



Reflections on Orbital Debris Mitigation Measures

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near-Earth satellite population reflects use of space

>17000 tracked objects concentrated in distinct orbits

with unique characteristics

CATEGORIES OF TRACKED OBJECTS

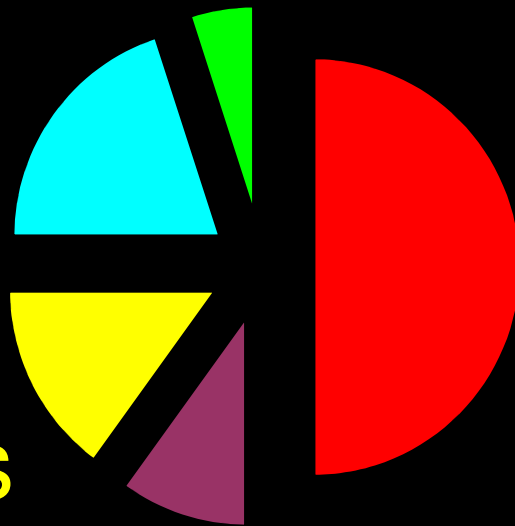
mission
related
objects

operational
spacecraft

rocket
bodies

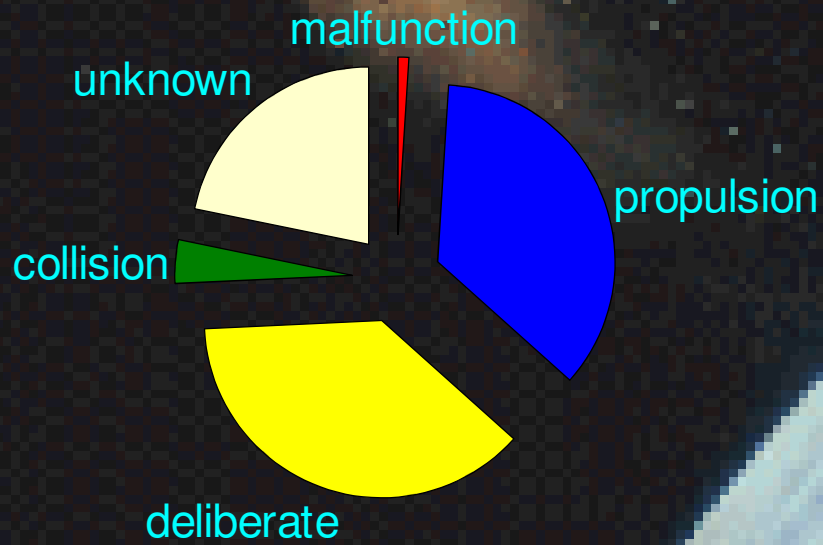
defunct
spacecraft

fragments

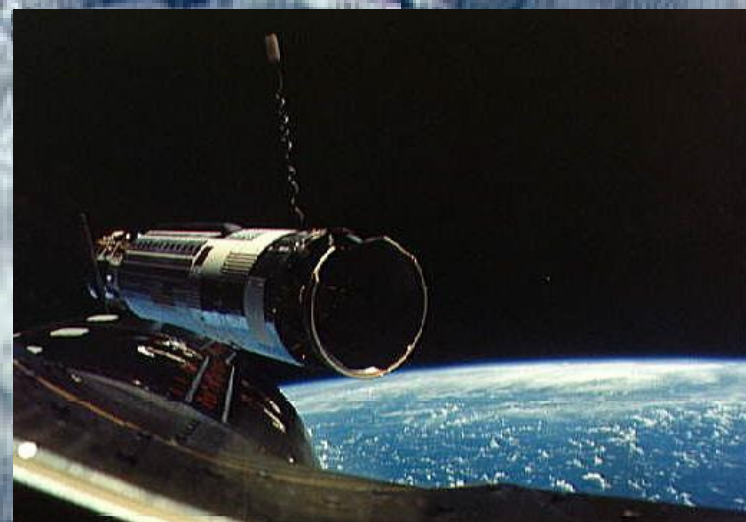


FRAGMENTS

>250 break-up events



ROCKET BODIES



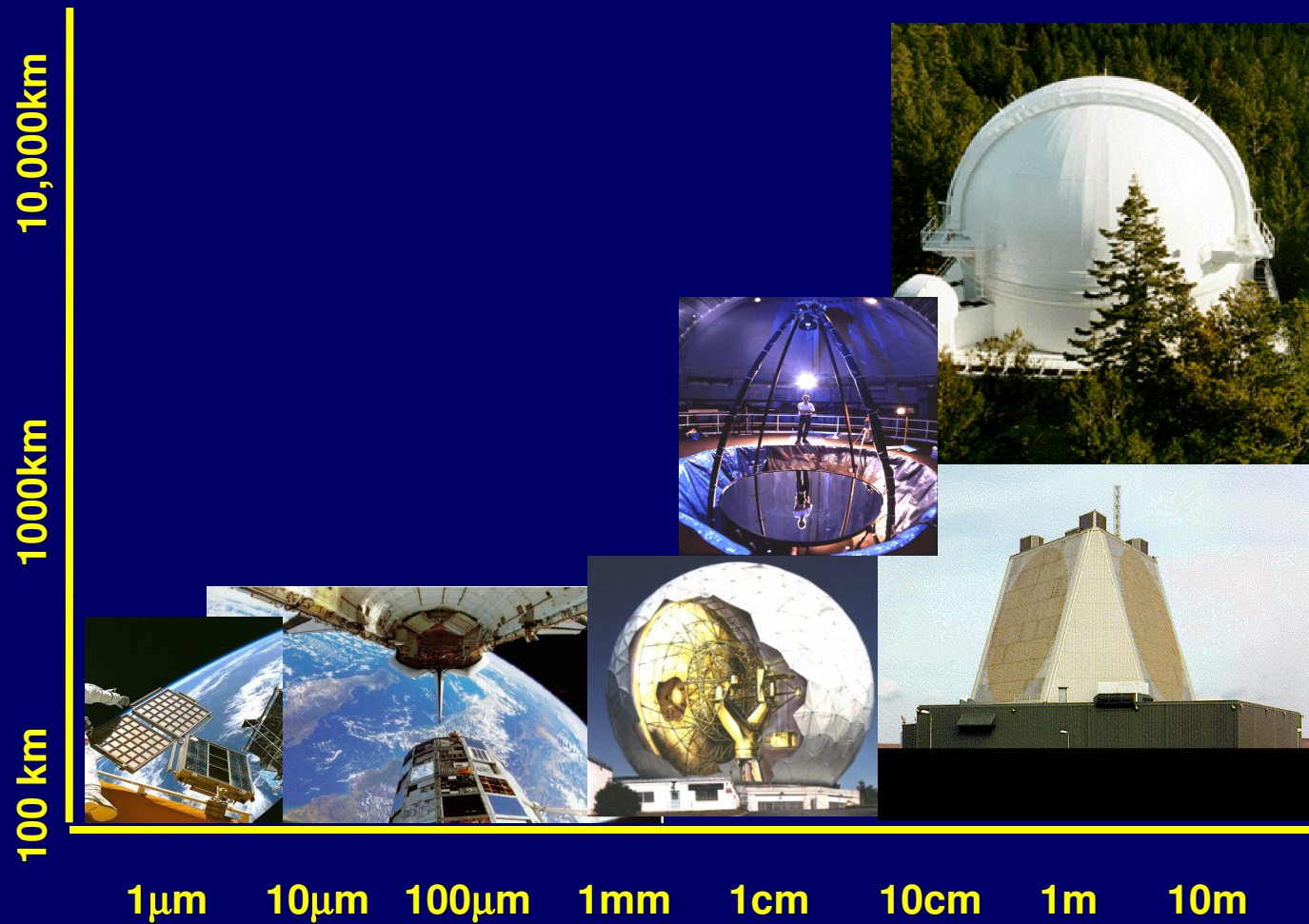
MISSION-RELATED OBJECTS



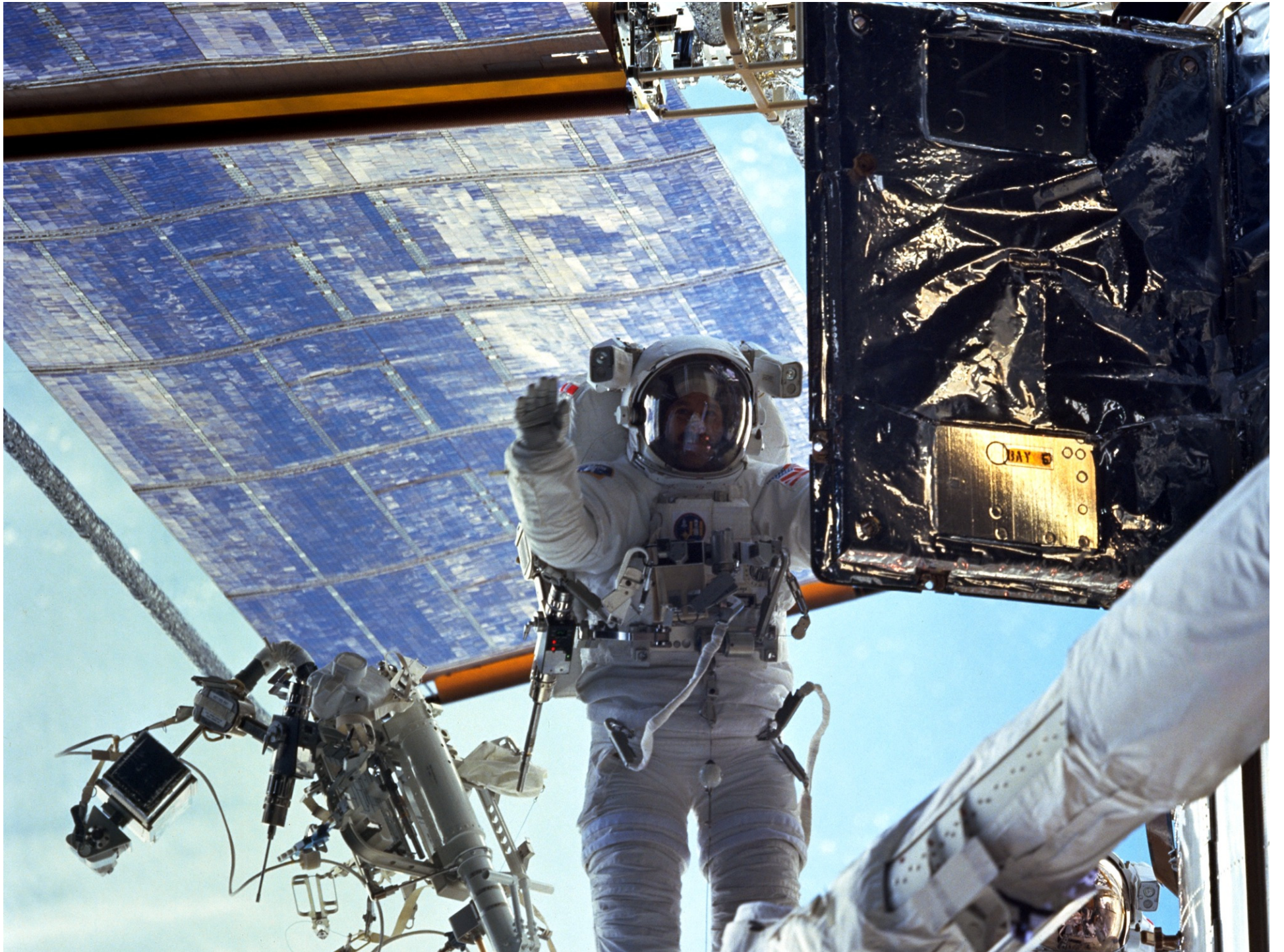
DEFUNCT SPACECRAFT



Estimating the orbital population









T180-2

T180-38

T180-5

T180-7

T180-42

T180-9

T180-10

T180-11

T180-1

T180-40

T180-3

T180-4

T180-6

T180-41

T180-8

T180-44

T180-39

T180-13

T180-14

T180-15

T180-16

T180-17

T180-45

T180-20

T180-46

T180-47

T180-36

T180-18

T180-19

T180-50

T180-21

T180-52

T180-48

T180-22

T180-23

T180-24

T180-49

T180-25

T180-51

T180-26

T180-59

T180-53

T180-54

T180-29

T180-55

T180-58

T180-37

T180-28

T180-30

T180-60

T180-64

H

T180-61

T180-62

T180-34

T180-63

T180-65

T180-35

T180-69

T180-33

T180-32

T180-68

T180-67

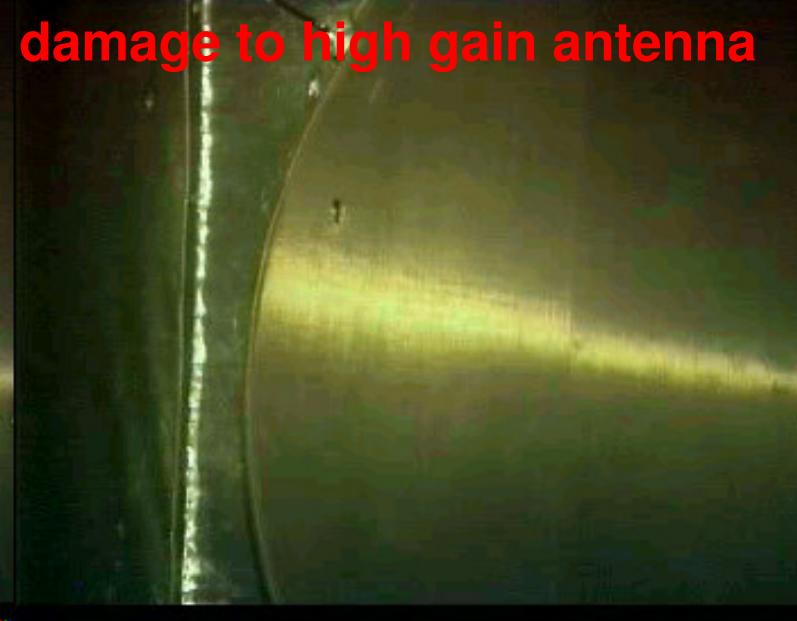
-V3

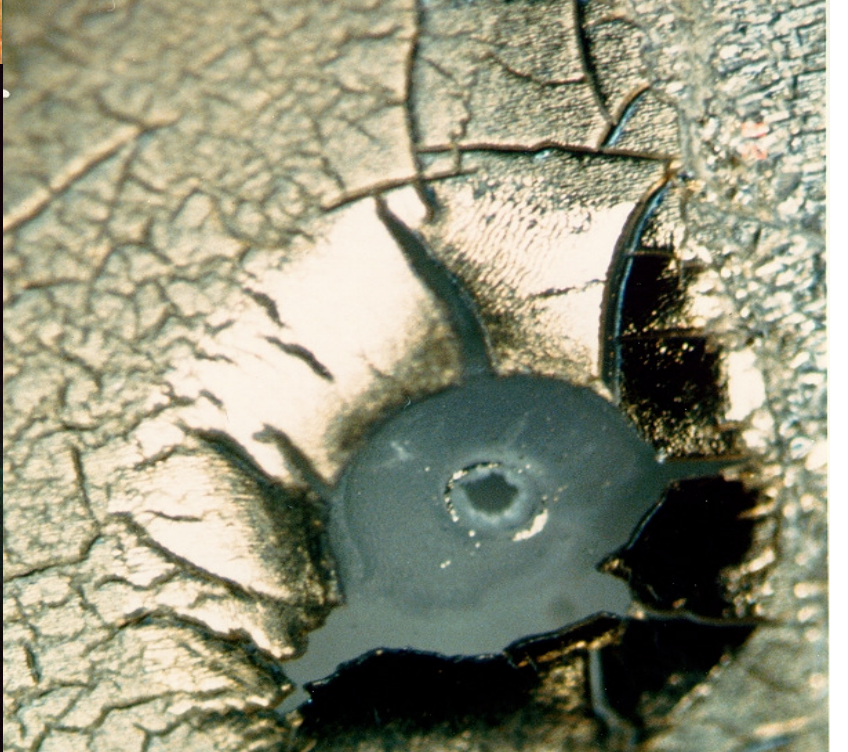
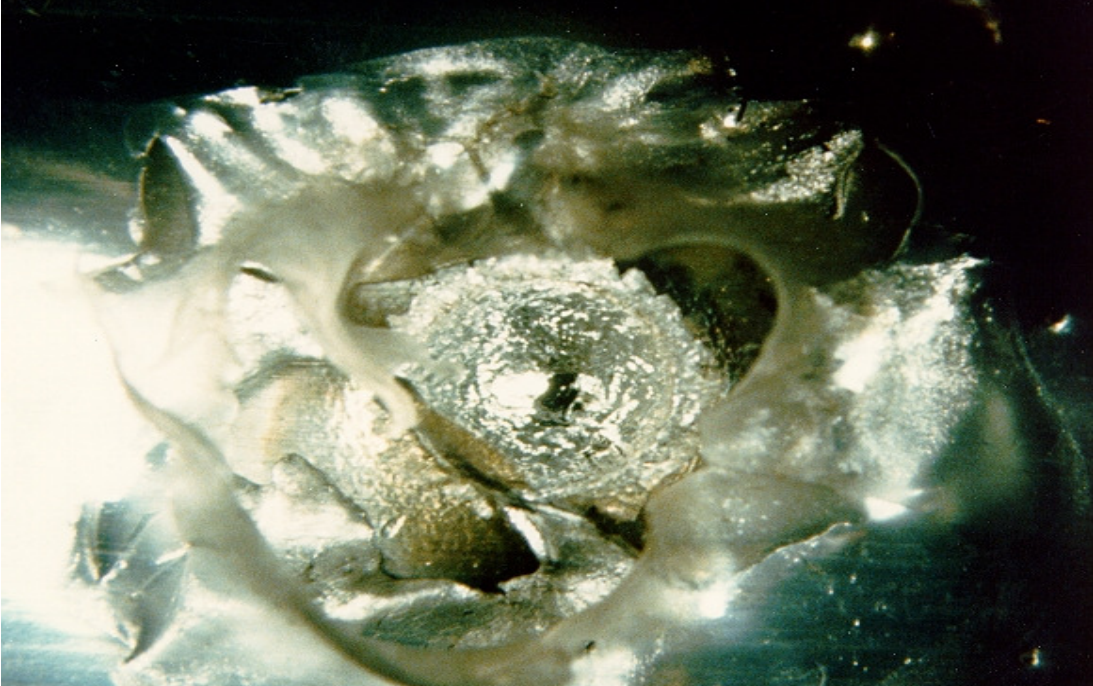
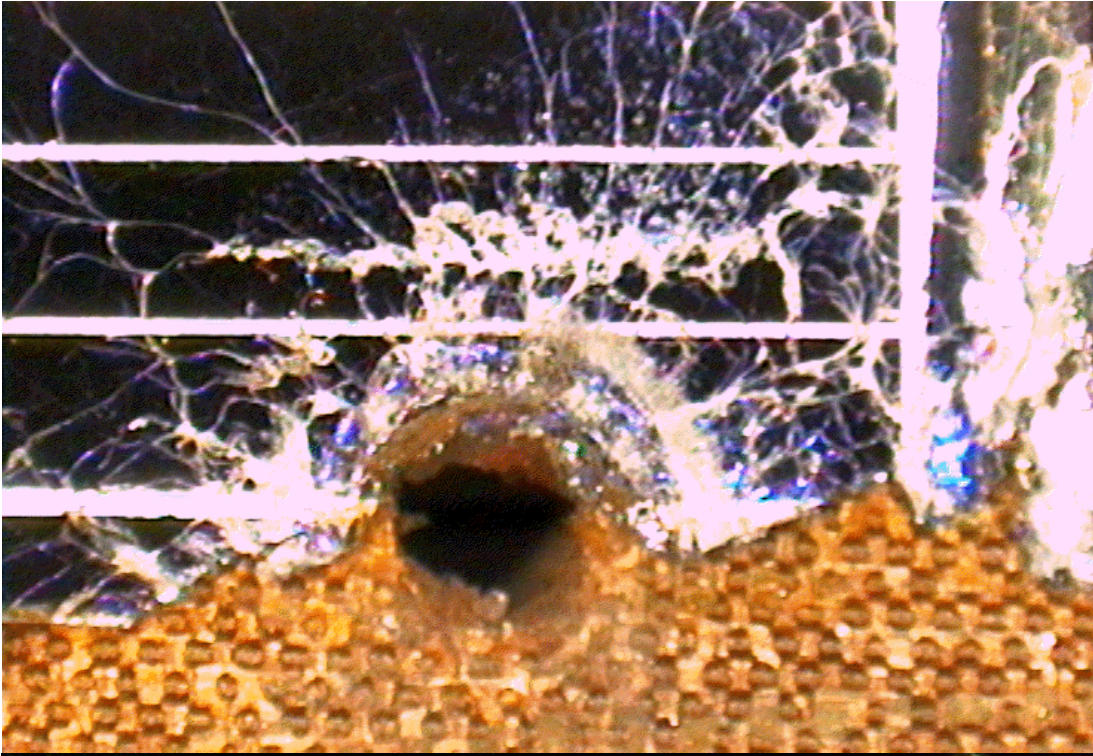
150

180

PHOTO-SURVEY RESULTS

156





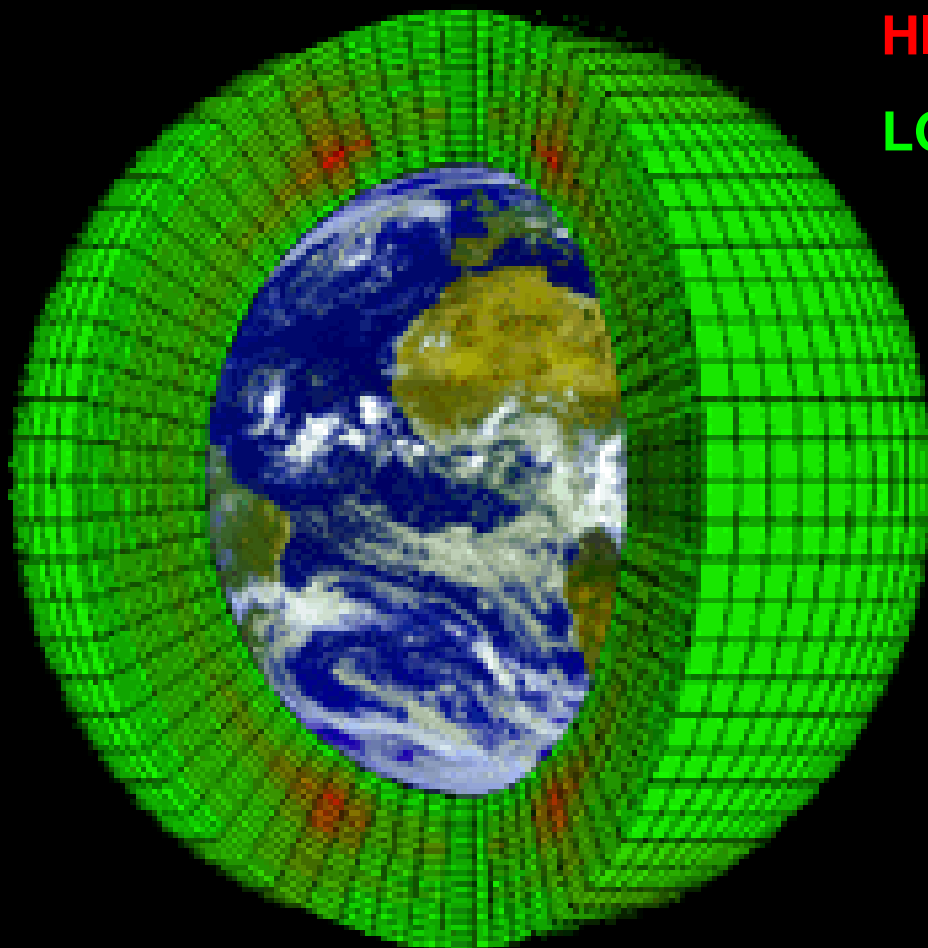
Estimated Orbital Population

<u>Size</u>	<u>Number</u>	<u>% Mass</u>
>10 cm	>17000	99.93
1-10 cm	>400,000	0.035
<1 cm	>35,000,000	0.035
<u>Total</u>	<u>>35,000,000</u>	<u>>6,000 tonnes</u>

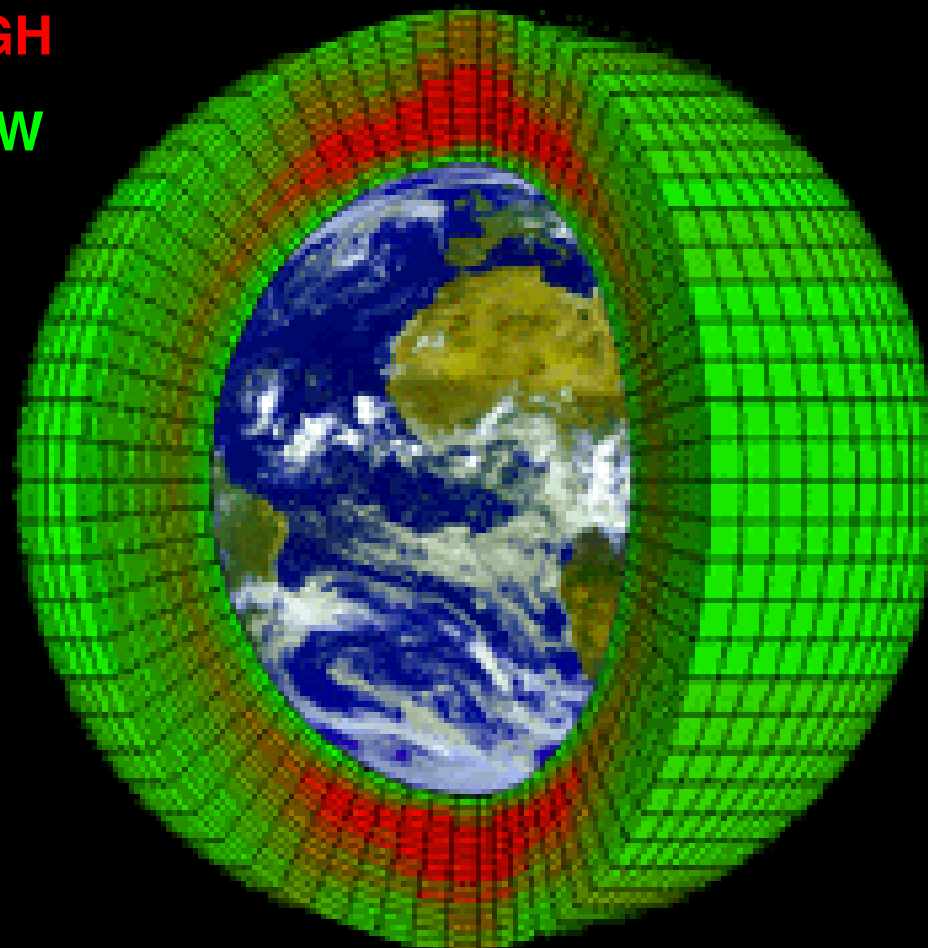
COLLISION PROBABILITY IN LOW EARTH ORBIT

HIGH

LOW

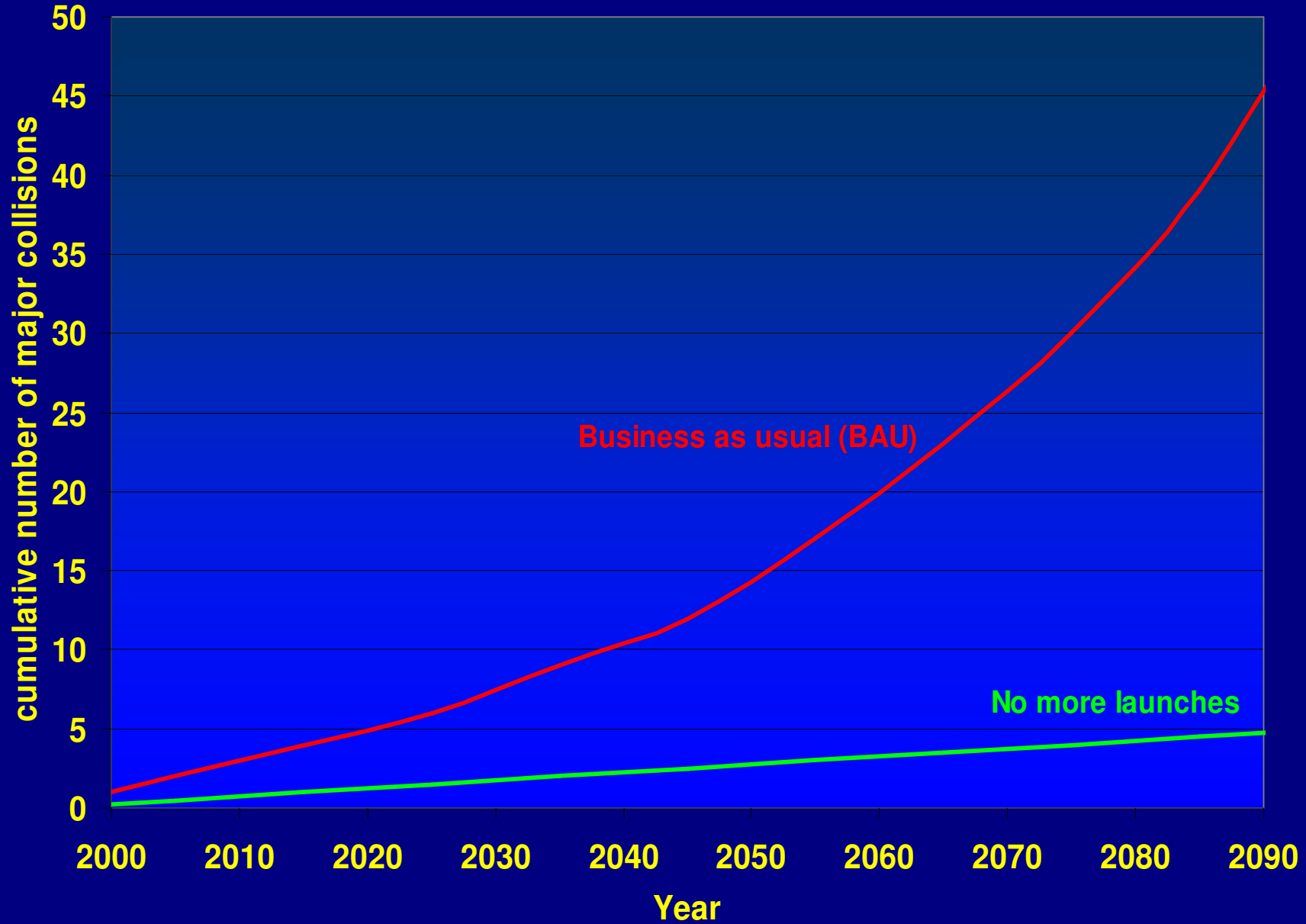


2001



2070

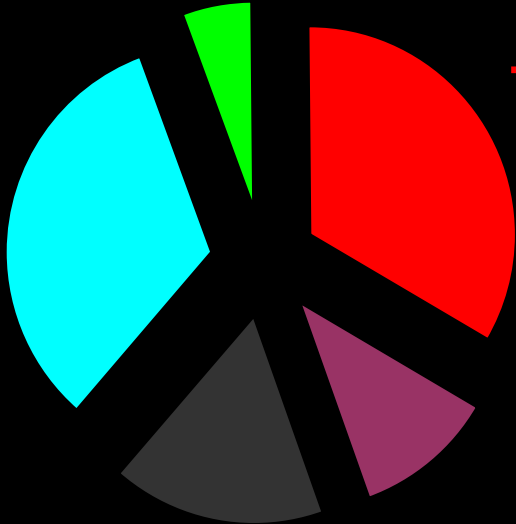
Predicted Major Collisions



operational
spacecraft

mission
related
objects

fragments



rocket
bodies

defunct
spacecraft

protect

operational
spacecraft

reduce
potential for

fragments

avoid
release
of

mission
related
objects



remove

rocket
bodies

&

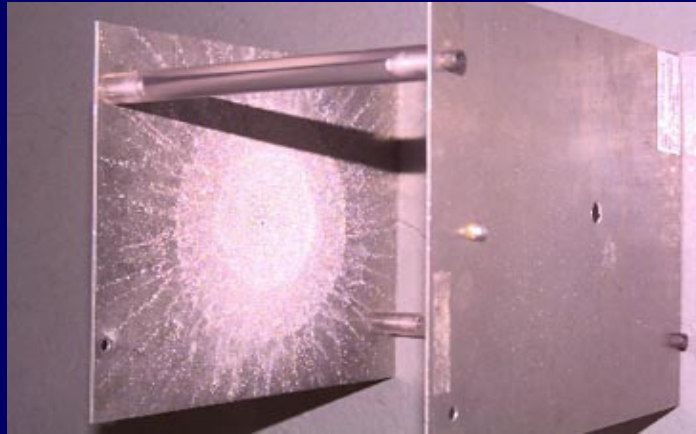
defunct
spacecraft

Predict and Protect

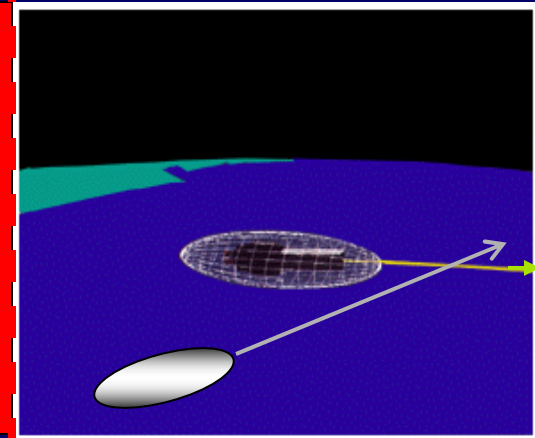


Short Term Partial Solution

SHIELDING



**COLLISION
AVOIDANCE**



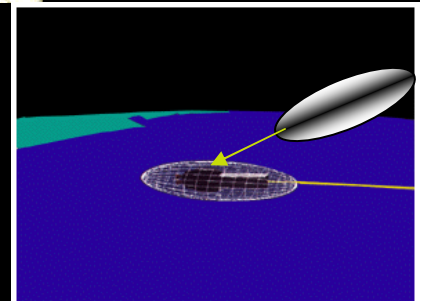
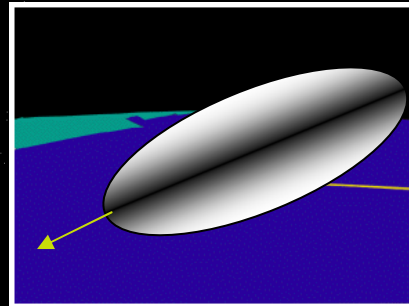
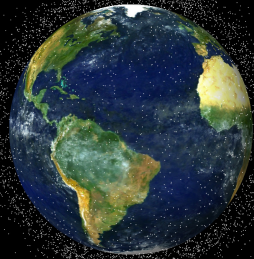
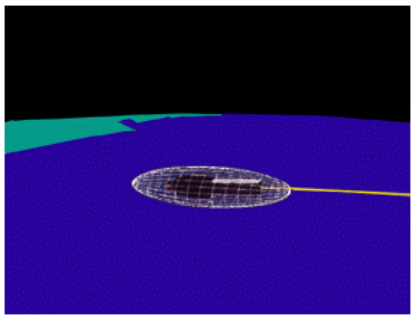
1 μ m 10 μ m 100 μ m 1mm 1cm 10cm 1m 10m

**WHAT IS THE LONG TERM
SOLUTION TO SPACE
DEBRIS?**

Regulation of Space Activities

- **Guidelines and Standards are being developed which promote practices that have been demonstrated to limit space debris**
- **Measures cover impact of missions on environment with focus on:**
 - **Limitation of debris released during normal operations**
 - **Minimisation of the potential for on-orbit break-ups**
 - **Post-mission disposal**
 - **Prevention of on-orbit collisions**
- **Applicable to planned Earth orbiting spacecraft, and existing systems where possible, addressing:**
 - **Mission Planning**
 - **Design**
 - **Operation**

Collision Avoidance



Mitigation Measures

- Residual propellants and other fluids should be depleted
- Batteries should be designed to prevent break-ups and at end of operations charging lines should be de-activated
- High pressure vessels should be vented to ensure no break-ups can occur
- Power to flywheels and momentum wheels should be terminated during disposal phase
- Other forms of stored energy should be assessed and adequate mitigation measures applied
- Potential hazard of both intact and severed tethers should be analysed

V 503

00:43:14.10

V 503

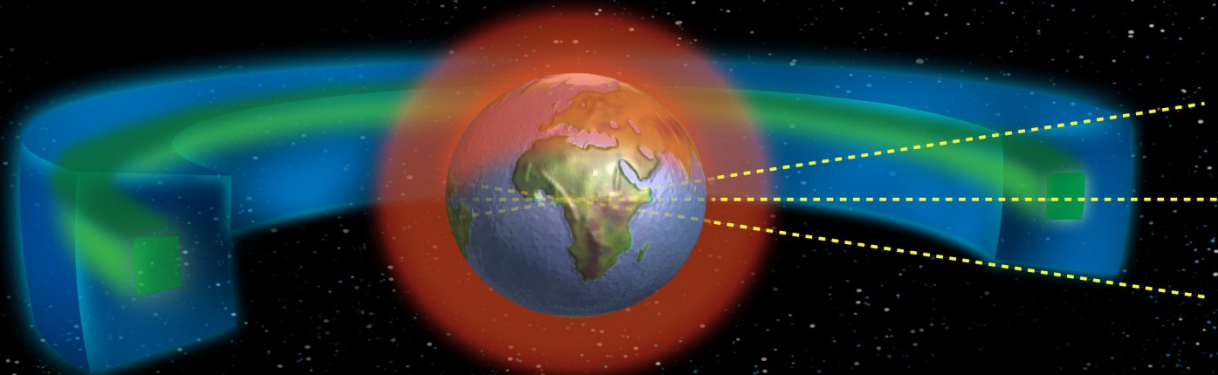
00:43:14.10

Definition of Protected Regions

- **Activities in space should recognise the unique nature of 2 regions in space:**

LOW EARTH ORBIT REGION

Earth surface up to 2000 km



GEOSYNCHRONOUS REGION

Geostationary altitude +/- 200 km

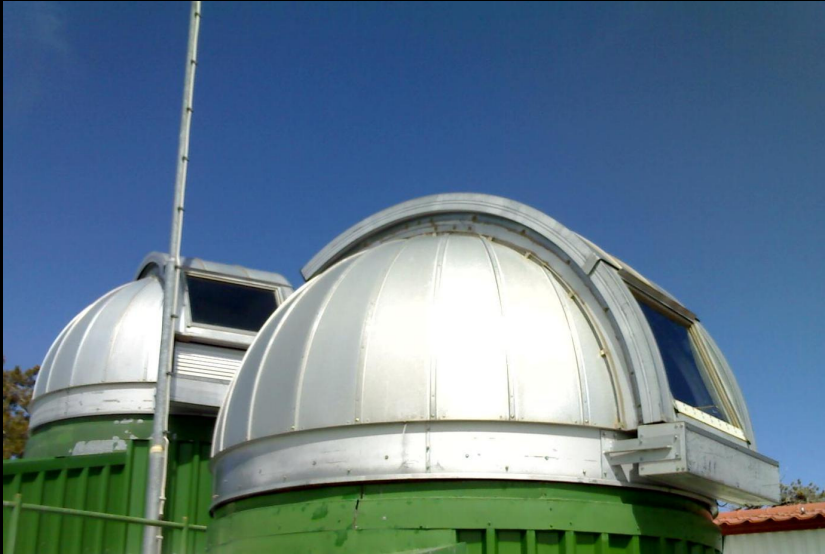
Equatorial latitude +/- 15 deg

Mitigation Measures

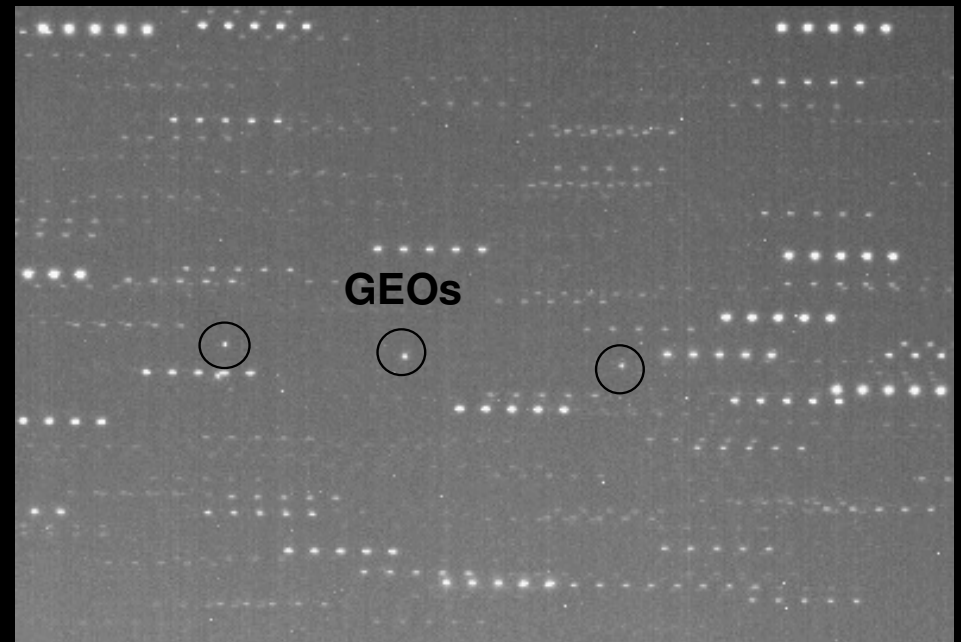
- **Space systems should be designed not to release debris during normal operations**
 - Where this is not feasible, any release of debris should be limited in number, area, and orbital lifetime
- **Project should estimate and limit probability of accidental collision with known objects**
 - If reliable orbit data is available, avoidance of collisions and co-ordination of launch windows may be considered if non-negligible risk
- **During operational phases, system should be monitored to detect malfunctions.**
 - **If recovery measures cannot be conducted, disposal and passivation measures to be applied**



Compliance Monitoring



Starbrook operation by Space Insight commissioned by BNSC in 2006 to monitor UK registered space objects in GEO



Outer Space Treaty
1967

Rescue Agreement
1968

Liability Convention
1972

Registration
Convention 1975

Outer Space Act
1986

Introductory Guidance
Licensing Process, Timescales, Pre-Application Consultation, Initial Screening

Background
Definitions

Responsibilities
Risk
Apportionment

Requirements
Insurance Levels
& Cover

Procedures
MPL Process

**System
Definition
Requirements**

**Risk
Management
Methodologies**

**Safety
Organisation
Responsibility**

Responsibilities
Roles/Timescales

Requirements
Compliance
Criteria

Procedures
E/EA Process

Insurance
Certificate

Maximum
Probable Loss
Analysis

**System
Specifications**

**Risk
Assessment**

**Safety Plans &
Procedures**

Environmental
Assessment

Environmental
Impact Statement

Financial
Assessment

**Safety
Assessment**

Environmental
Assessment

Licence

Lessons Learnt To Date

- **National regulatory activities have been informed by work of COPUOS STSC and in particular the Mitigation Guidelines**
- **STSC work has itself been informed by the work of the Inter-Agency Debris Coordination Committee (IADC)**
- **IADC is currently reviewing its Mitigation Guidelines**
- **We are learning about limitations of effectiveness of measures**
- **Also learning about issues of implementation, and compliance monitoring**
- **We anticipate that new measures will be required to manage the debris environment, and also existing measures will need to be revisited**