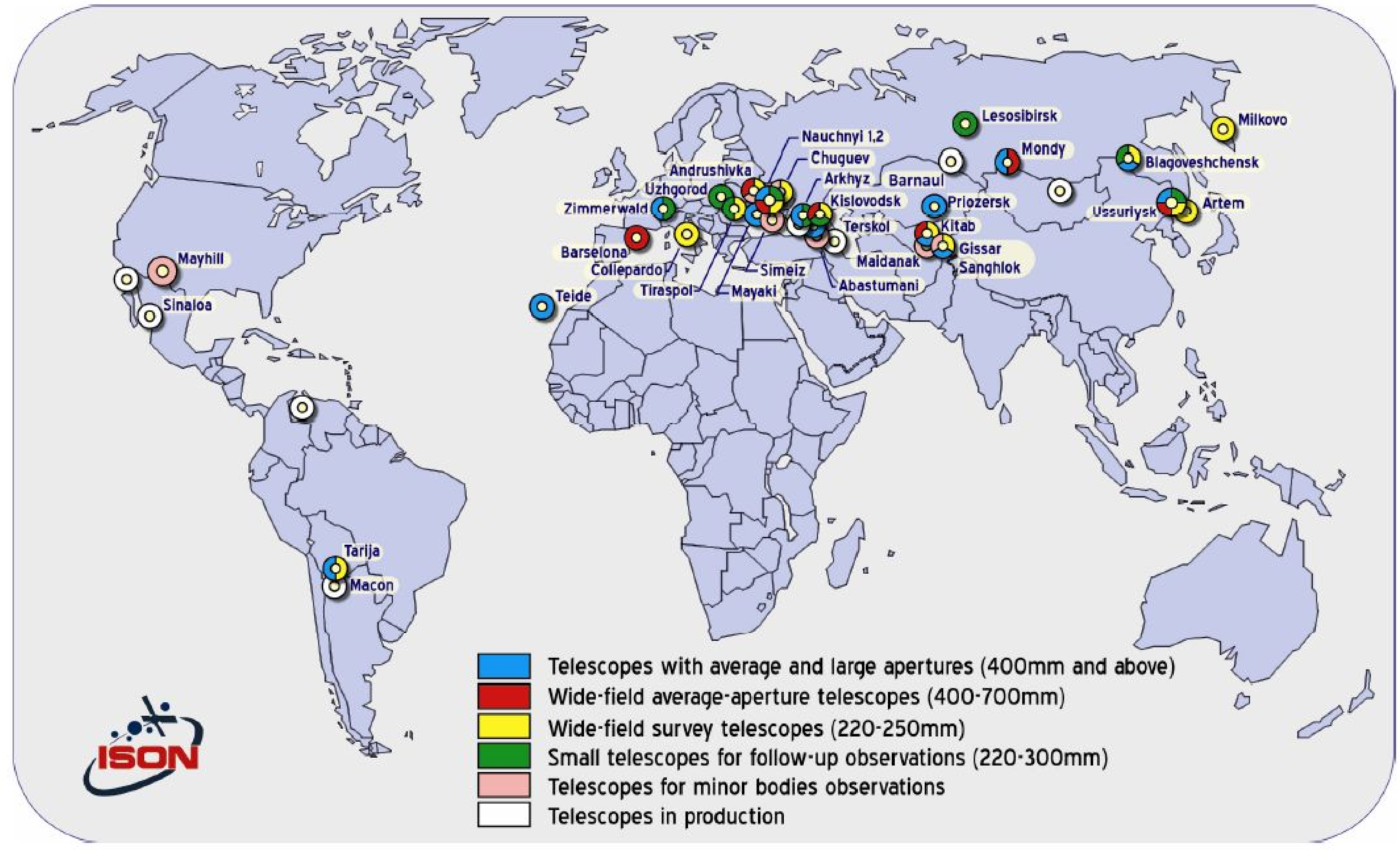
http://globalssasensors.org/

SSA Networks - SSN



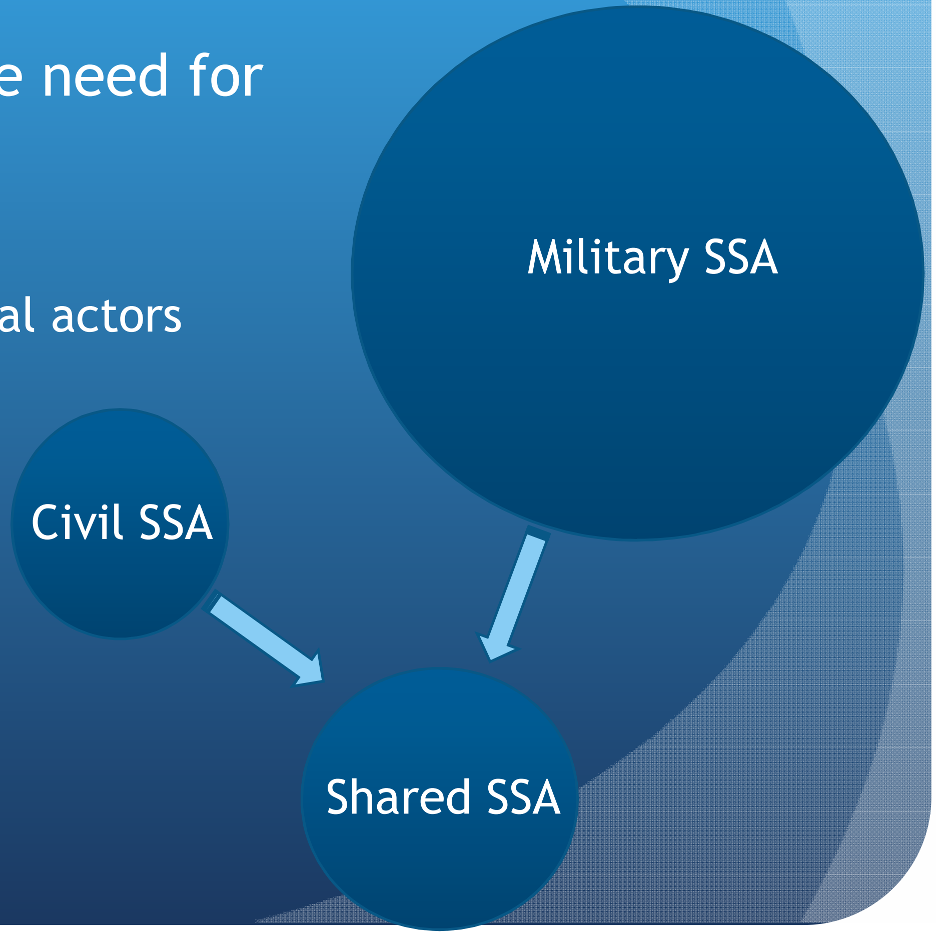
Public satellite catalog at http://www.space-track.org

SSA Networks - ISON



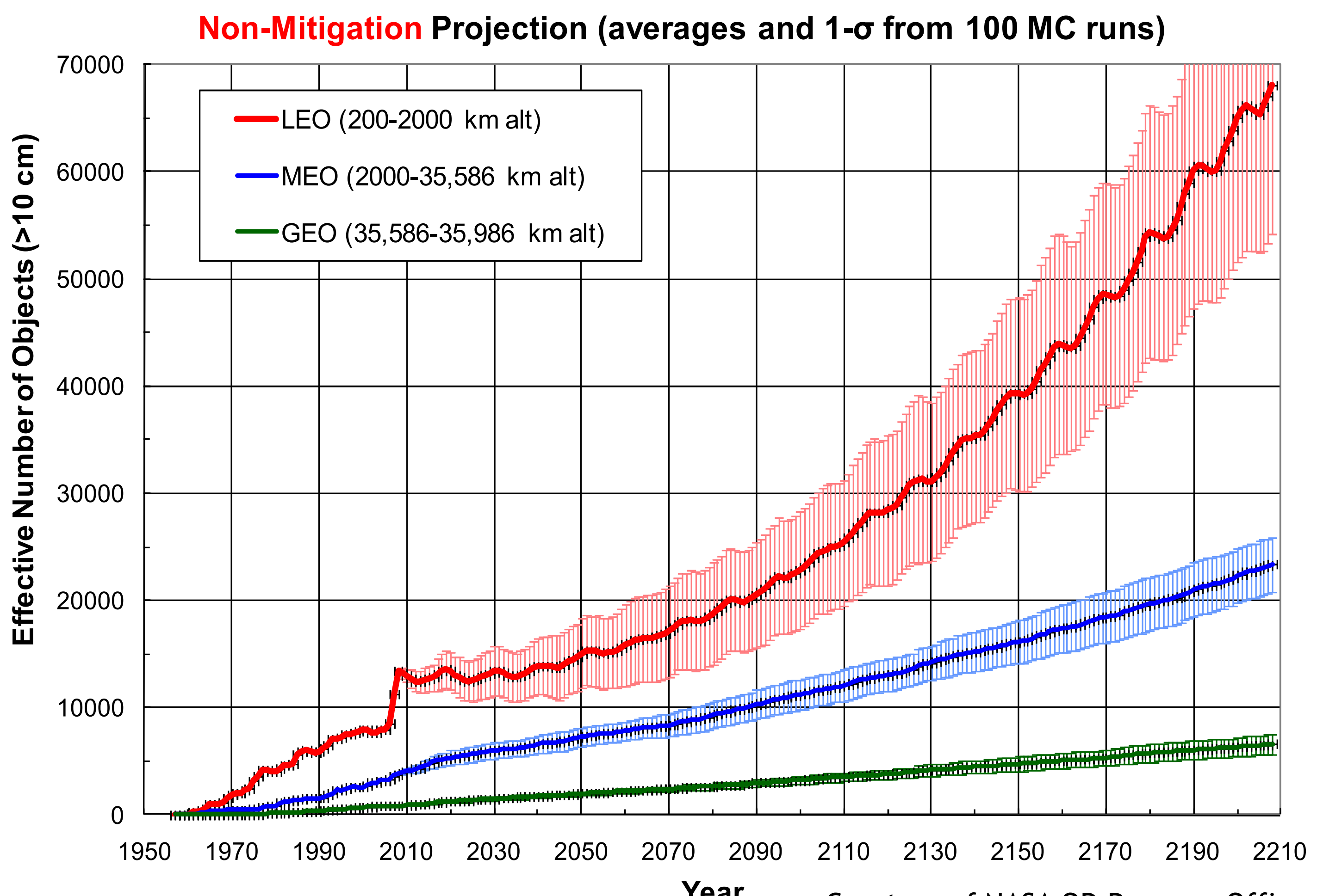
SSA – Broadening the SSA base

- Currently, almost all SSA is done for ***military purposes***
- Emerging recognition of the need for
  - Civil SSA to support safety
  - Sharing of SSA between
    - Government and commercial actors
    - With other governments
    - With the public



Active debris removal (ADR)

Projected debris growth



Courtesy of NASA OD Program Office


DON'T LITTER
sanitation

The logic of ADR

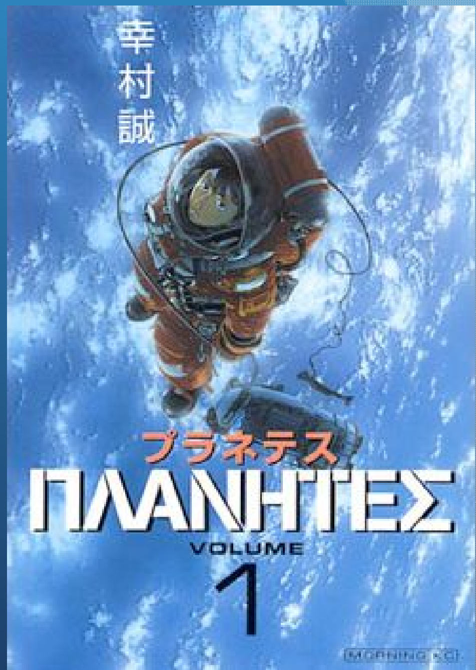
- Biggest current debris problem is in LEO
- Future debris most likely to derive from fragmentations of large spacecraft and rocket stages left in orbit
- Removing 5-10 large debris objects per year from LEO would slow down long-term debris growth
- Technologies vary depending on the orbital region and size and type of object

Active debris removal ideas

Depends on whether target is cooperating or not, size/mass and orbit, ….

- Laser ablation
- Magnetic coupling
- Sweeping surfaces
- Foam / Aerogel
- Thrust
- Capture vehicle

- Tethers
- Tentacles
- Basket / Net
- Sail
- ???



ADR is not a new idea!

For two hundred years, satellites of all shapes and sizes, from loose nuts and bolts to entire space villages, had been accumulating in Earth orbit. All that came below the extreme elevation of the Tower, at any time, now had to be accounted for, since they created a possible hazard. Three-quarters of this material was abandoned junk, much of it long forgotten. Now it had to be located, and somehow disposed of. Fortunately, the old orbital forts were superbly equipped for this task. Their radars - designed to locate oncoming missiles at extreme ranges with no advance warning - could easily pinpoint the debris of the early Space Age. Then their lasers vaporized the smaller satellites, while the larger ones were nudged into higher and harmless orbits.

The Fountains of Paradise
Arthur Clarke.
Published by Ballantine in 1978

The challenges of ADR

- ADR is unproven
  - Many technical challenges - need to demonstrate technologies
  - Runs risk of creating more debris than it removes
- ADR is expensive
  - Little economic incentive to remove debris
  - Most debris is in LEO, where few commercial entities operate
- Challenges include
  - No internationally agreed definition of space debris
  - Developing an international cooperative approach to debris removal

Legal frameworks

International legal framework

- Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the "Outer Space Treaty") 1967;
- Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (the "Rescue Agreement") 1968;
- Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention")1972;
- Convention on Registration of Objects Launched into Outer Space (the "Registration Convention") 1976;
- Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (the "Moon Agreement") 1984.

Domestic legislation

- National legislation domesticates international treaty obligations
- National register of space objects
- Licensing and other regulatory practices allows States to implement non-binding international norms into national practices
- Non-binding does not mean non-legal

Some proposed multilateral voluntary and legal measures

UN COPUOS Space Sustainability WG

- Working Group on Long-Term Sustainability of Outer Space Activities to produce a report on space sustainability and a set of best-practise guidelines for safe and sustainable space activities
- Voluntary – not binding
- Four expert groups have been established to develop the draft guidelines
  - **Expert Group A: Sustainable space utilization supporting sustainable development on Earth**
    CO-CHAIRS: FILIPE DUARTE SANTOS (PORTUGAL), ENRIQUE PACHECO CABRERA (MEXICO)
  - **Expert Group B: Space Debris, Space Operations and Tools to Support Collaborative Space Situational Awareness**
    CO-CHAIRS: RICHARD BUENNEKE (USA), CLAUDIO PORTELLI (ITALY)
  - **Expert Group C: Space Weather**
    co-CHAIRS: TAKAHIRO OBARA (JAPAN), IAN MANN (CANADA)
  - **Expert Group D: Regulatory Regimes and Guidance for Actors In the Space Arena**
    CO-CHAIRS: SERGIO MARCHISIO (ITALY), ANTHONY WICHT (AUSTRALIA)

UN GGE on TCBMs

- UN Group of Govt Experts on Transparency and Confidence Building Measures (TCBMs) for Outer Space Activities
- UN General Assembly Resolution A/Res/65/68 of 2010
- 15 Experts selected for geographical balance & knowledge
- The GGE is to conduct a study on outer space transparency and confidence-building measure
  - making use of relevant reports of the UN Secretary-General
  - without prejudice to the substantive discussions on the prevention of an arms race in outer space within the framework of the CD
  - and to submit to the General Assembly at its sixty-eighth session (in 2013) a report with an annex containing the study of governmental experts
- TCBMS are meant to be voluntary and not legally binding

Code of Conduct

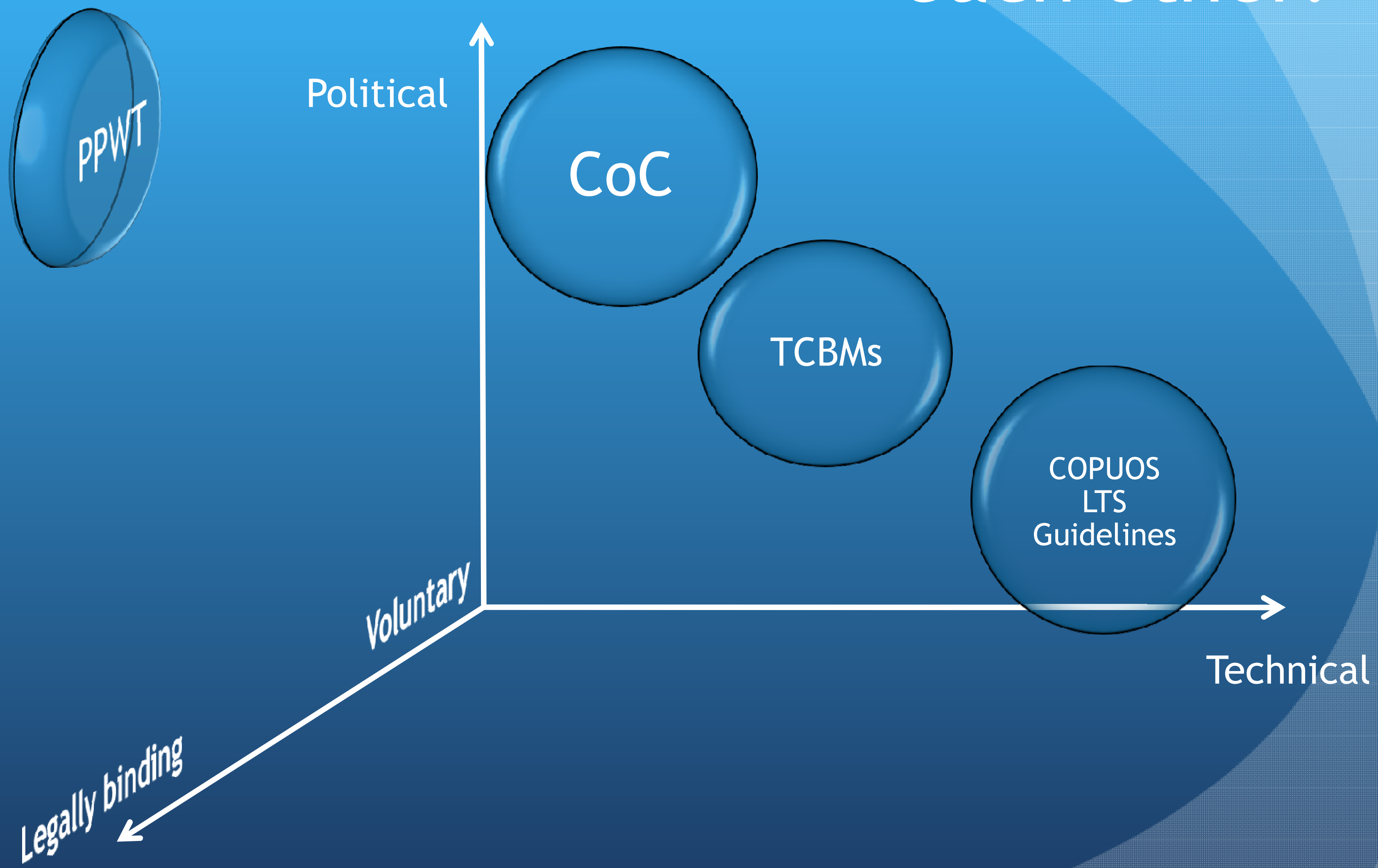
- Proposed by EU
- Principles
  - freedom for all to use outer space for peaceful purposes
  - preservation of the security and integrity of space objects in orbit
  - due consideration for the legitimate security and defence interests of States
- All-encompassing in scope
- Focuses on establishing norms of behaviour and proscribing irresponsible behaviours
- Not legally-binding, a political commitment

EU lacks a multilateral mandate. Process needs to be “multilateralised”

Conference on Disarmament (CD)

- Some States believe that conflict in outer space would have such terrible consequences that they would like to ban the use of weapons in space through a legally binding treaty
  - However, there are definitional problems
- CD has discussed Prevention of an Arms Race in Outer Space (PAROS) for a number of years
- However, CD is deadlocked because States cannot agree on its agenda, so there has been no progress on PAROS
- In 2008 China and Russia introduced draft Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects (PPWT)
- PPWT has support of many States, but not all, because of definitional issued and verification concerns of the PPWT

How do these initiatives relate to each other?



What can APRSAF do to promote space sustainability?

- Educate and raise awareness of space sustainability issues in the region
- Encourage States in the region to
  - Ratify and implement existing space Treaties
  - Develop domestic legislation and build capacity in space law
  - Adopt internationally accepted best practices (eg COPUOS SDMGs)
- The strength of APRSAF is its pragmatic, voluntary, open and flexible approach and also its network in the Asia-Pacific Region
- APRSAF could consider placing space sustainability on its agenda
  - Adoption of SDM practices and standards
  - Develop SSA capabilities and info sharing procedures
  - Engagement with commercial sector in the region
  - Share legal and regulatory expertise