



**Verso una nuova
Ecologia Spaziale:
la sindrome di Kessler e il problema
degli Space Debris**

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Collision Frequency of Artificial Satellites: The Creation of a Debris Belt

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As the number of artificial satellites in earth orbit increases, the probability of collisions between satellites also increases. Satellite collisions would produce orbiting fragments, each of which would increase the probability of further collisions, leading to the growth of a belt of debris around the earth. This process parallels certain theories concerning the growth of the asteroid belt. The debris flux in such an earth-orbiting belt could exceed the natural meteoroid flux, affecting future spacecraft designs. A mathematical model was used to predict the rate at which such a belt might form. Under certain conditions the belt could begin to form within this century and could be a significant problem during the next century. The possibility that numerous unobserved fragments already exist from spacecraft explosions would decrease this time interval. However, early implementation of specialized launch constraints and operational procedures could significantly delay the formation of the belt.

INTRODUCTION

Since the beginning of the space age, thousands of satellites have been placed in earth orbit by various nations. These satellites may be grouped into three categories: payloads, rocket motors, and debris associated with the launch or breakup of a particular payload or rocket; most satellites fall into the last category. Because many of these satellites are in orbits which cross one another, there is a finite probability of

reached by this study that over the next few decades a significant amount of debris could be generated by collisions, affecting future spacecraft designs.

SATELLITE ENVIRONMENT MODEL

A model describing the environment resulting from orbiting satellites was constructed by first calculating the spatial density

Donald J. Kessler

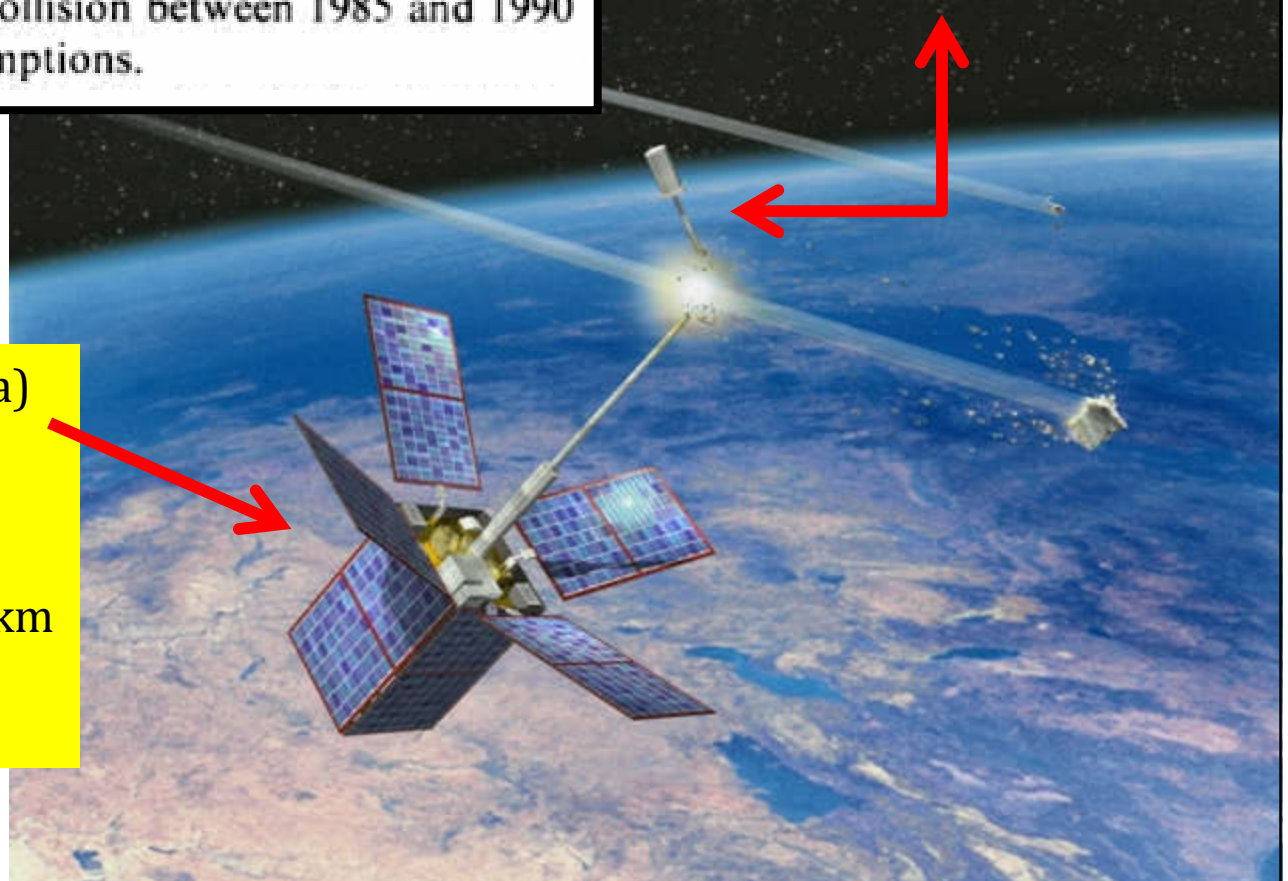
24 Luglio 1996: la prima “collisione”

Note that under the more conservative assumption (320 objects/yr) the first collision would be expected around 1997. However, at a growth rate of 13%/yr this collision would occur around 1989. If the average collision cross section is overestimated by a factor of 2, the first collision could be as late as the year 2005, while an underestimation by a factor of 3 results in a first collision between 1985 and 1990 under any of the growth assumptions.

(Kessler & Cour-Palais, 1978)

Area radar: 0.07m²
Orbita: 445.1 x 457.1 km
Periodo: 93.6min
Inclination: 98.3°

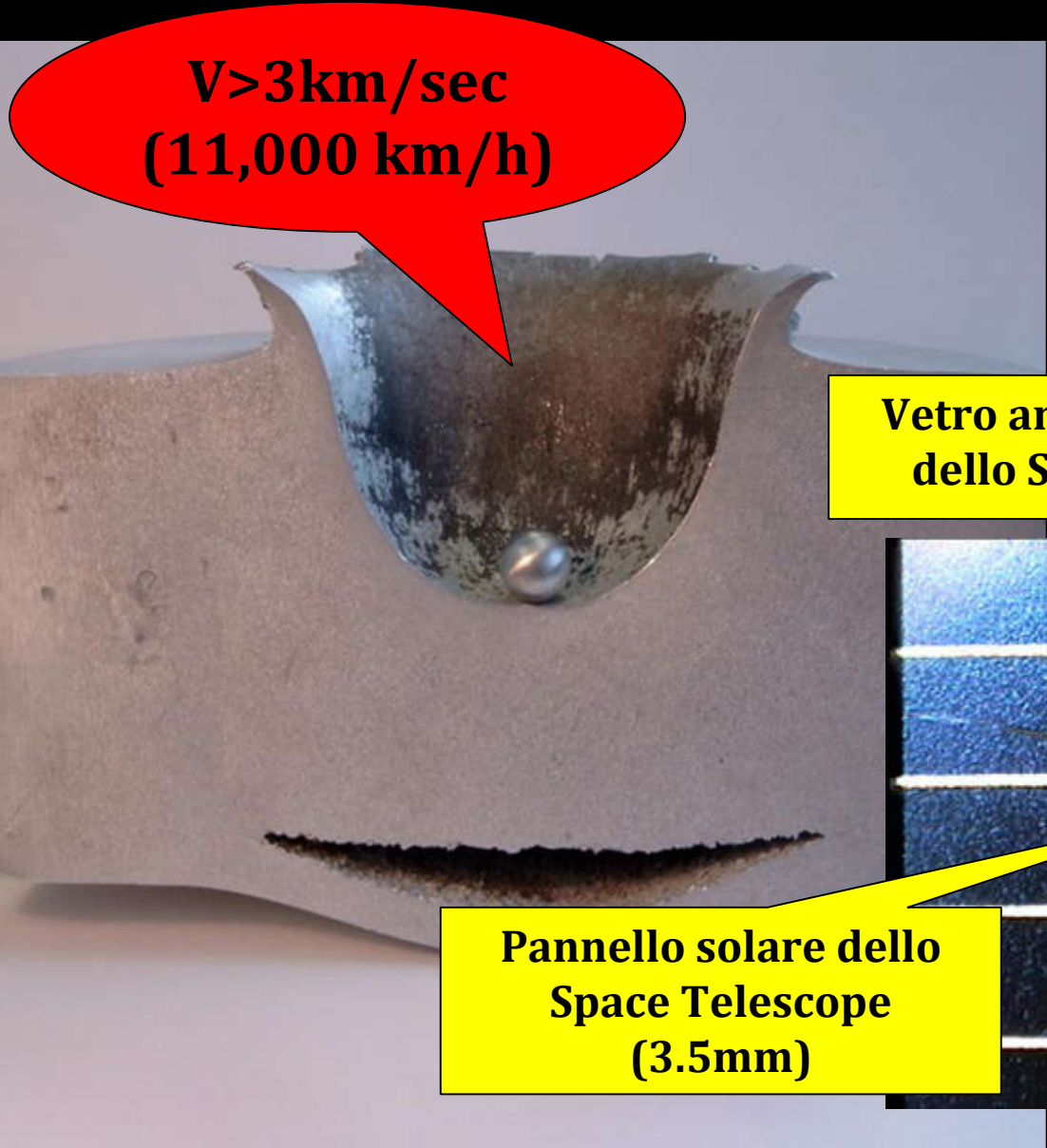
Satellite: **Cerise** (Francia)
Uso: Militare
Lancio: 07 Luglio 1995
Area radar: 0.65m²
Orbita: 582.5 x 589.3 km
Periodo: 96.4min
Inclinazione: 98.2°



Futuro prossimo?



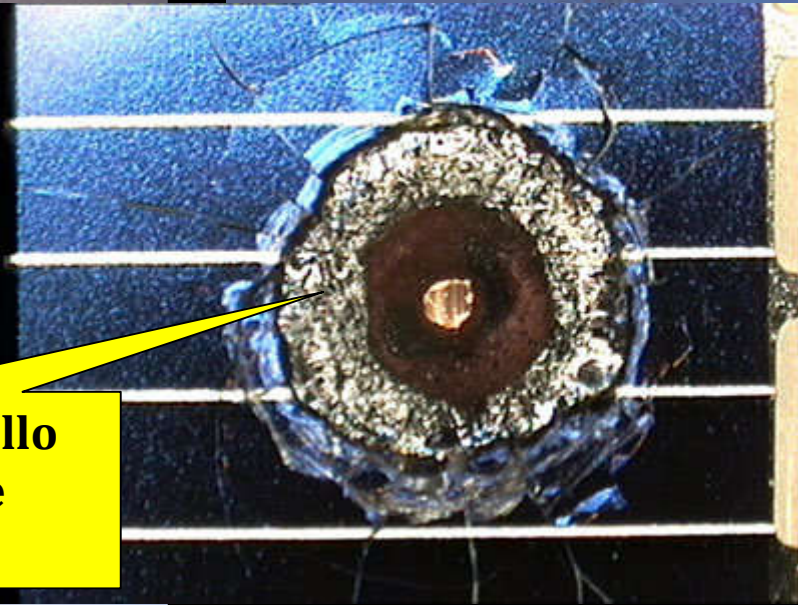
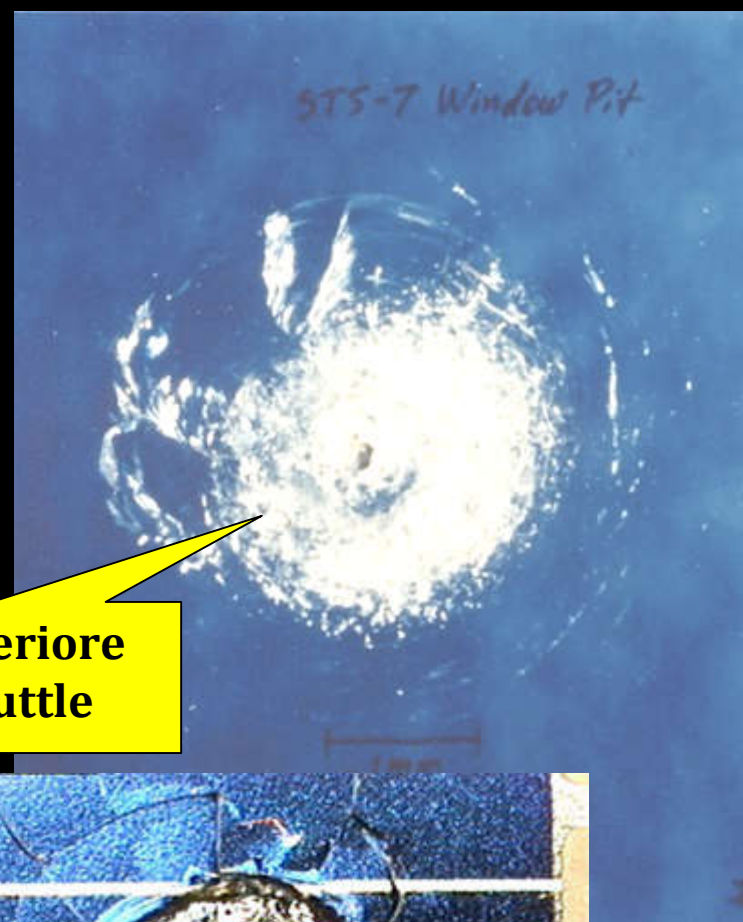
Gli urti ad Ipervelocita'



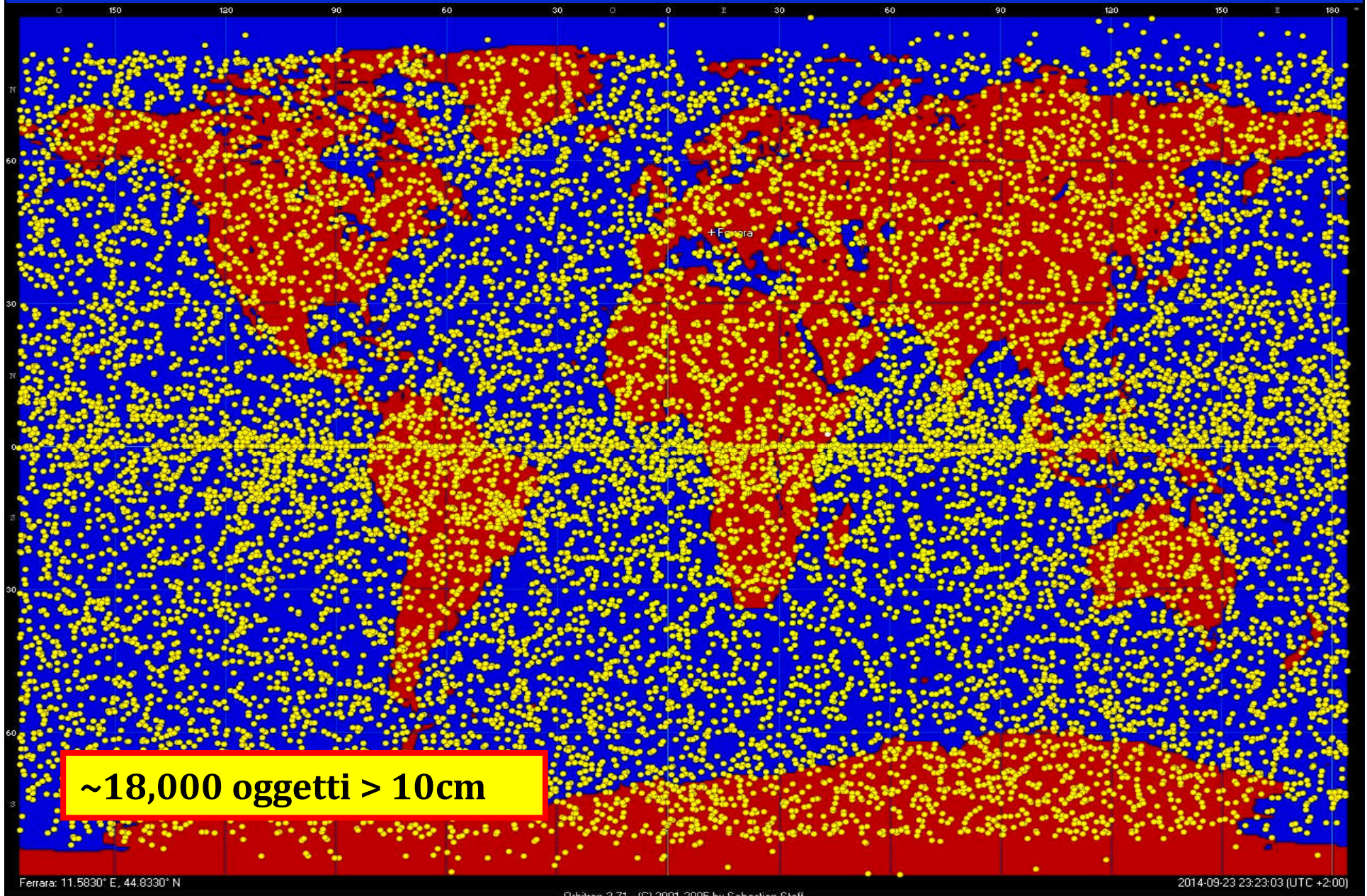
**$V > 3 \text{ km/sec}$
(11,000 km/h)**

Vetro anteriore dello Shuttle

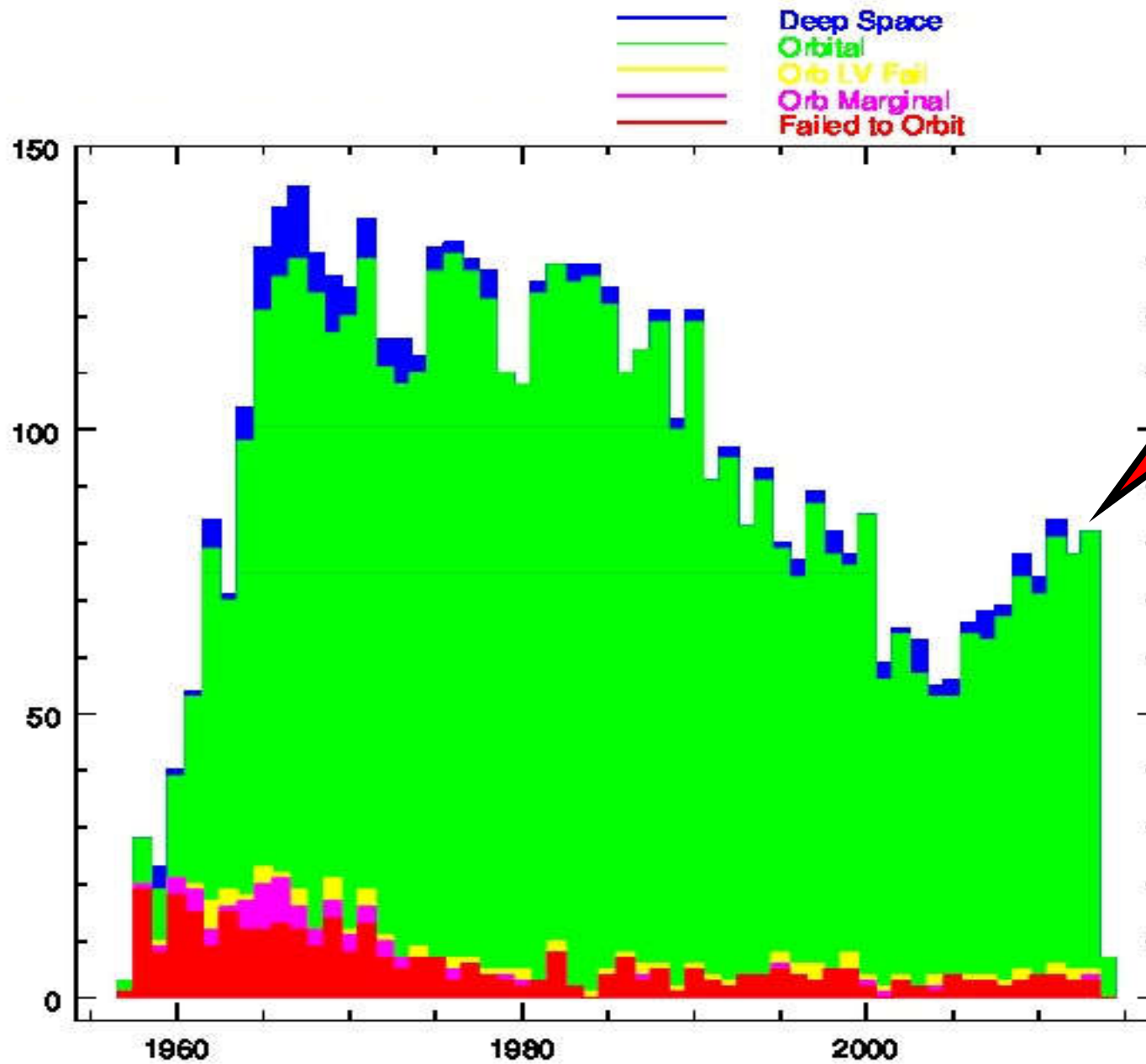
Pannello solare dello Space Telescope (3.5mm)



La situazione oggi



Traffico Spaziale

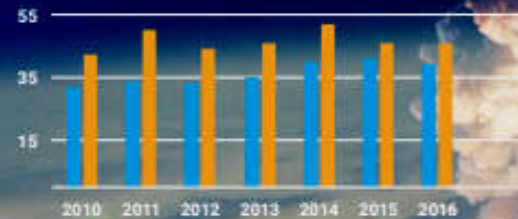


Credit: Jonathan McDowell's Space pages

Settembre 2017: i lanci "commerciali" superano quelli "goverantivi"

Credits: Space Angels - Space
Investment Quarterly

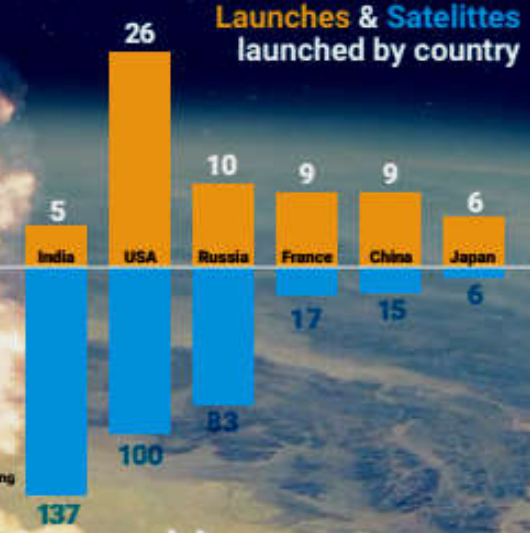
Commercial⁽¹⁾ vs
Governmental⁽²⁾ Launches



SEP.
2017



Launches & Satellittes
launched by country



SPACE ANGELS

(1) Commercial Launch vehicle developed with risk capital by a profit-seeking company to serve commercial and government customers
(2) Governmental Launch vehicle developed under contract funded by a state-owned entity, government agency, military, or similar
Source Space Angels

Traffico Spaziale

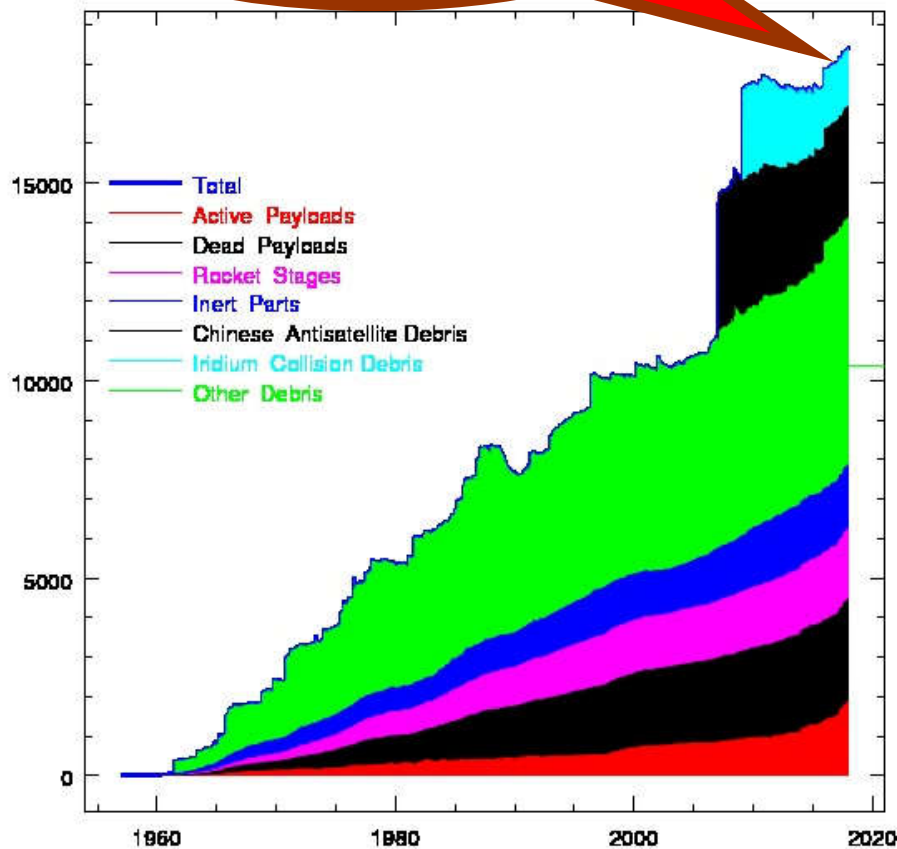
<u>COSPAR ID</u>	<u>Data</u>	<u>Payload(s)</u>	<u>Lanciatore</u>
2018-085	01.11.2018	BD-3 G1Q (Beidou 41)	CZ-3B/G2
2018-086	03.11.2018	Kosmos 2529 (Uragan-M #48)	Soyuz-2-1b Fregat-M
2018-087	07.11.2018	METOP C	Soyuz-ST-B Fregat-M
2018-088	11.11.2018	CICERO 10 + <u>6 Satellites</u>	Electron Curie
2018-089	14.11.2018	GSat 29	GSLV Mk.3
2018-090	15.11.2018	Es'hail 2	Falcon-9 v1.2 (Block 5)
2018-091	16.11.2018	Progress-MS 10	Soyuz-2-1a
2018-092	17.11.2018	Cygnus CRS-10 + <u>26 Satellites</u>	Antares-230
2018-093	17.11.2018	Mass simulator (CubeSat)	LauncherOne
2018-094	18.11.2018	SkySat 14 + <u>71 Satellites</u>	Falcon-9 v1.2 (Block 5)
2018-095	19.11.2018	BD-3 M17/M18 (Beidou 42+43)	CZ-3B/YZ1
2018-096	25.11.2018	?	Kuaizhou-1A
2018-097	26.11.2018	HySIS + <u>26 Satellites</u>	PSLV-CA
2018-098	29.11.2018	Dragon CRS-16 (SpX 16) GEDI	Falcon-9 v1.2 (Block 5)
2018-099	xx.11.2018	ICON (MIDEX 8)	Pegasus-XL

“Dispensatori” di satelliti

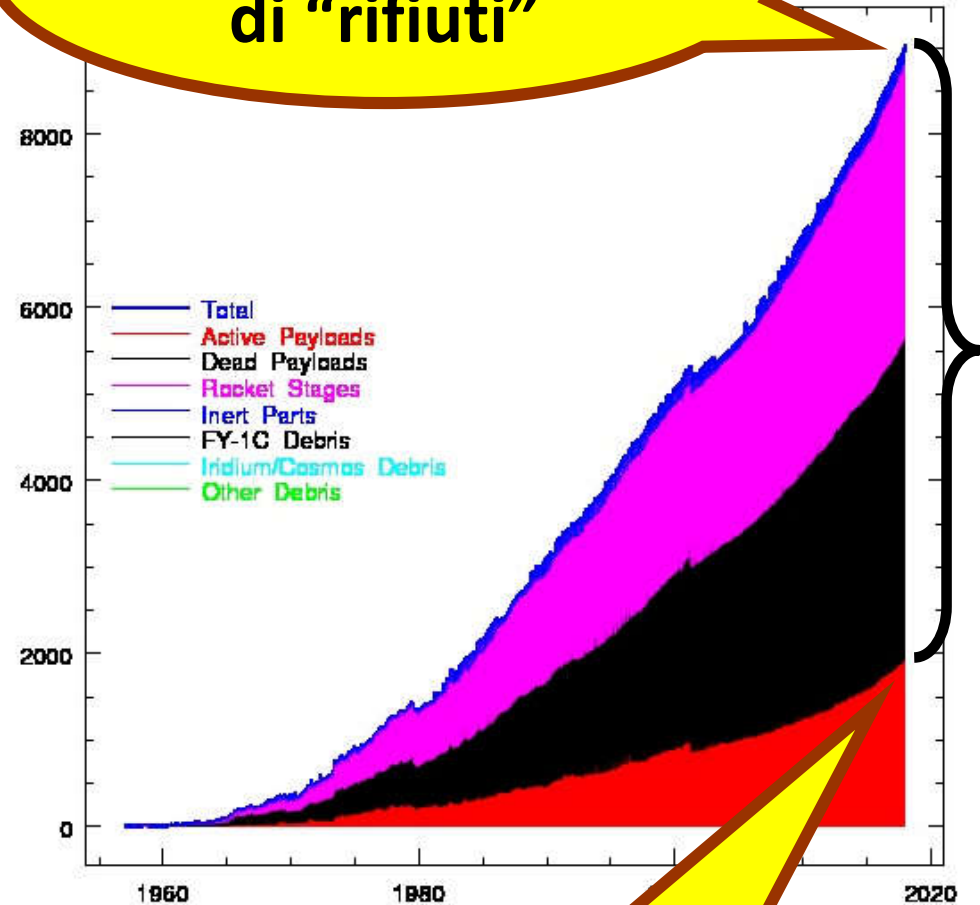


Traffico Spaziale

18,000 oggetti
>10cm



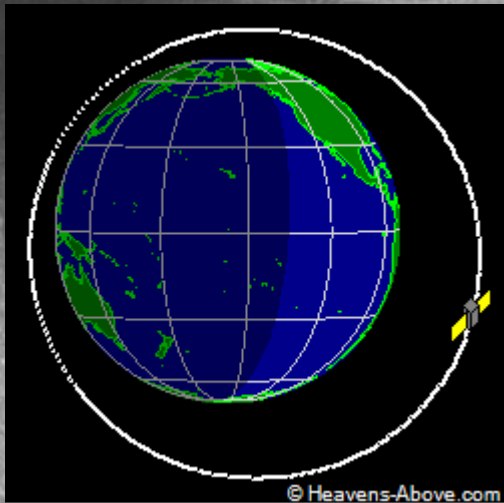
7,000 tonnellate
di "rifiuti"



2,000 tonnellate
"utili"

L'esperimento West Ford (1963)

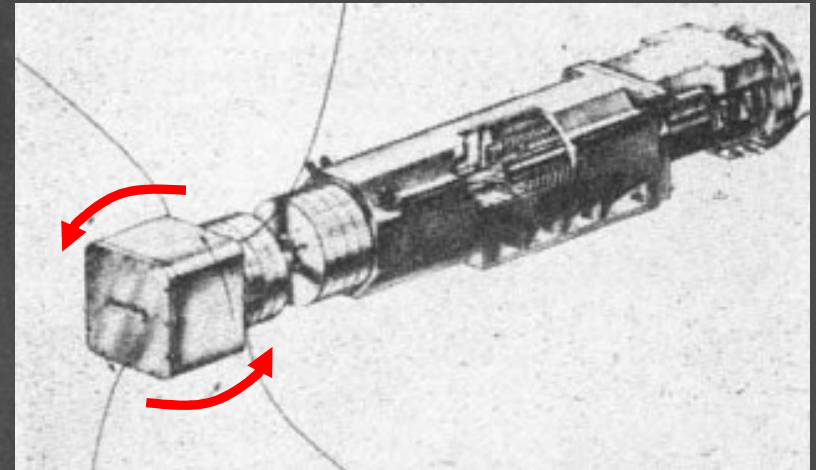
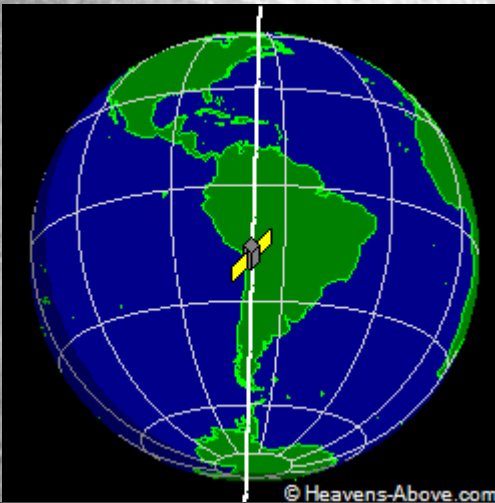
400 Milioni di "aghi"
fusi in un "panetto" di
Naftalene



Orbita: 578 x 3418 km

Inclinazione: 88.4 gradi

Periodo: 127.1 minuti



Lancio: 9 Maggio '63

Satellite: MIDAS (6?)

Orbita: 3603 x 3681 km

Inclinazione: 87.4 gradi

Periodo: 166.5 minuti

Il “fumo” dei missili

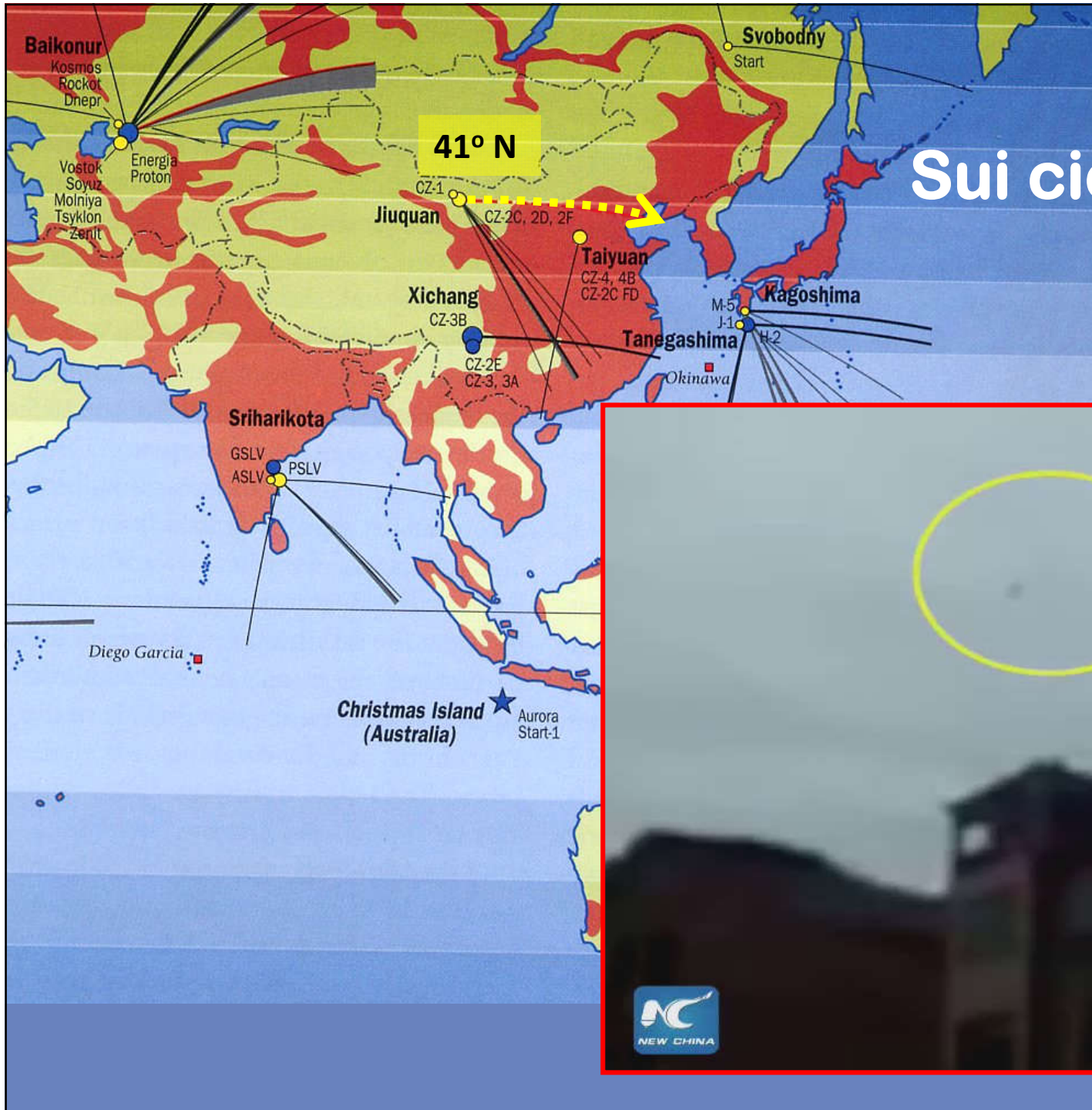
Delta IV + Orion



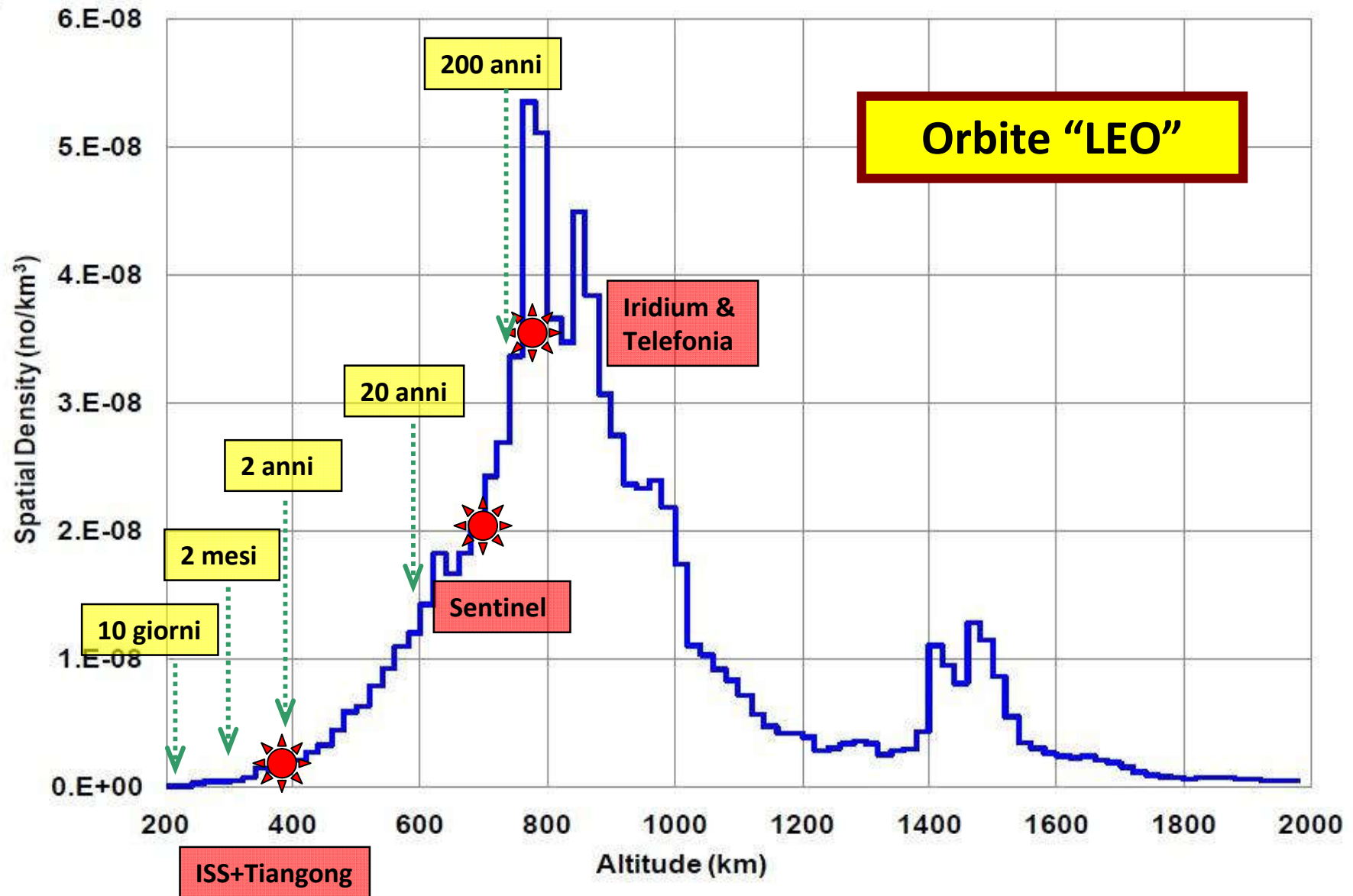
Palle!

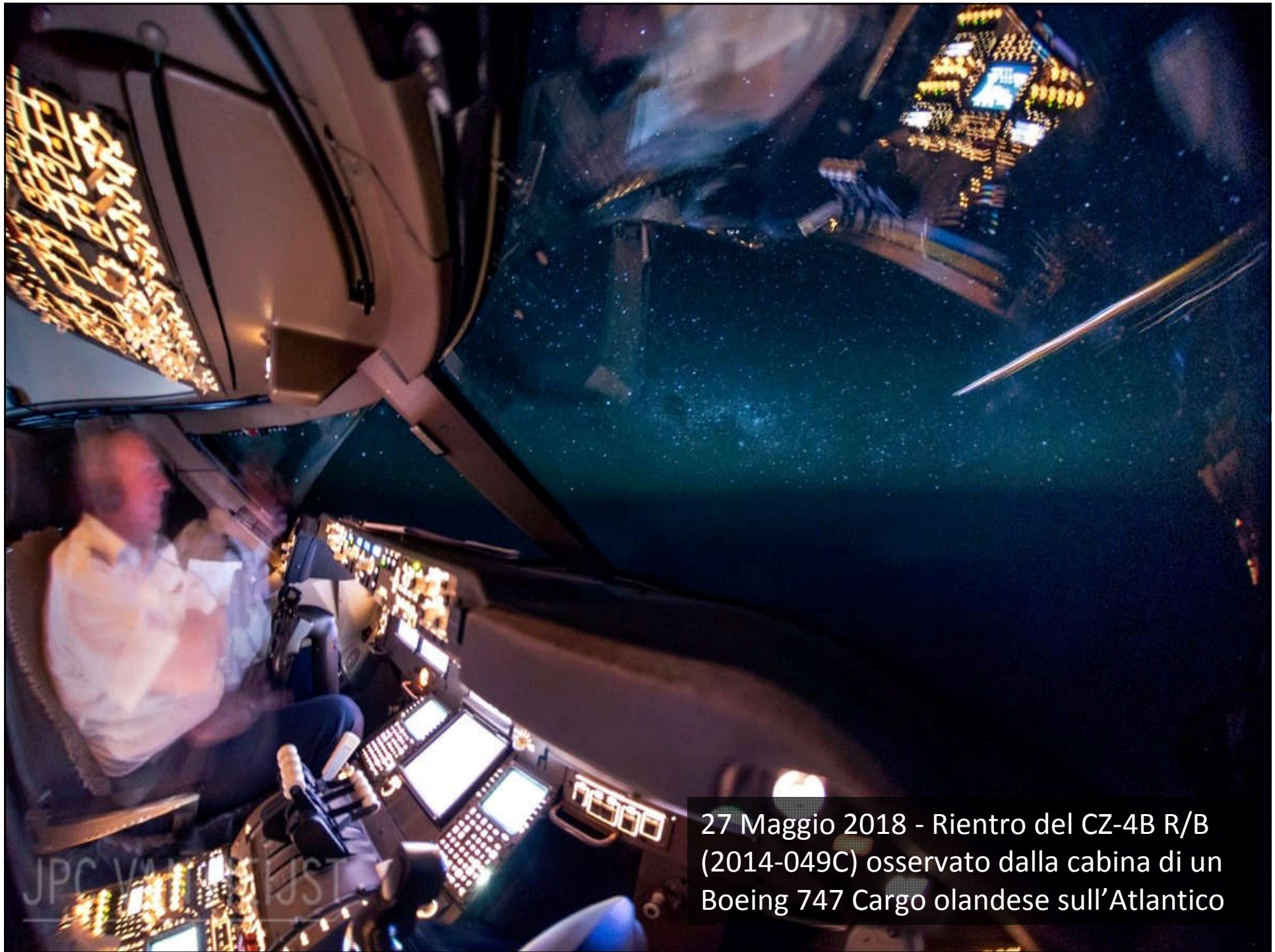


Sui cieli cinesi...



I tempi di vita in orbita





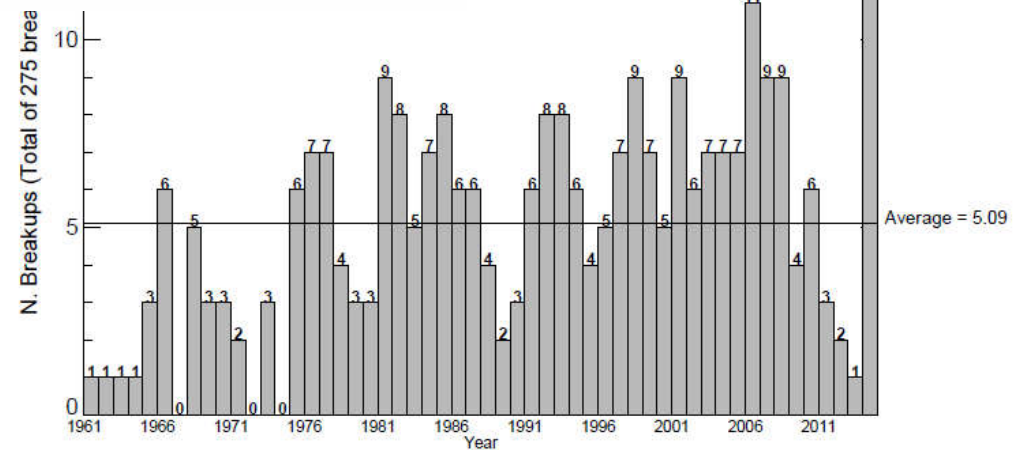
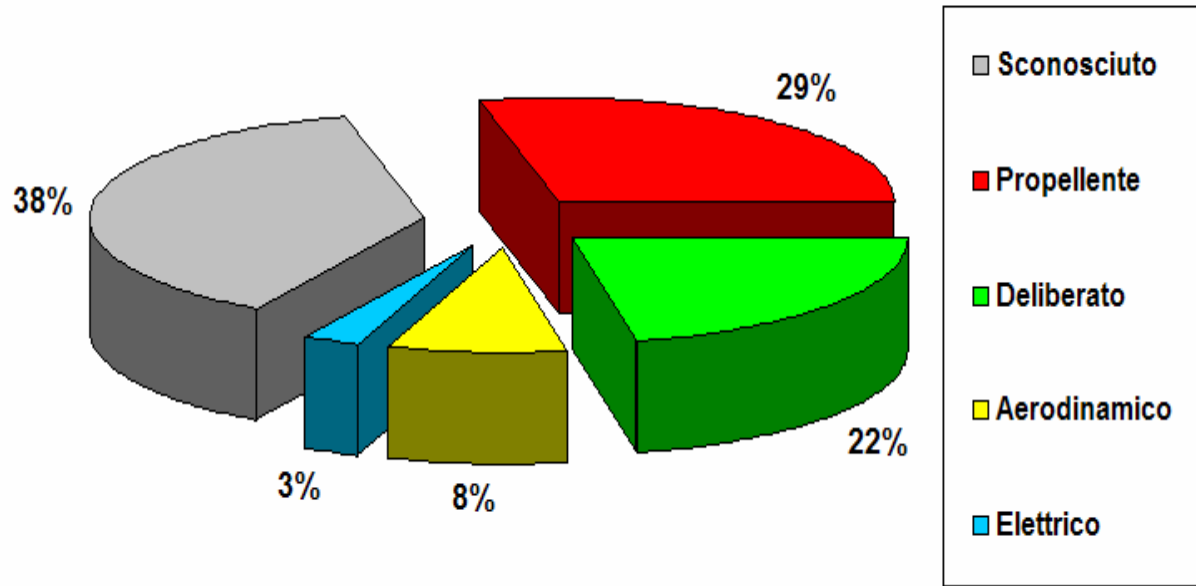
27 Maggio 2018 - Rientro del CZ-4B R/B (2014-049C) osservato dalla cabina di un Boeing 747 Cargo olandese sull'Atlantico

Il rientro del Cosmos 1315 - Settembre 2015



Joshua Lambus / theMAKaproject

Scoppio a bordo



Esperimenti ASAT (Anti-Satellite)

Russia ~20 (anni '60-'70)
America 5 (anni '80)
Cina 1 (2007)



La triste storia dell'Iridium 33

(Scontri Spaziali)

10 Febbraio 2009

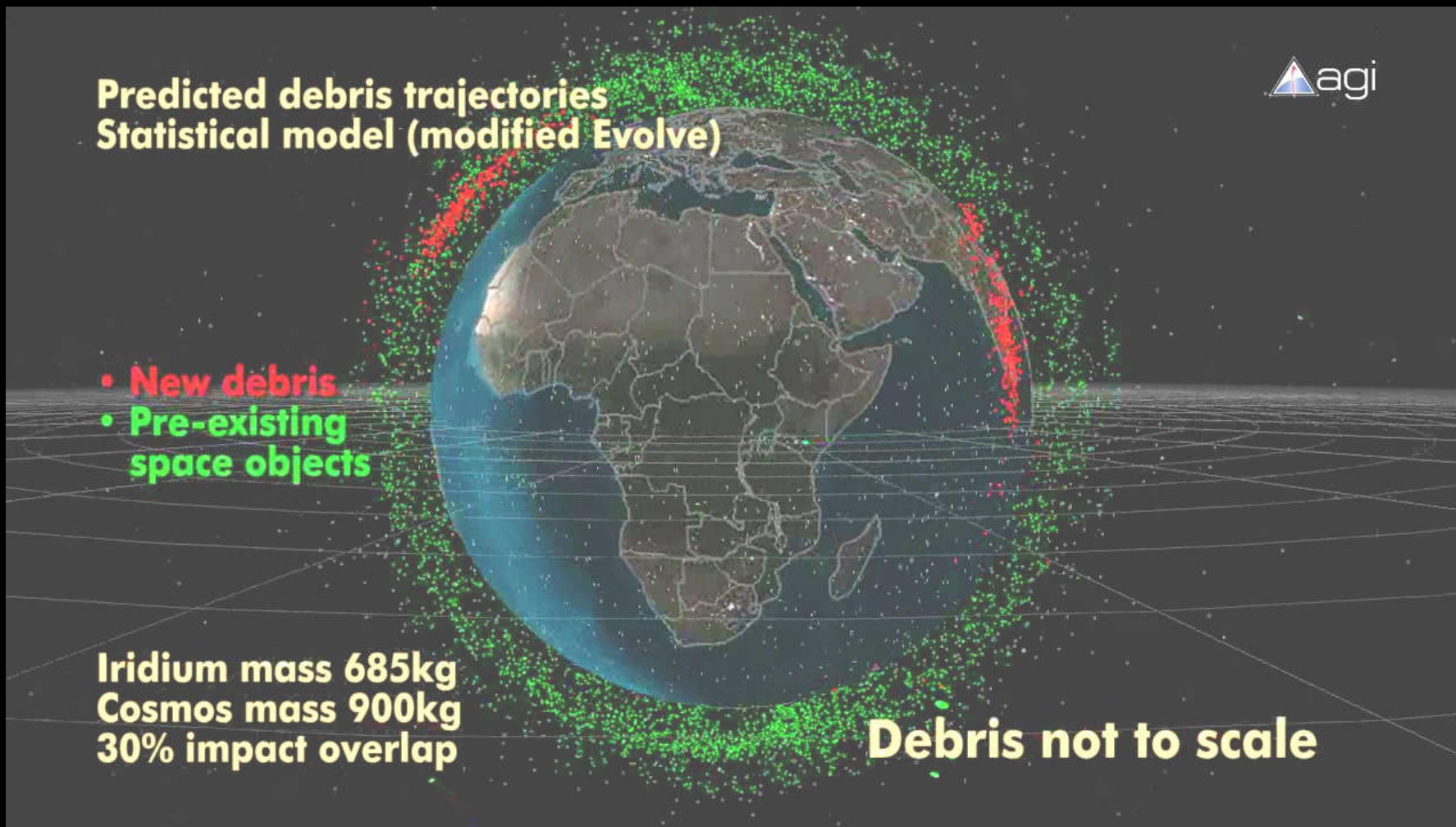
Predicted debris trajectories
Statistical model (modified Evolve)



- New debris
- Pre-existing space objects

Iridium mass 685kg
Cosmos mass 900kg
30% impact overlap

Debris not to scale





19 Marzo 1985



12 Gennaio 1990

L'esperimento

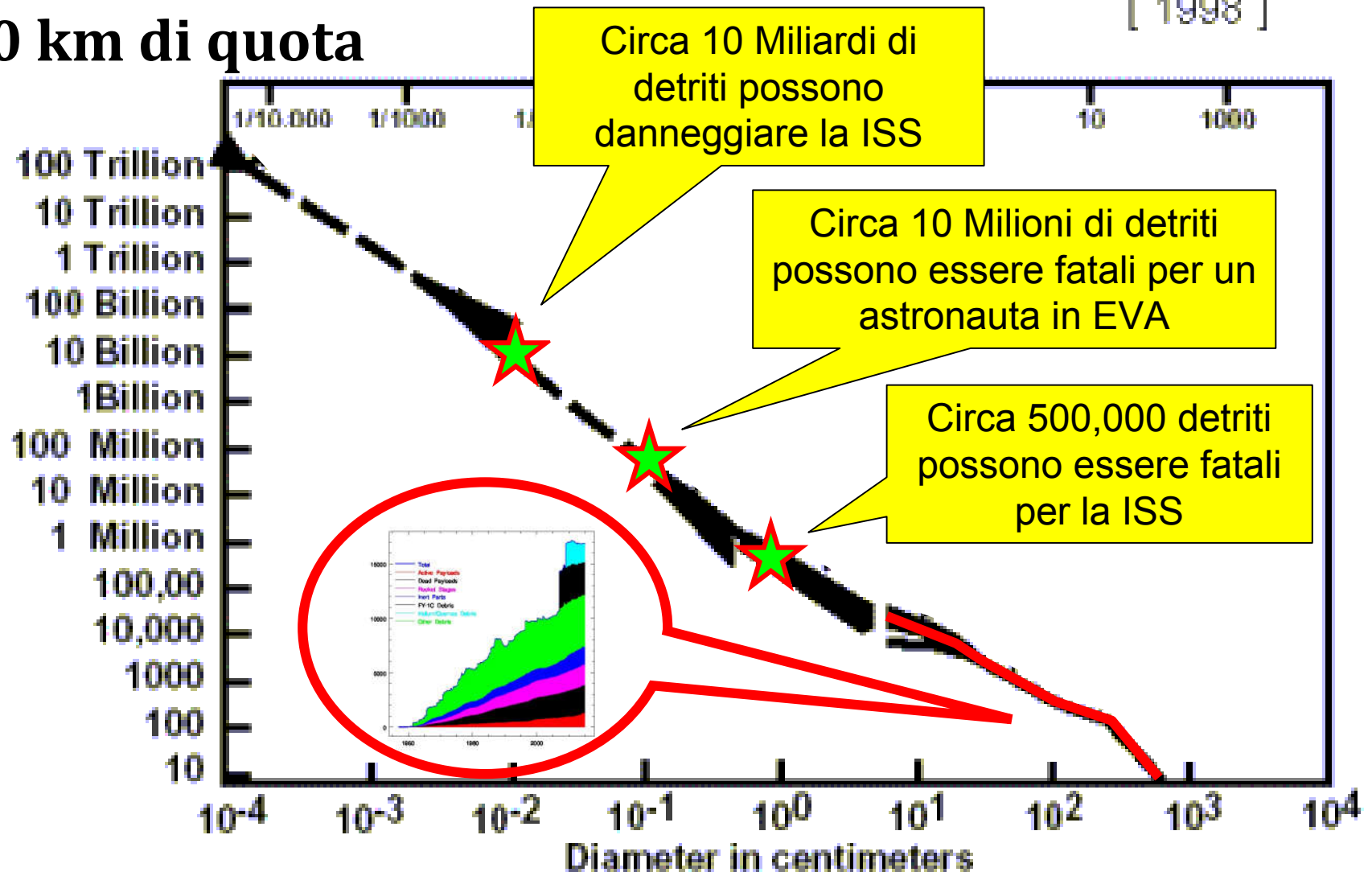
LDEF

(Long Duration Exposure Facility)

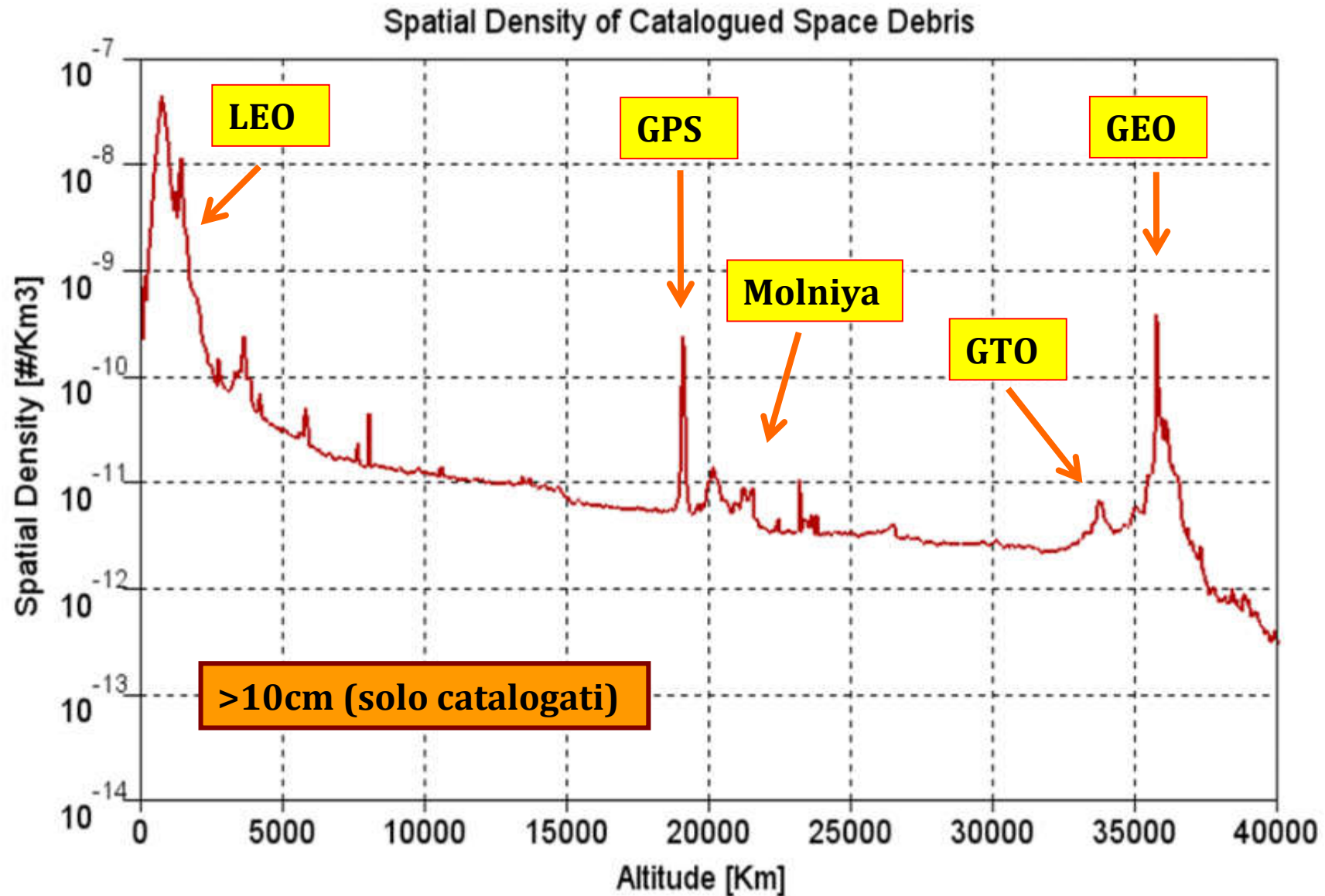
Raccolta differenziata?

Numero totale entro
2000 km di quota

[1998]



La distribuzione in altezza



Il sistema di controllo Americano



Air Force Space Command Worldwide Locations

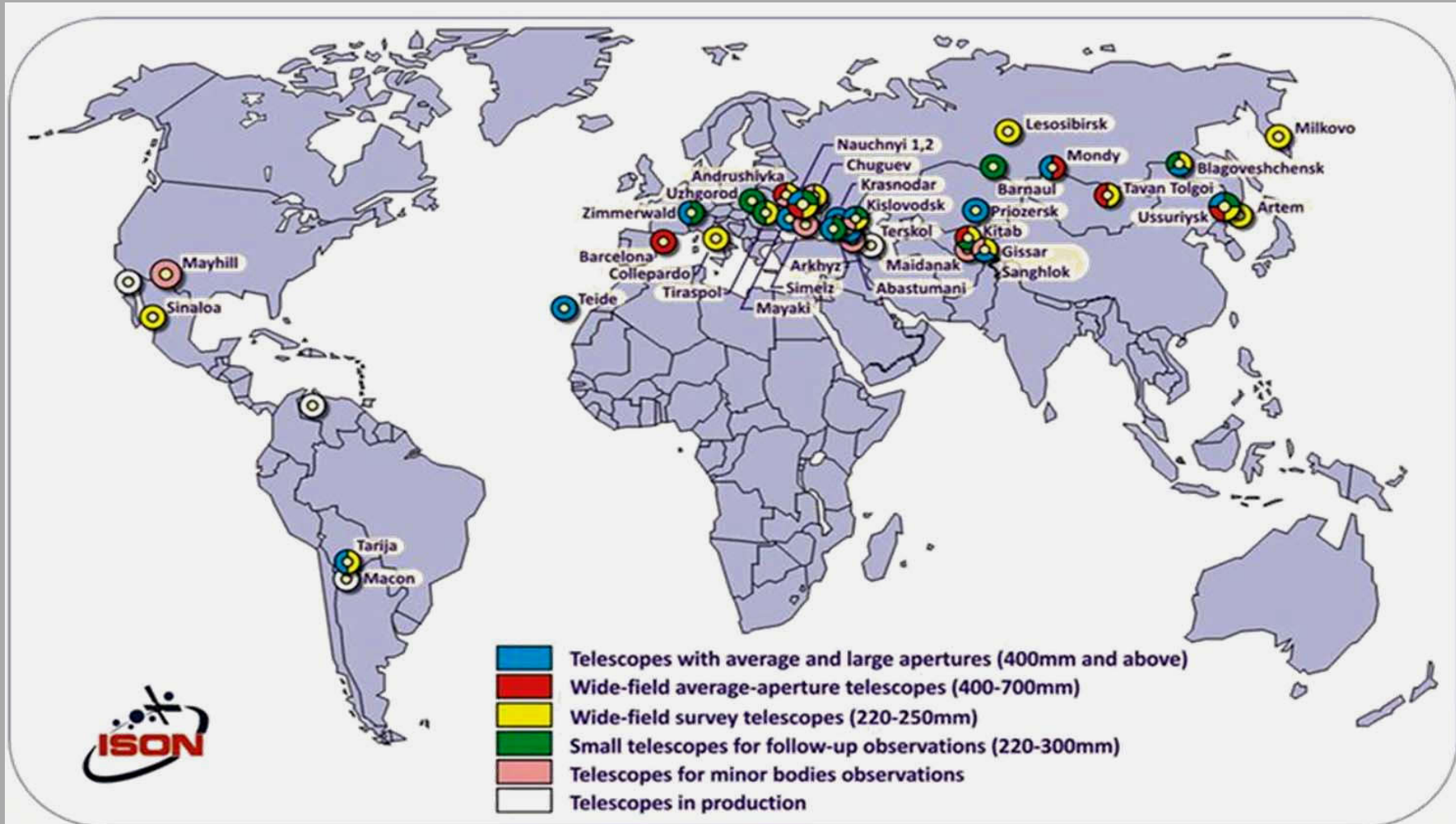


La base NORAD Mount Cheyenne, Colorado



... e i Russi?

Il progetto **ISON**



ISON is an open international project started in 2004 for regular monitoring of the near-Earth space

The 821st Main Space Intelligence Centre (SKKP)

 en servicio
 previstas



La base OKNO (Tagikistan)



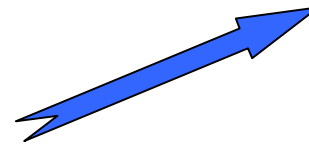
SSA/SST coordination in Italy

OCIS

Organismo di Coordinamento e di Indirizzo delle attività relative all'iniziativa "Space Surveillance and Tracking Support" (SST) della Commissione Europea

OCIS is composed by

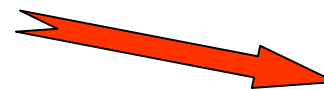
Agenzia Spaziale Italiana (ASI)*



Istituto Nazionale di Astrofisica (INAF)

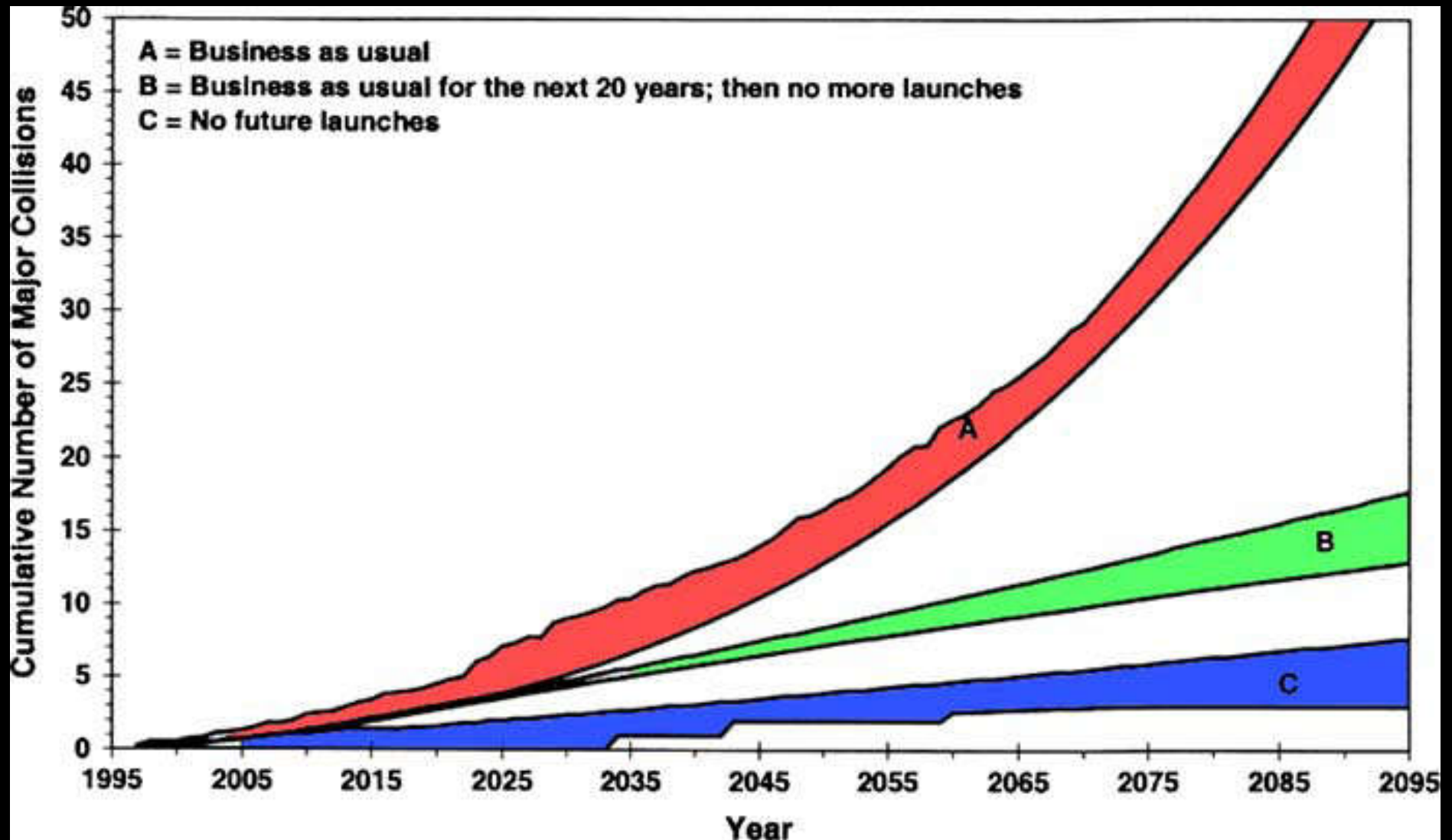


Aeronautica Militare (AM)

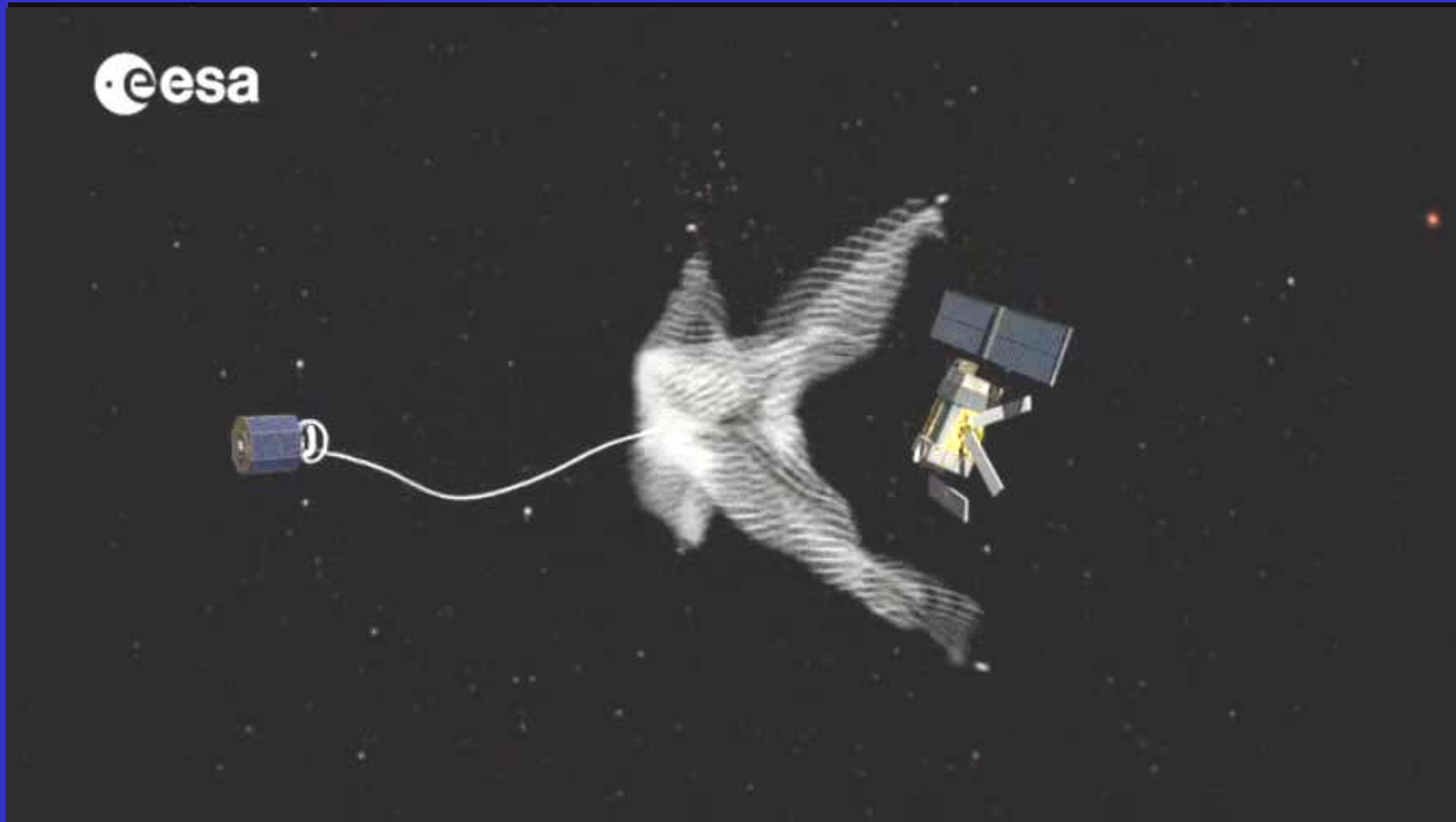


(*) ASI is the National Entity (NE) and Italian Representative in the SST European Consortium

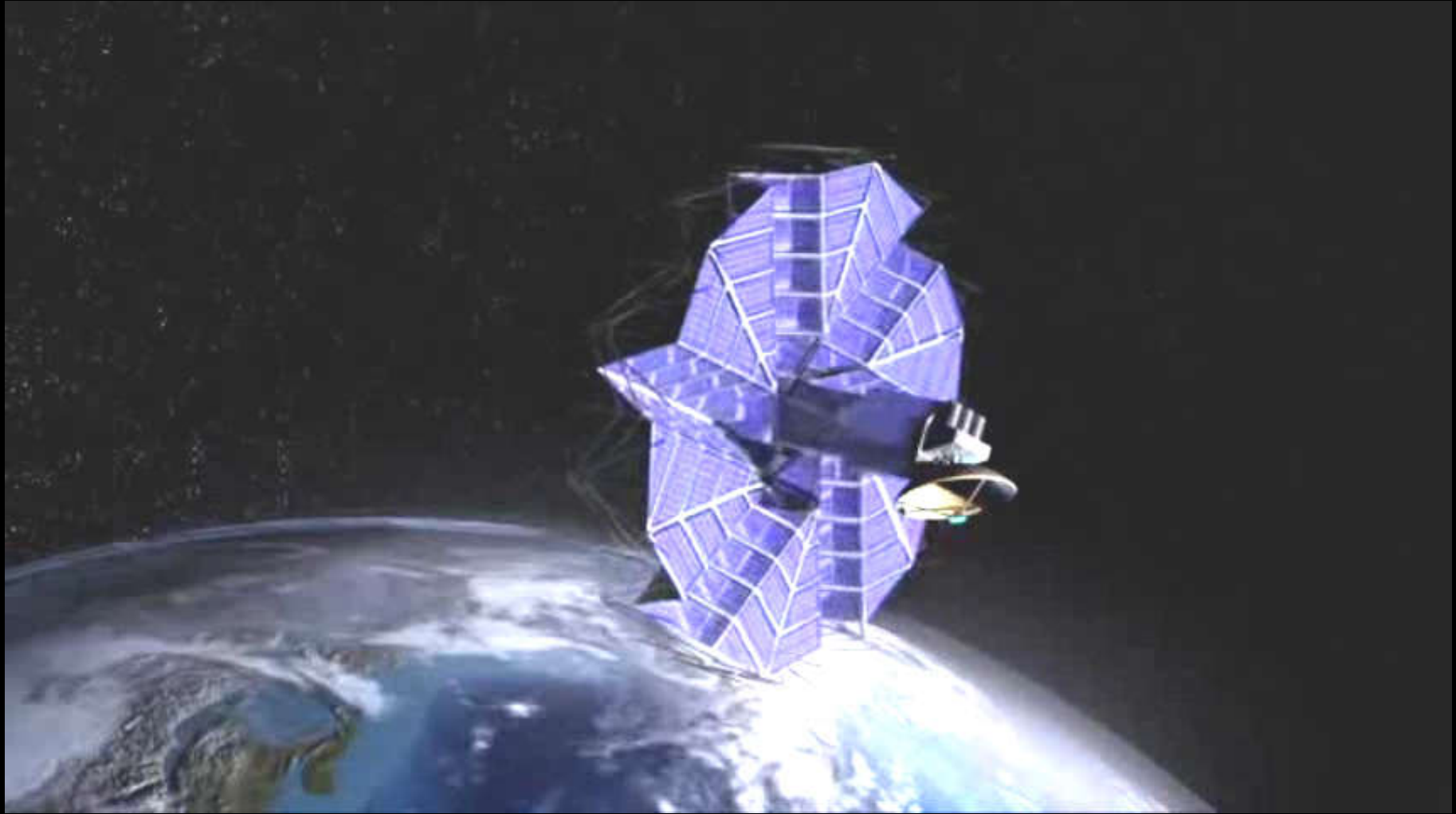
Se non si fa qualcosa...



Andarli a prendere...



Vele & Origami



Il Satellite Fionda (SlingSat)...

