Day #2 – Part 1

Part. 1 Introduction		
09:00 – 09:15	Welcome and Overview of the Day	
09:15 – 09:40	Space Debris Mitigation Principles and their Effects	Holger Krag, ESA
09:40 – 10.10	International Guidelines	Thomas Schildknecht, AIUB
10:10 – 10:30	Current Implementation Levels	Stijn Lemmens, ESA
10.30 – 11.00	Coffee Break	

Day #2 – Part 2

Part 2 **Standards and Processes**		
11.00 – 11.30	The GVF Best Practices Document	Dan Oltrogge, AGI
11.30 – 11.45	Space Debris Standards on ISO Level	Dan Oltrogge, AGI
11.45 – 12.00	Debris related subordinated ISO-standards	Vitali Braun, ESA
12.00 – 13.00	Lunch Break	
13.00 – 13.30	Future Debris Management Concepts	Stijn Lemmens, ESA

Day #2 – Part 3

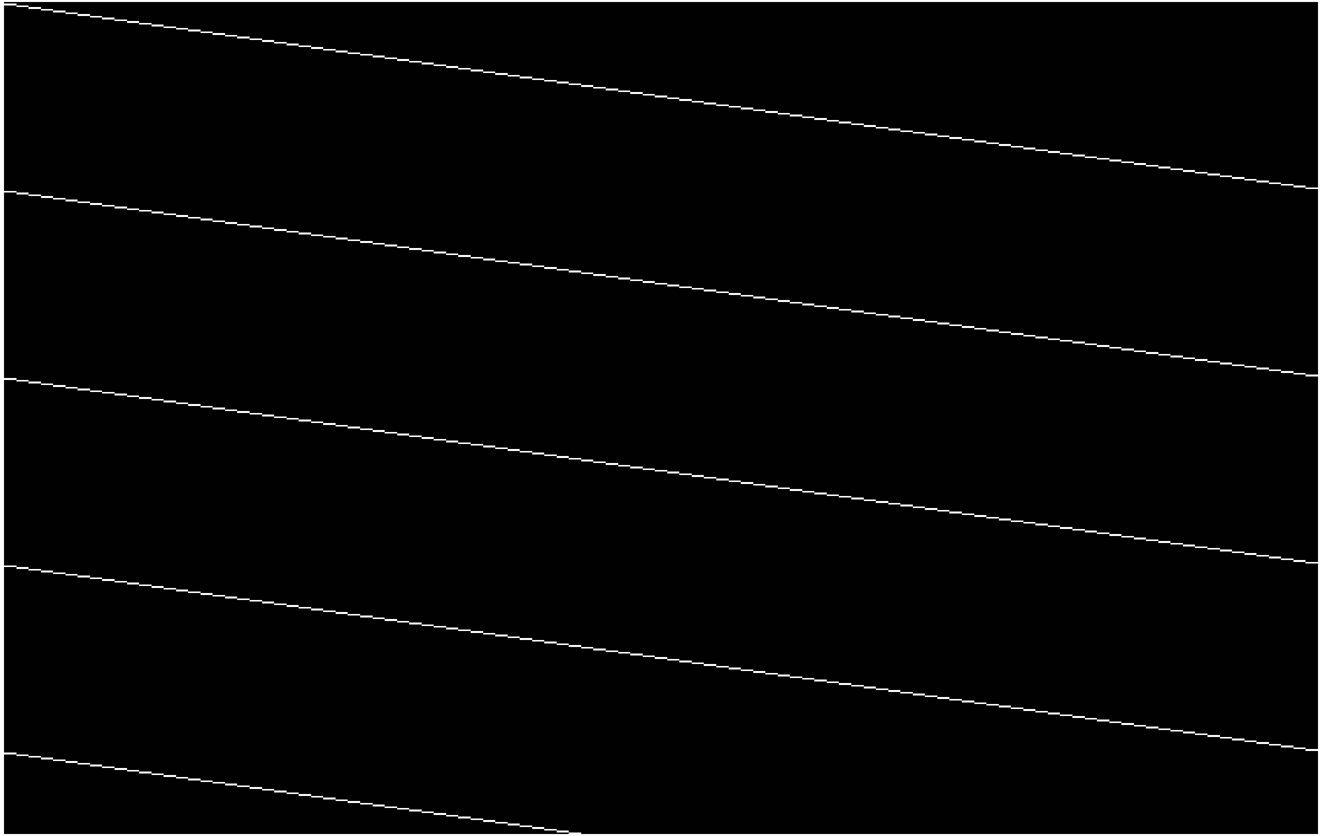
Part 3 Processes and Implementation Examples		
13.30 – 14.30	The ESA Space Debris Mitigation Process, Handbooks and Examples	Rosario Nasca, ESA
14:30 – 15:00	French Process for Debris Mitigation Compliance Verification	Laurent Francillaut, CNES
15:00 – 15:30	The Belgium Space Debris Mitigation Process	Jean-Francois Mayence, BELSPO
15.30 – 16.00	Coffee Break	
16:00 – 16:30	Licensing Space Activities in the era of New Space	Toby Harris, UKSA
16:30 – 17:00	The New Zealand Process for Space Debris Mitigation	Dave Willing, New Zealand Space Agency
17:00 – 17:30	Space Debris Mitigation – Implementation by DLR	Jan Grosser, DLR
17:30	Adjourn	

Space Debris Mitigation Principles and their Effects

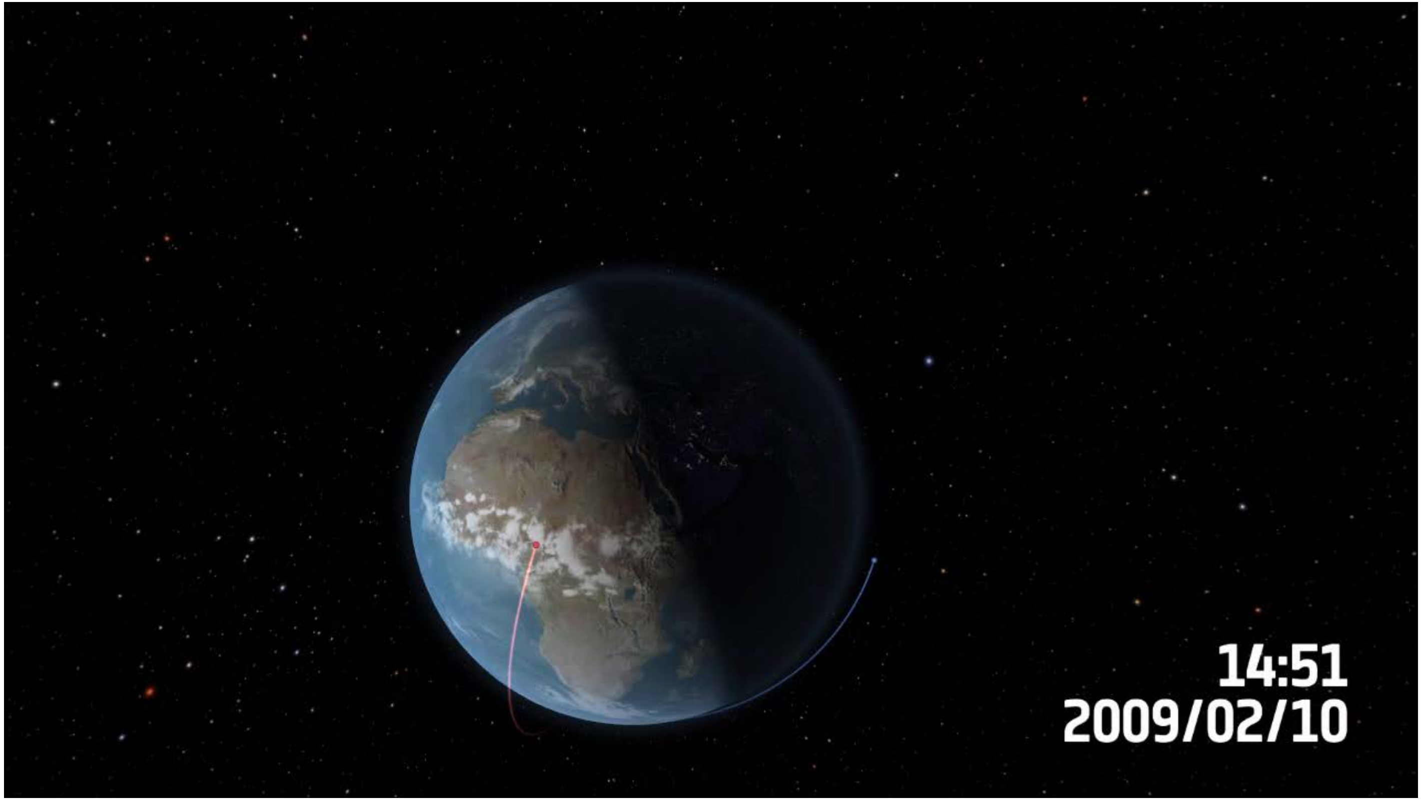
Holger Krag, Head of ESA's Space Debris Office

20/03/2019

Evolution of a Fragment Cloud - Animation

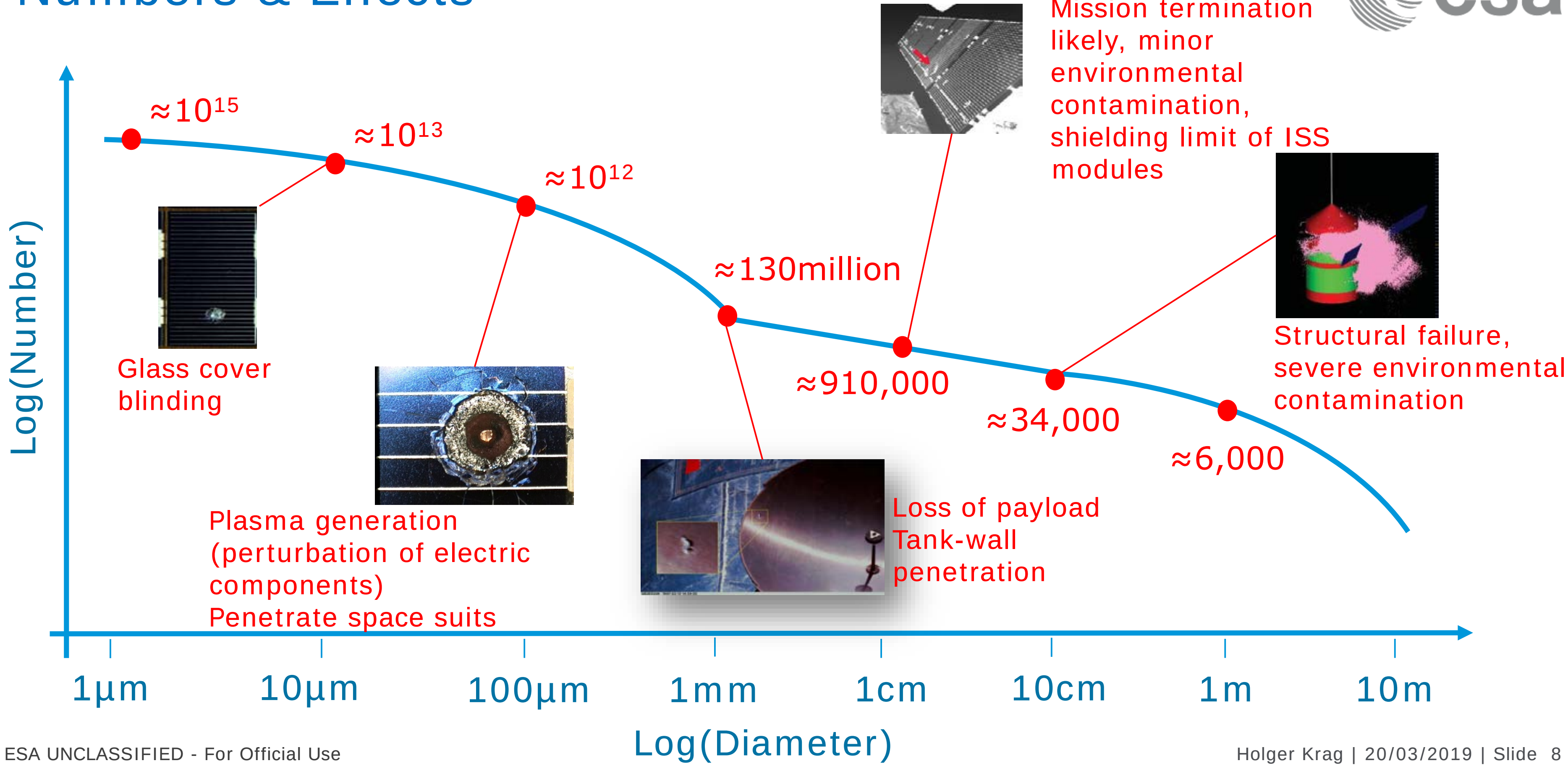


Iridium/Cosmos Collision (Animation)

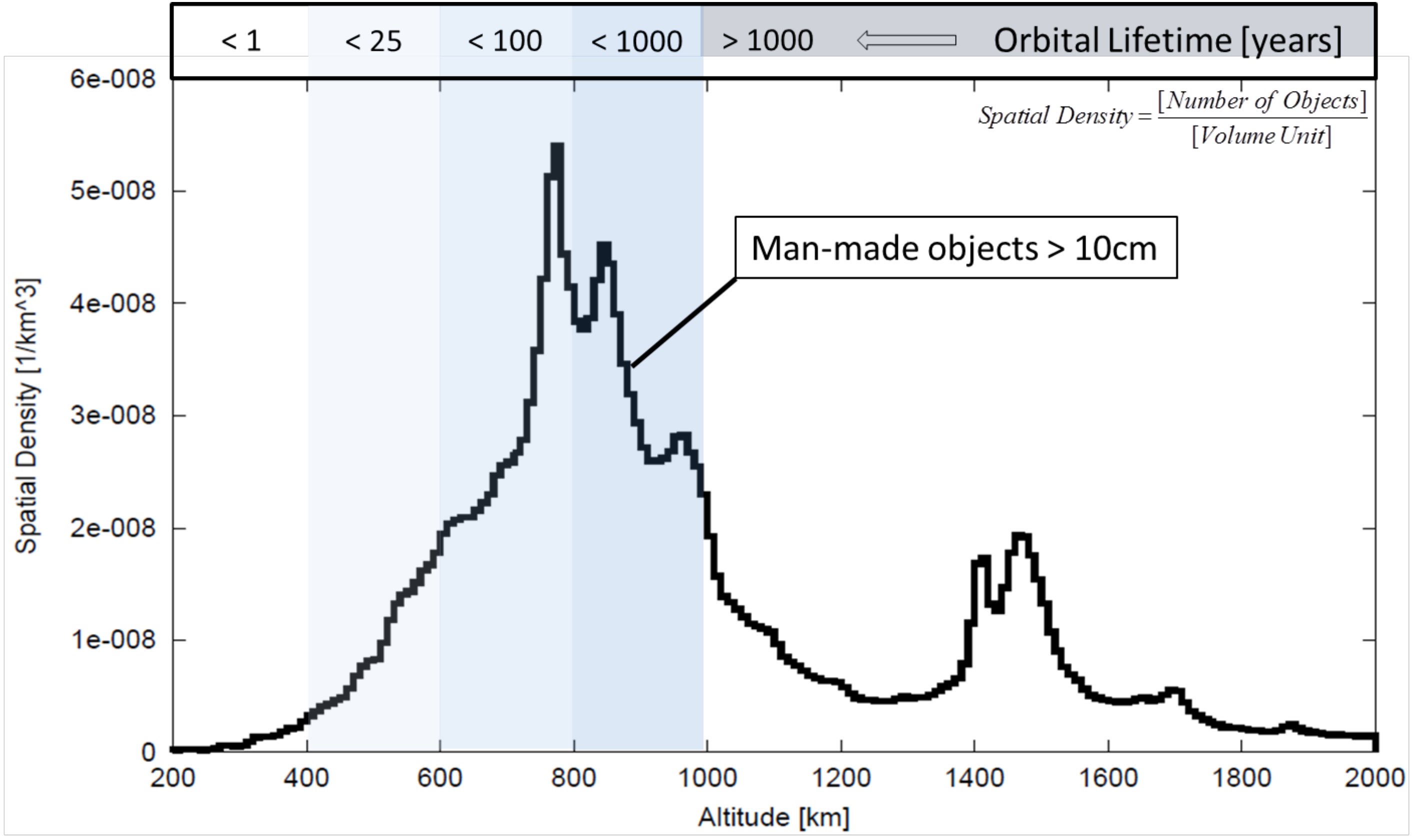



business
as usual
object
count
time
2010

Numbers & Effects



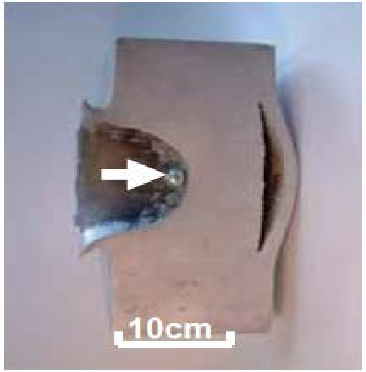
Spatial Density



HVI Impact Test

– HVI sample: impact of an Al-sphere of d = 1.2cm (m ≈ 1.7g)at v = 6.8km/s on an Al-block of diameter 18cm and height 8.2cm
– Crater depths: 5.3cm

Impact Energy



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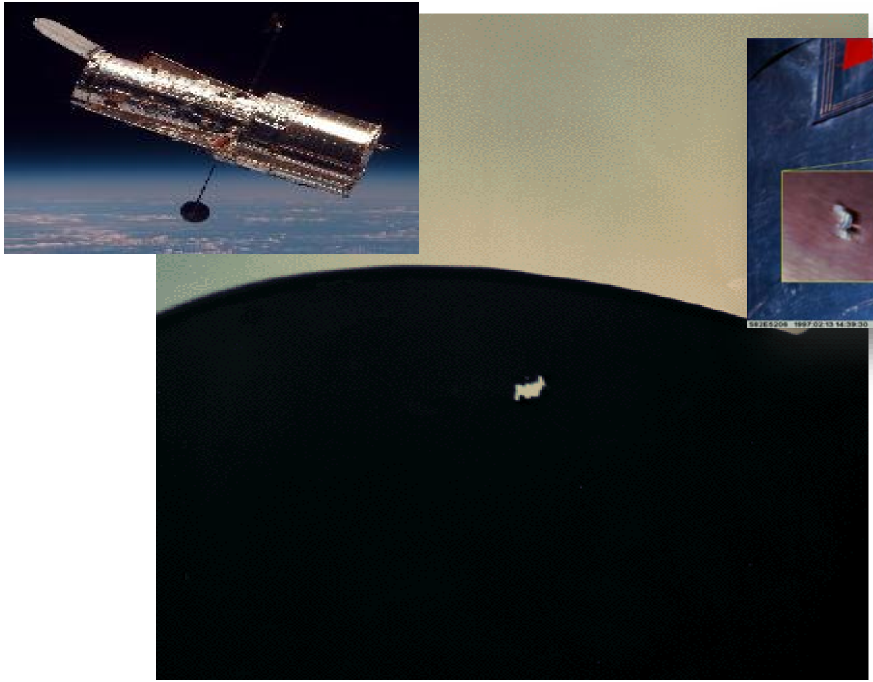
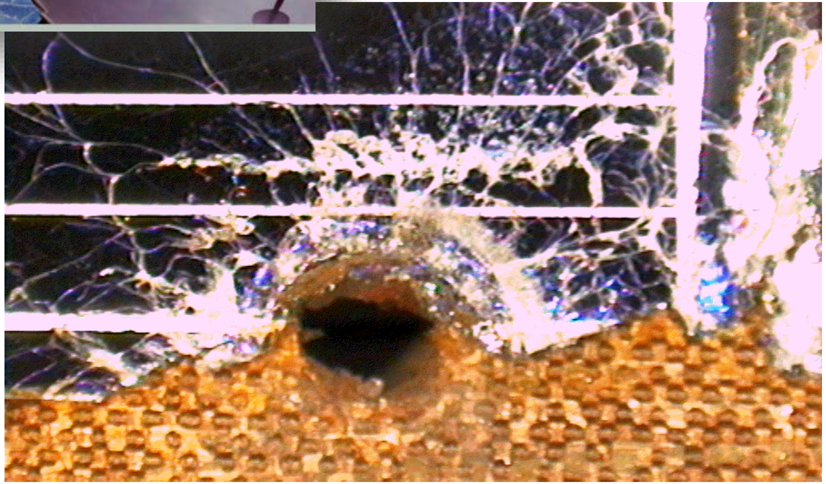
HST Solar Array Retrieval



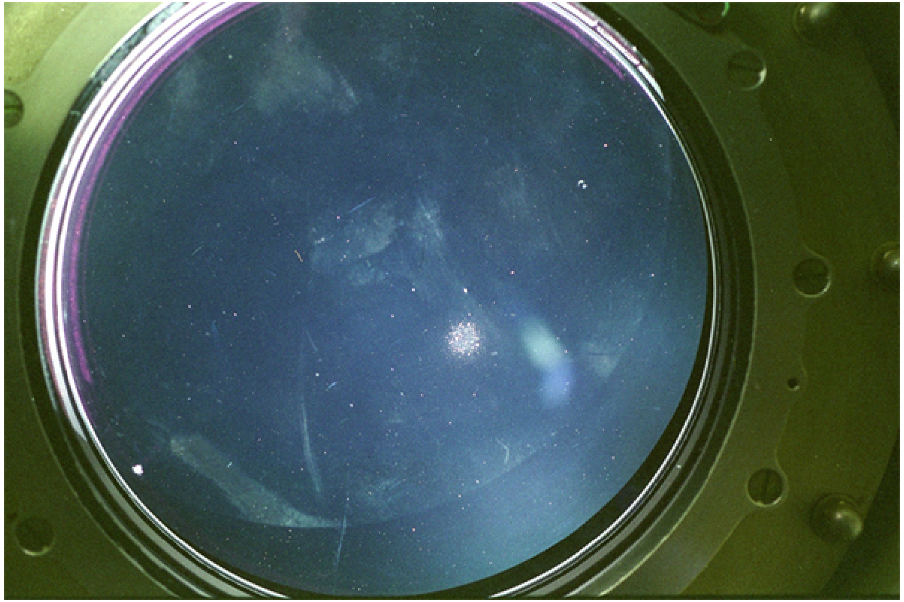
Hole in HST High-Gain antenna
(1,9 cm x 1,7 cm)



Impacts in Solar Arrays

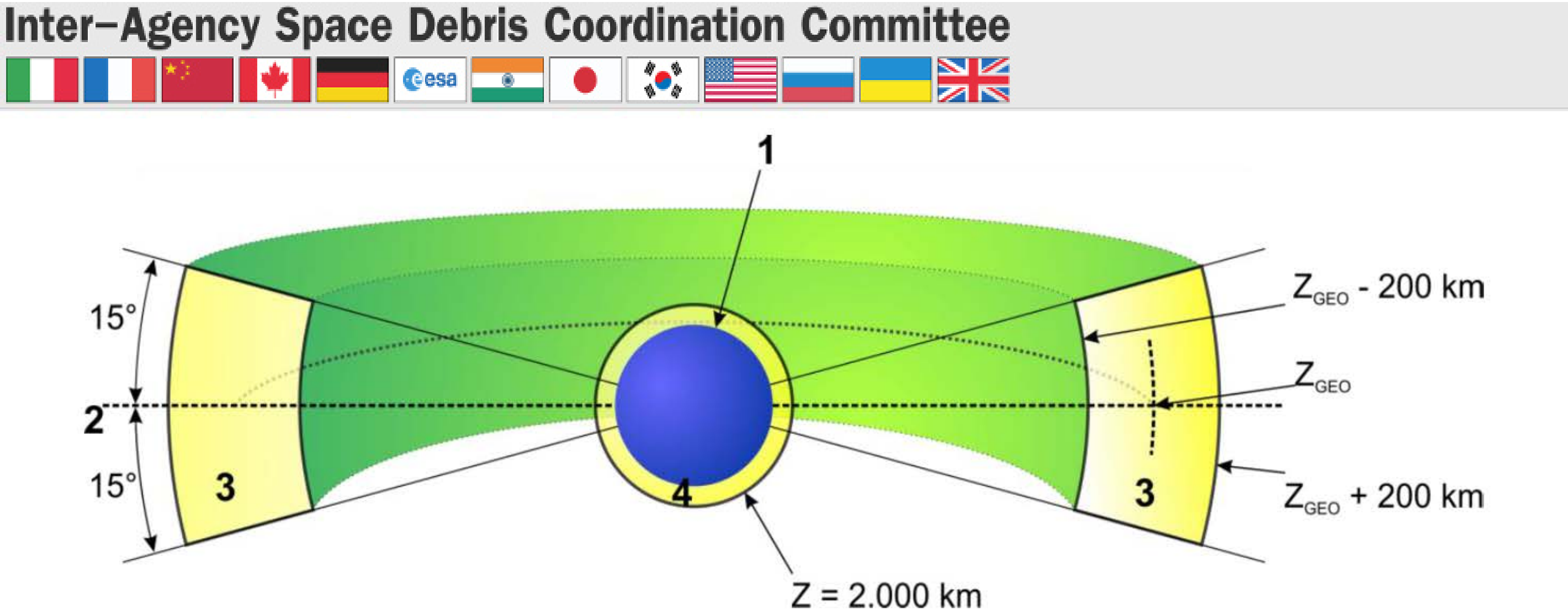
MIR Impact

Mir Station – Starboard Window Service Module Jan 1996



[Source: Thomas Reiter]

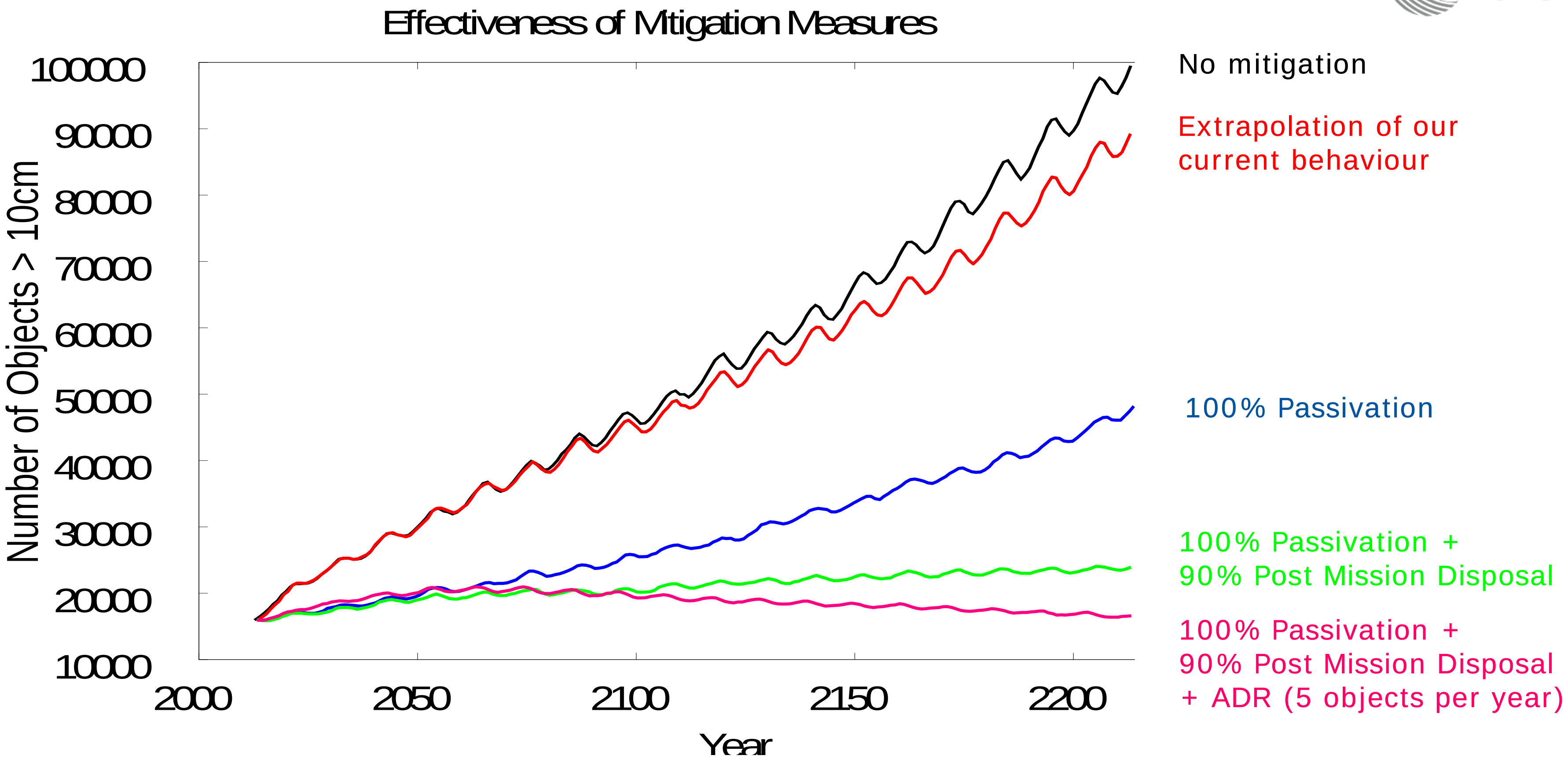
IADC - Protected Regions



Current Guidelines

- Drafted on request of UNCOPUOUS (presented in 2003)
  - Prevent Release of mission related objects:
  - Passivation
  - Disposal (90% reliability):
    - GEO: Graveyard orbit
    - LEO: Limit Orbital Lifetime to < 25 years after mission in LEO
  - Collision Avoidance
  - Limit Risk on-ground to 1:10.000 per re-entry event

Effectivity of Measures

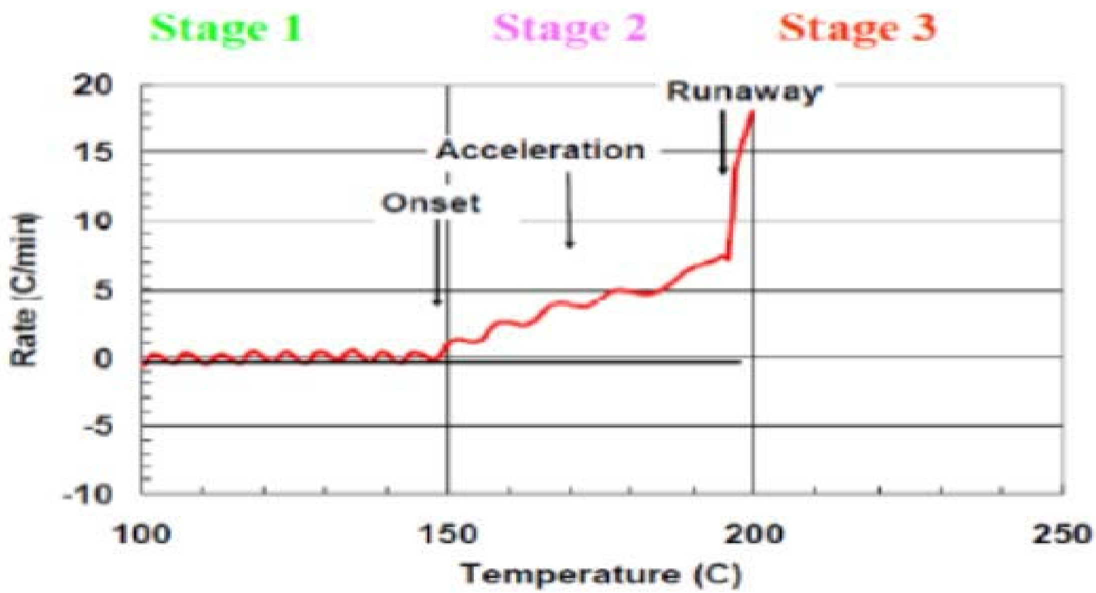


Battery Break-up Causes

Battery Failure Modes potentially leading to break-up:

- Over-temperature
- Short-circuit (internal or external)
- Over-charge
- Over-discharge
- Structural issues, damage

Battery Break-up Causes

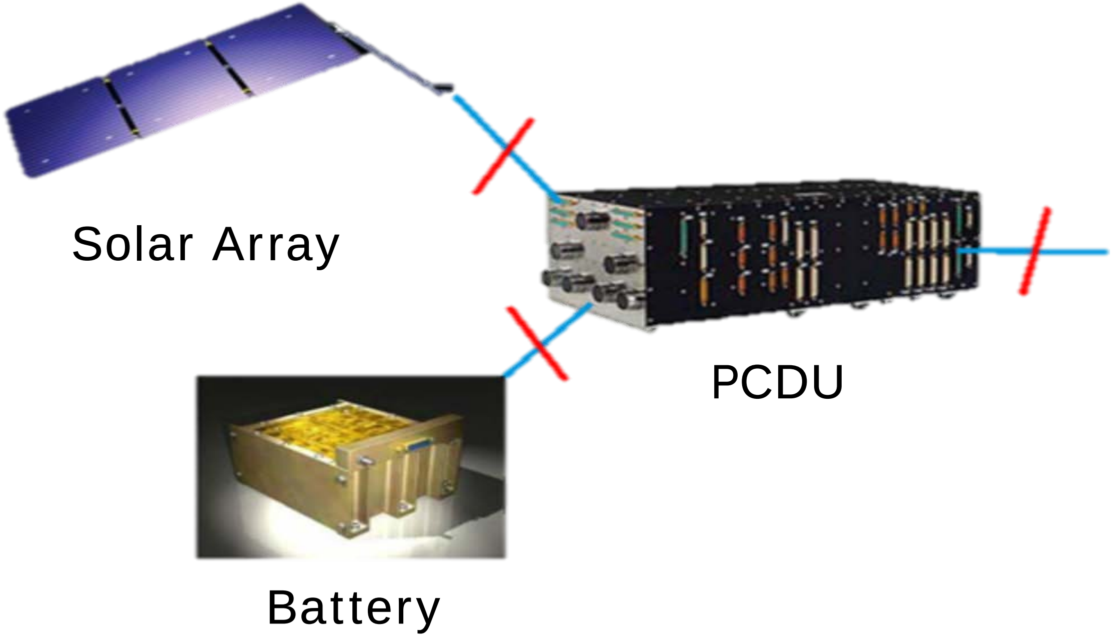


Leading to thermal runaway

→ **Increase of internal pressure**

→ **Break-up if reaction is too quick for protections to react in time**

Electrical Passivation: Methods



Why Propulsion Passivation?

- Current technology only allows to deplete hydrazine tanks to ~5 bar and about 1% residual propellant

Main risks

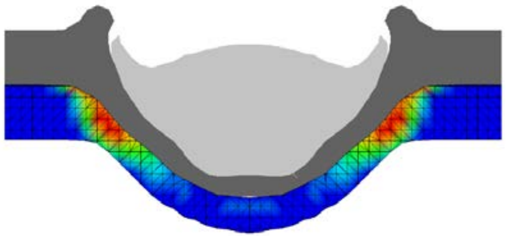
1. Propellant dissociation causing tank burst

2. Hypervelocity impacts causing explosion

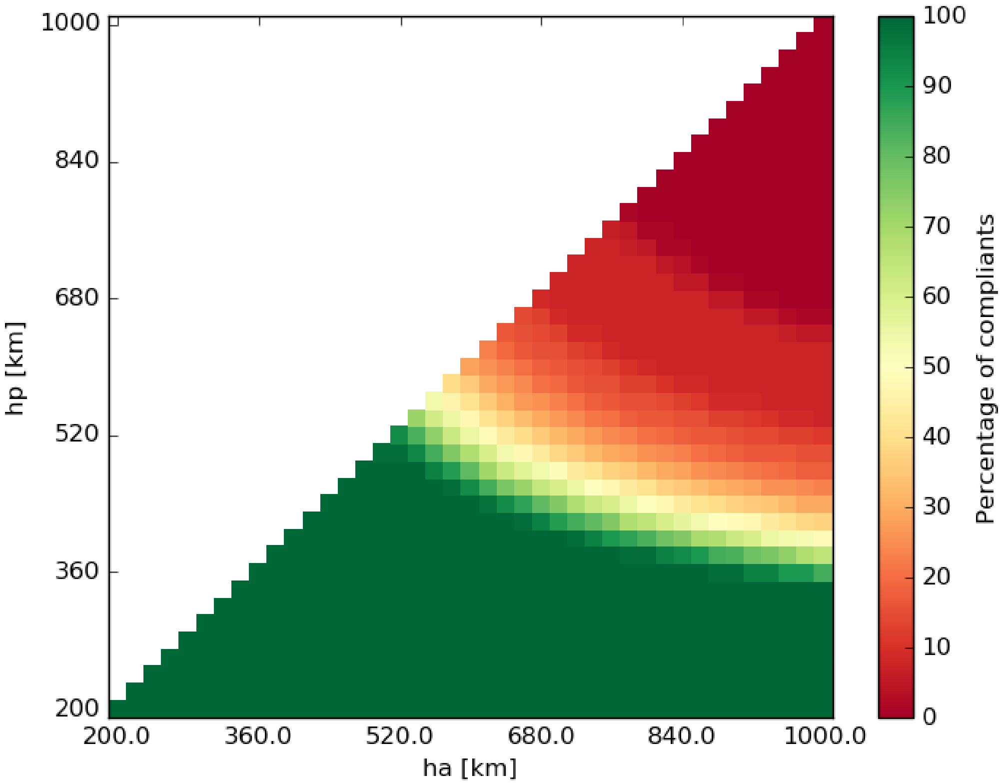
T (°K)	T (°C)	Thermal Runaway
373	100	20 days
423	150	19 hours
473	200	1.5 hours

> 50°C, hydrazine can begin to dissociate

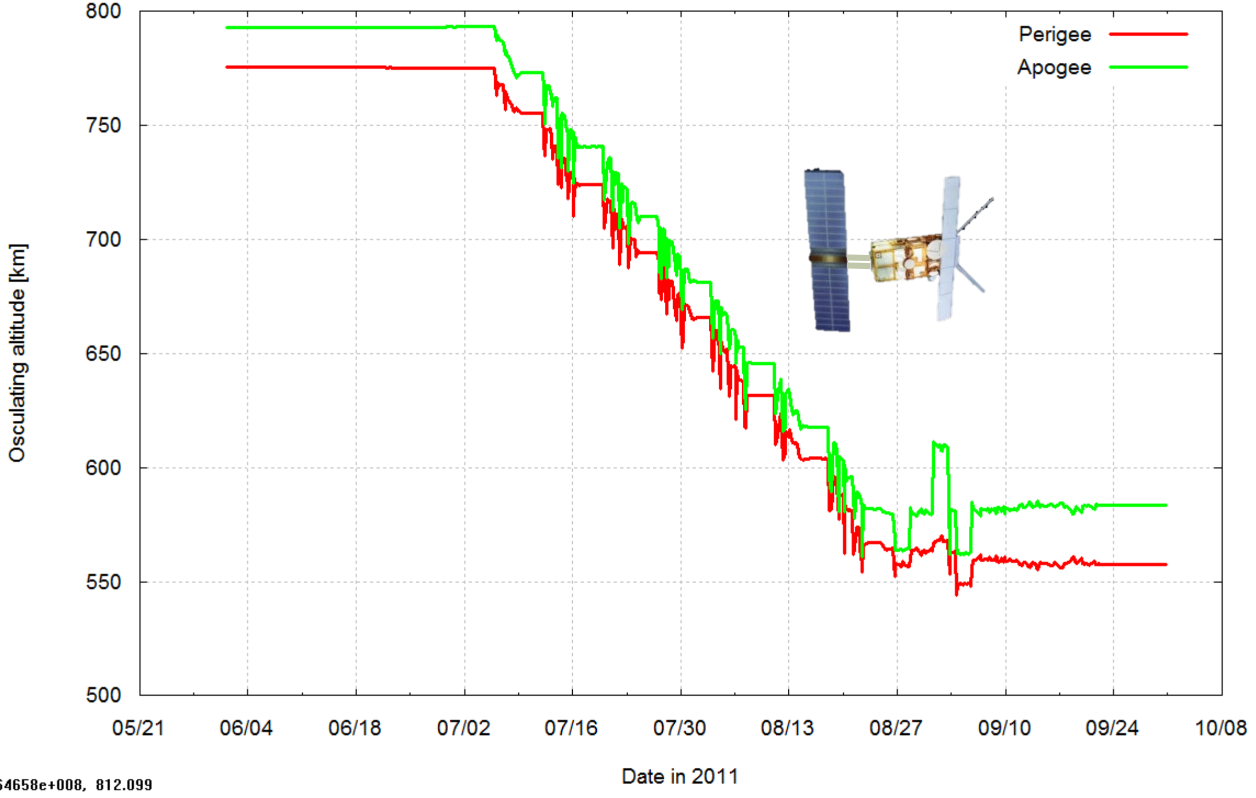
Reaction is exothermic



Disposal from LEO



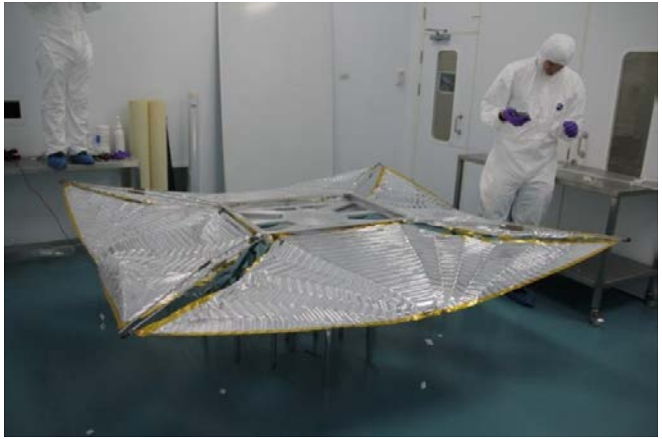
Disposal from LEO



- Up-down manoeuvre due to Earth-sensor constraints (can be designed for!)
- Estimated remaining lifetime below 15y

Drag Augmentation Devices

- Particularly attractive for satellites without a propulsion system.
- Applicable to uncontrolled reentry of satellites in orbit altitudes below 700 km.
- Stabilization of the attitude is difficult to achieve for altitudes above 550 km.



Deployed Icarus sail (on an engineering model).

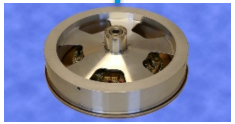
Risk on Ground

Source: Paul Maley

Critical elements in a spacecraft

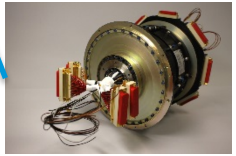
Propulsion tank

up to 20% of
platform footprint



Reaction wheels

Optical Payloads



Other elements

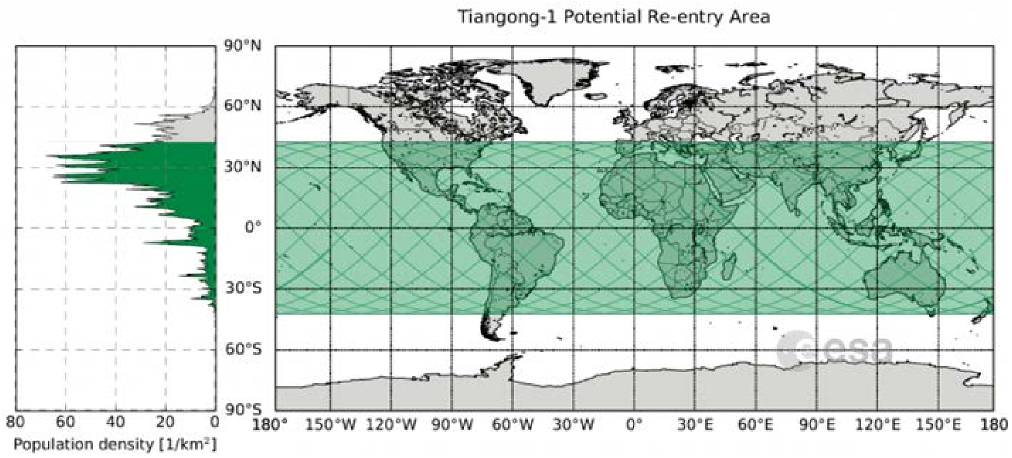
SADM
MTQ
Large mechanisms
Parts of structure
Etc.

Uncontrolled vs. Controlled Re-entry

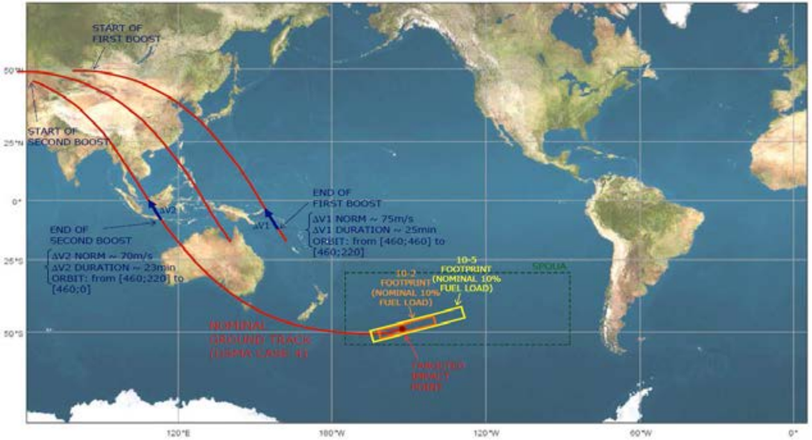
$P_c > 10^{-4}$

No

Yes



uncontrolled



controlled