LO SPAZIO CHE SI AFFOLLA - SPACE SITUATION AWARENESS E SPACE SURVEILLANCE AND TRACKING (SSA/SST): RUOLO AM

LA SICUREZZA NELLO SPAZIO

LA SICUREZZA NELLO SPAZIO - DEFINIZIONI

Sicurezza nello spazio	• Spazio per la sicurezza	• Sicurezza dallo spazio
• **La protezione delle infrastrutture spaziali da minacce o rischi naturali o man-made, assicurando la sostenibilità delle attività spaziali**	• Uso dei sistemi spaziali per la sicurezza e la difesa	• La protezione della vita umana e dell’ambiente terrestre da minacce naturali e rischi provenienti dallo spazio

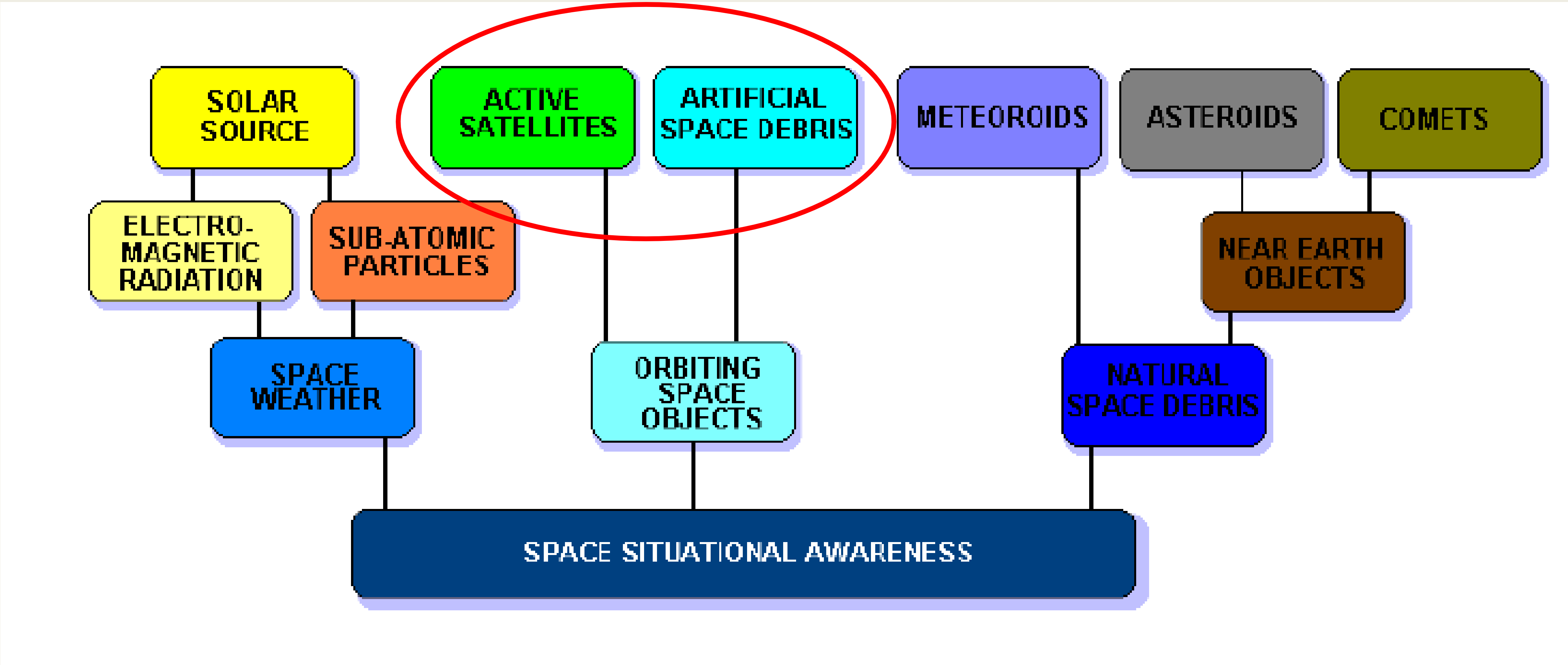
2

SICUREZZA DEGLI ASSETTI SPAZIALI

APPROCCIO LOGICO PER ARRIVARE ALLA ESIGENZA SSA/SST

- GLI ASSETTI SPAZIALI SONO ***ELEMENTI CHIAVE*** DELLA SOCIETA MODERNA E SONO ***ENABLERS FONDAMENTALI*** PER LE CAPACITA MILITARI
- GLI ASSETTI SPAZIALI SONO ***VULNERABILI*** AD EVENTI NATURALI E ATTACCHI INTENZIONALI
- GLI ASSETTI SPAZIALI SONO CONSIDERATI **ASSETTI CRITICI**
- GLI ASSETTI CRITICI VANNO ***MONITORATI E CONTROLLATI*** (CON OBIETTIVO DI ***DIFENDERLI SE NECESSARIO)***

CAPACITA SSA/SST HA QUESTO RUOLO



LA DIFESA CONCENTRATA AD ACQUISIRE LA SPACE DOMAIN AWARENESS

PROSPETTIVA DELLA DIFESA

Space Domain Awareness (SDA)

SDA implica un cambio di approccio

- non basta solo osservare, controllare e gestire il traffico spaziale
- considerare **ora lo spazio come settore di possibile conflitto quindi da monitorare, controllare, valutare nella sua possibile evoluzione (capacita di predire evoluzione) e quindi da <u>difendere</u>**
- Il dominio spazio quindi non differente dagli altri domini terra, mare, aria e cyber

STRATEGIA NAZIONALE DI SICUREZZA PER LO SPAZIO (2019)

…

Così come per le ***infrastrutture critiche sulla terra*** si valuta loro intrinseca affidabilità (***safety***) e resistenza a possibili azioni ostili (***security***) …. anche per le ***infrastrutture critiche spaziali*** - vanno adottate equivalenti precauzioni.

- Le misure di ***safety*** per garantire l'affidabilità (robustezza/resilienza) delle infrastrutture spaziali …..

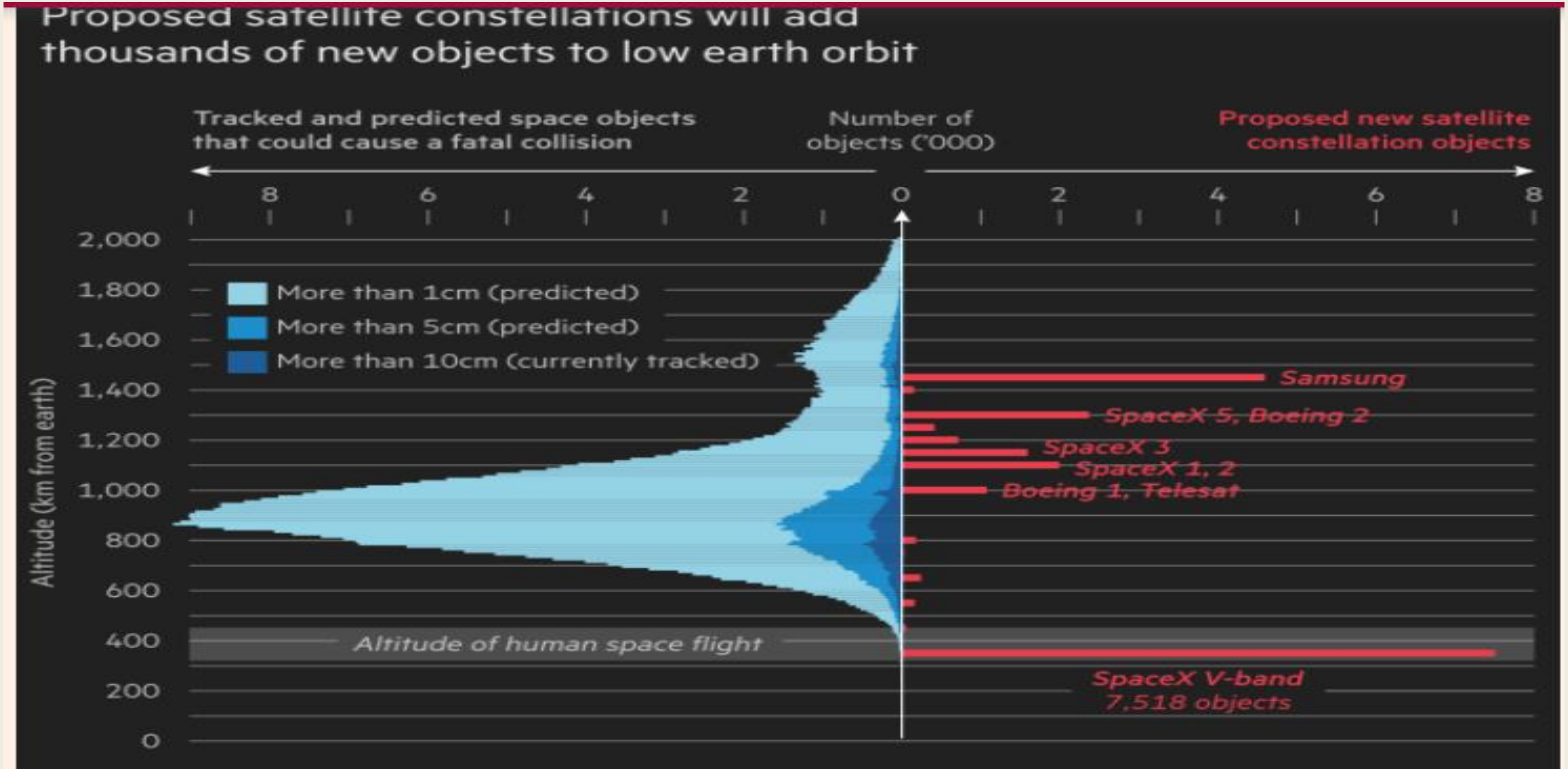
- Le misure di ***security*** per contrastare le minacce intenzionali sono più difficili da definire in quanto non sempre prevedibili nella loro tipologia, nella loro evoluzione tecnologica e nella modalità di attuazione.

MINACCE AGLI ASSETTI SPAZIALI

- **MINACCE NON INTENZIONALI**
  - *SPACE WEATHER*
  - *DETRITI SPAZIALI*
  - *CONGESTIONE DELLE ORBITE*
- **MINACCE INTENZIONALI**
  - HARD KILL
  - SOFT KILL

MINACCE NON INTENZIONALI

- *DETRITI SPAZIALI*
- *CONGESTIONE DELLE ORBITE*



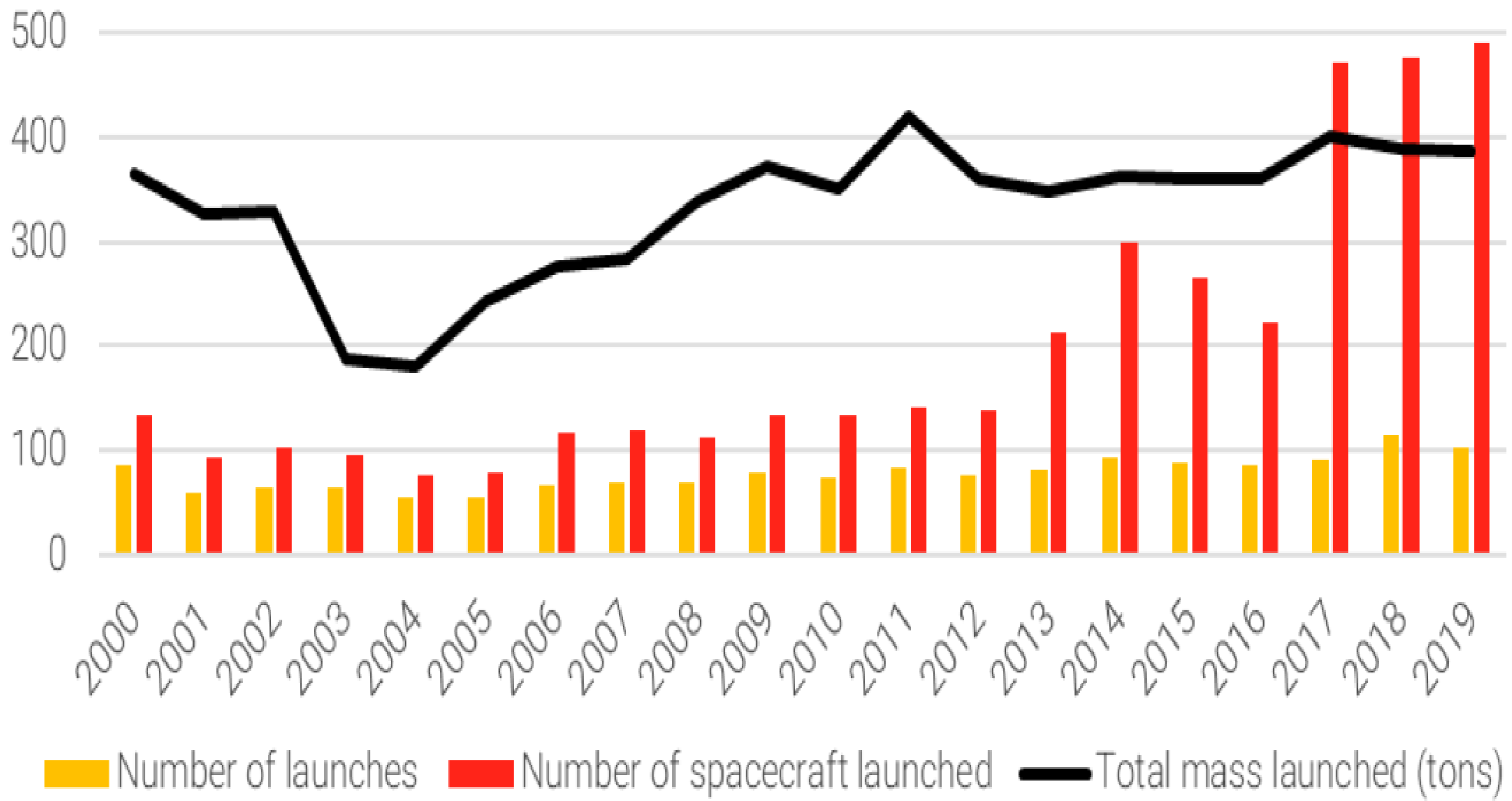
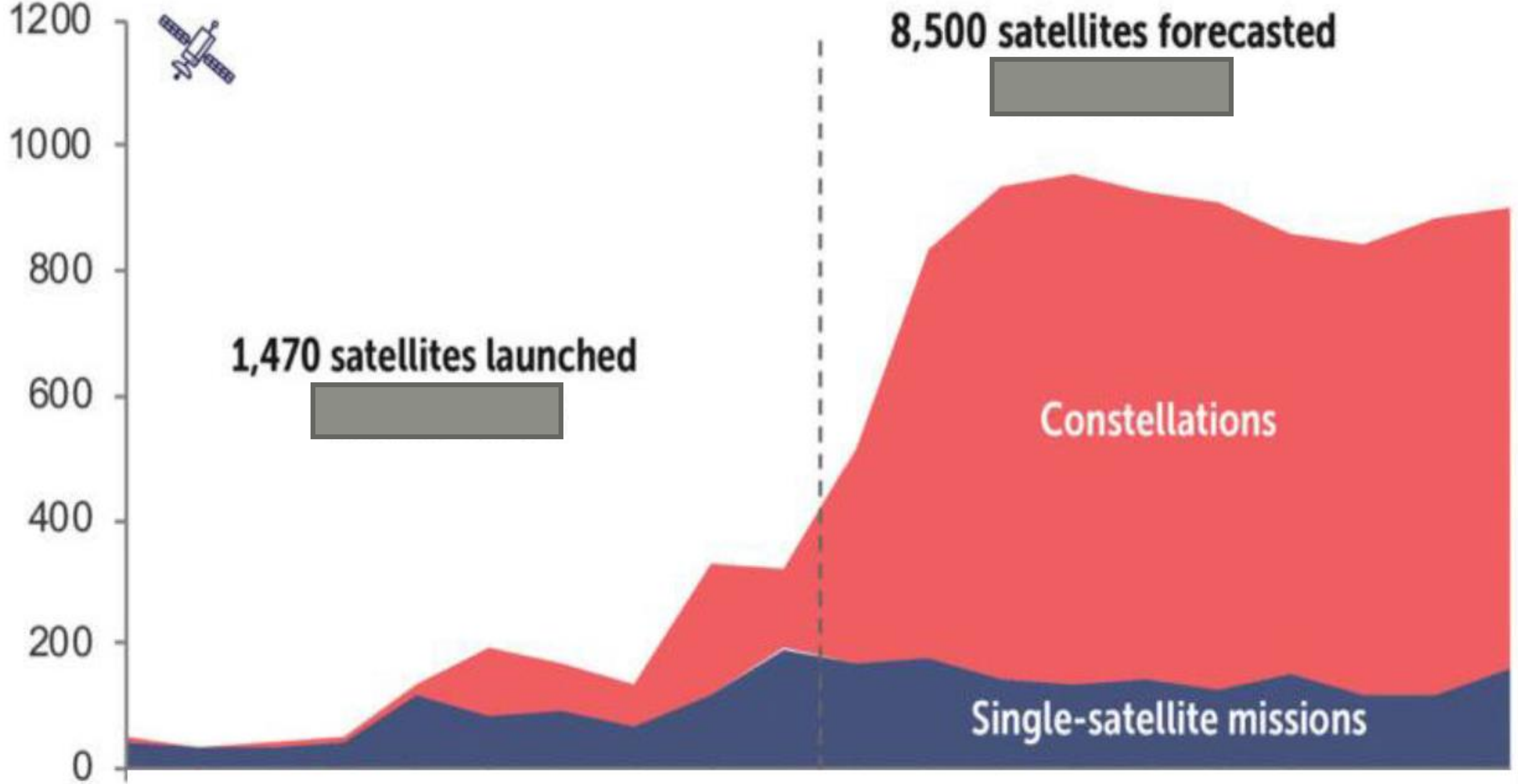
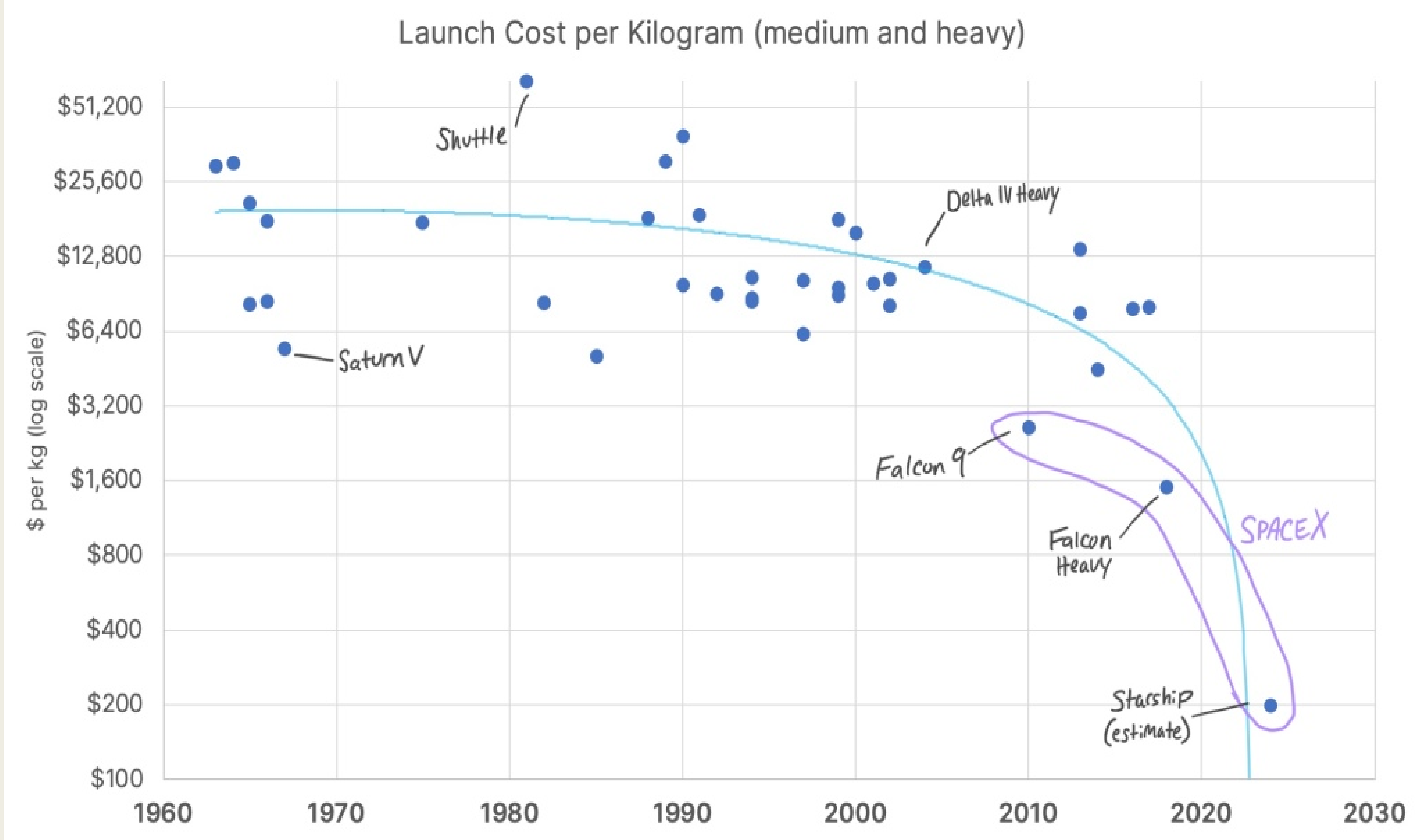


Figure 5: Evolution of the space activity since 2000 (source: ESPI database)

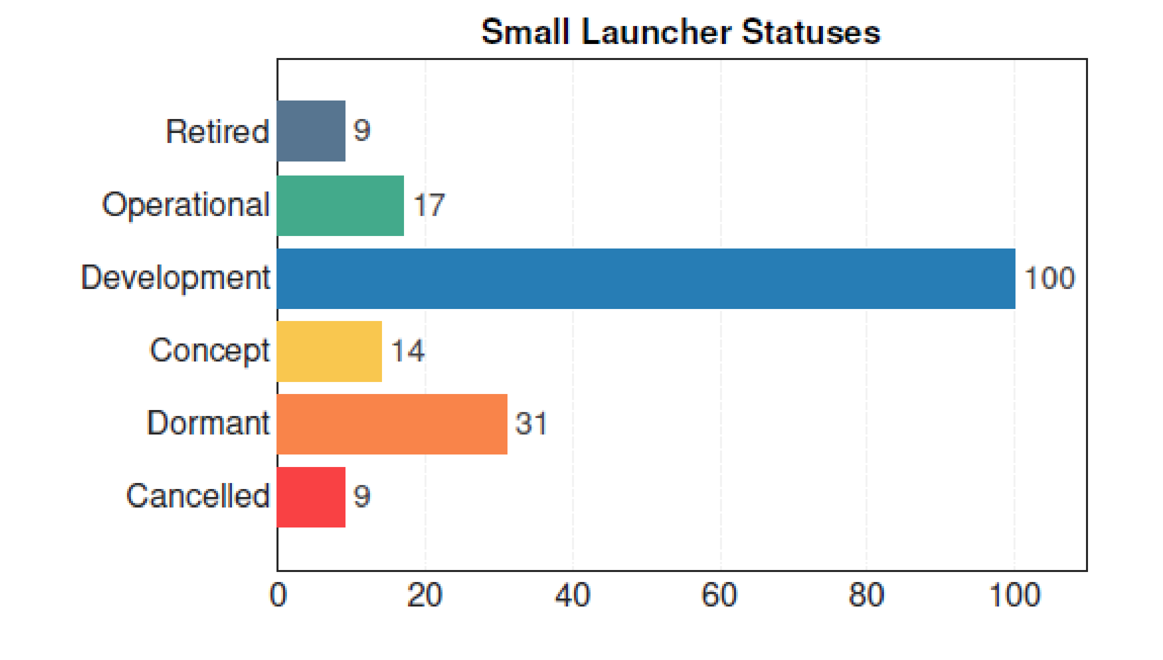


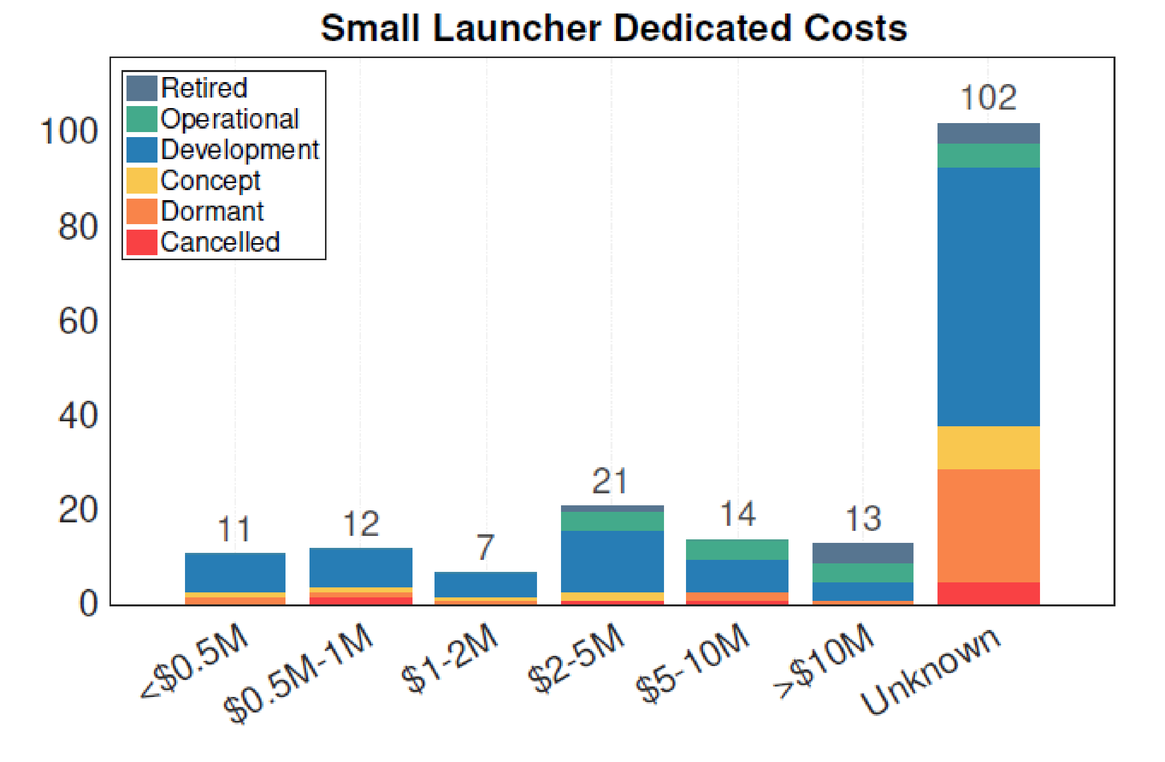
ure 9: Forecast of small satellites (<500kg) to be launched in 2019-2028 (source: Euroconsult, via SpaceNews)[24]



Launch Cost per Kilogram (medium and heavy)
$ per kg (log scale)
$51,200
$25,600
$12,800
$6,400
$3,200
$1,600
$800
$400
$200
$100
1960
1970
1980
1990
2000
2010
2020
2030
Shuttle
Saturn V
Delta IV Heavy
Falcon 9
Falcon Heavy
SPACEX
Starship (estimate)

PICCOLI LANCIATORI (AL 2021)

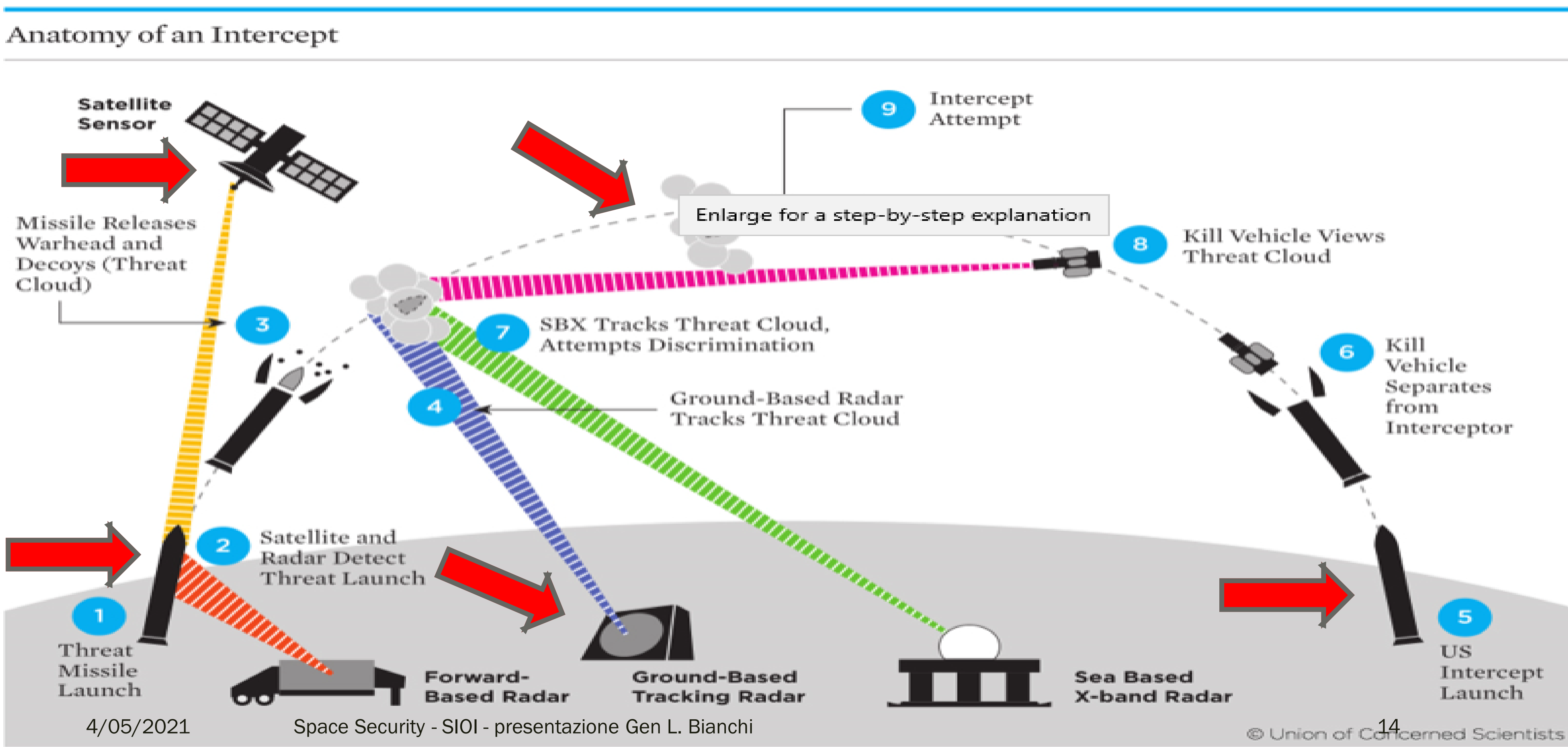


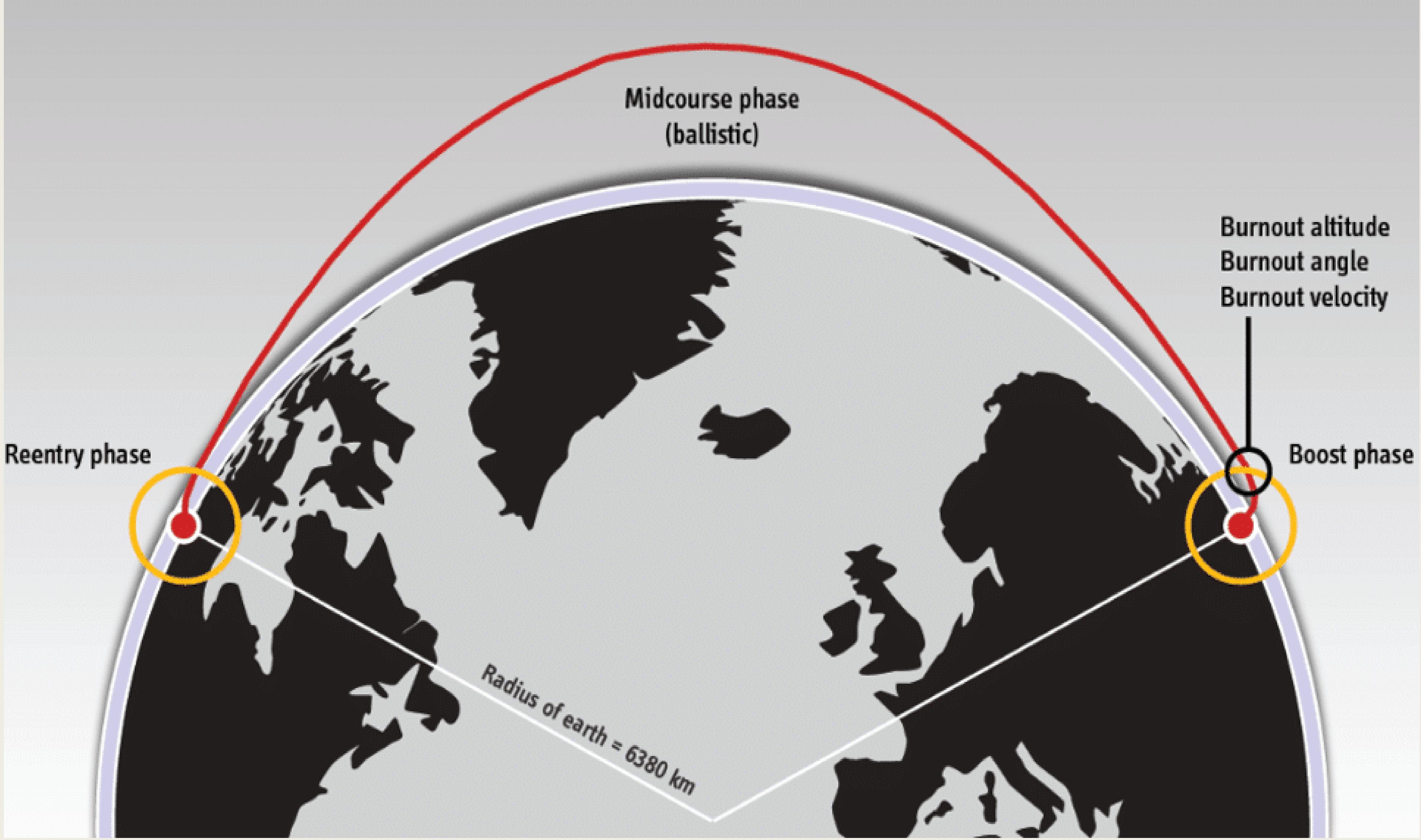


MINACCE AGLI ASSETTI SPAZIALI

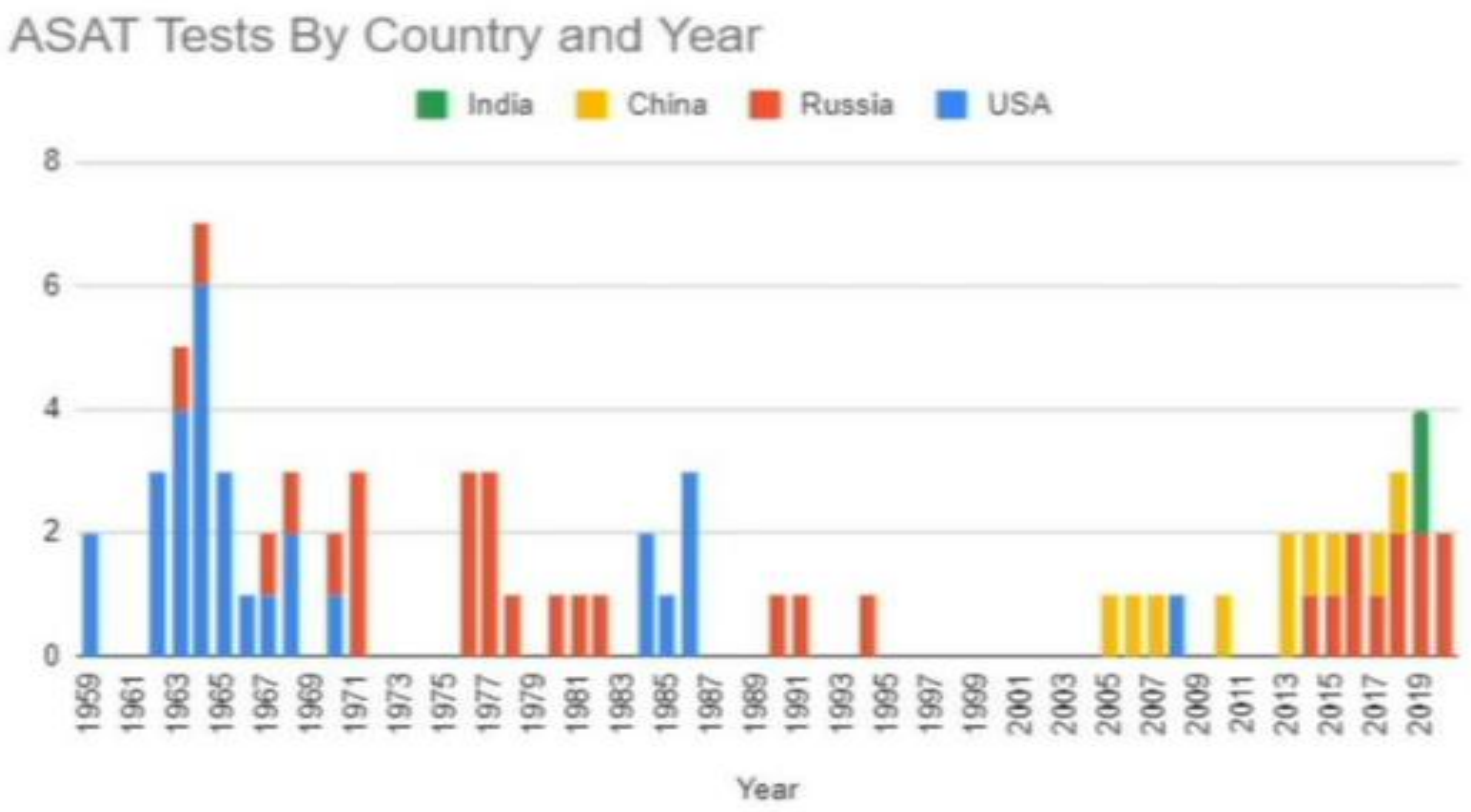
- MINACCE NON INTENZIONALI
  - *SPACE WEATHER*
  - *DETRITI SPAZIALI*
  - *CONGESTIONE DELLE ORBITE*
- MINACCE INTENZIONALI
  - HARD KILL
  - SOFT KILL

MINACCE HARD KILL
ORIGINATE DALLA CAPACITA DI MD

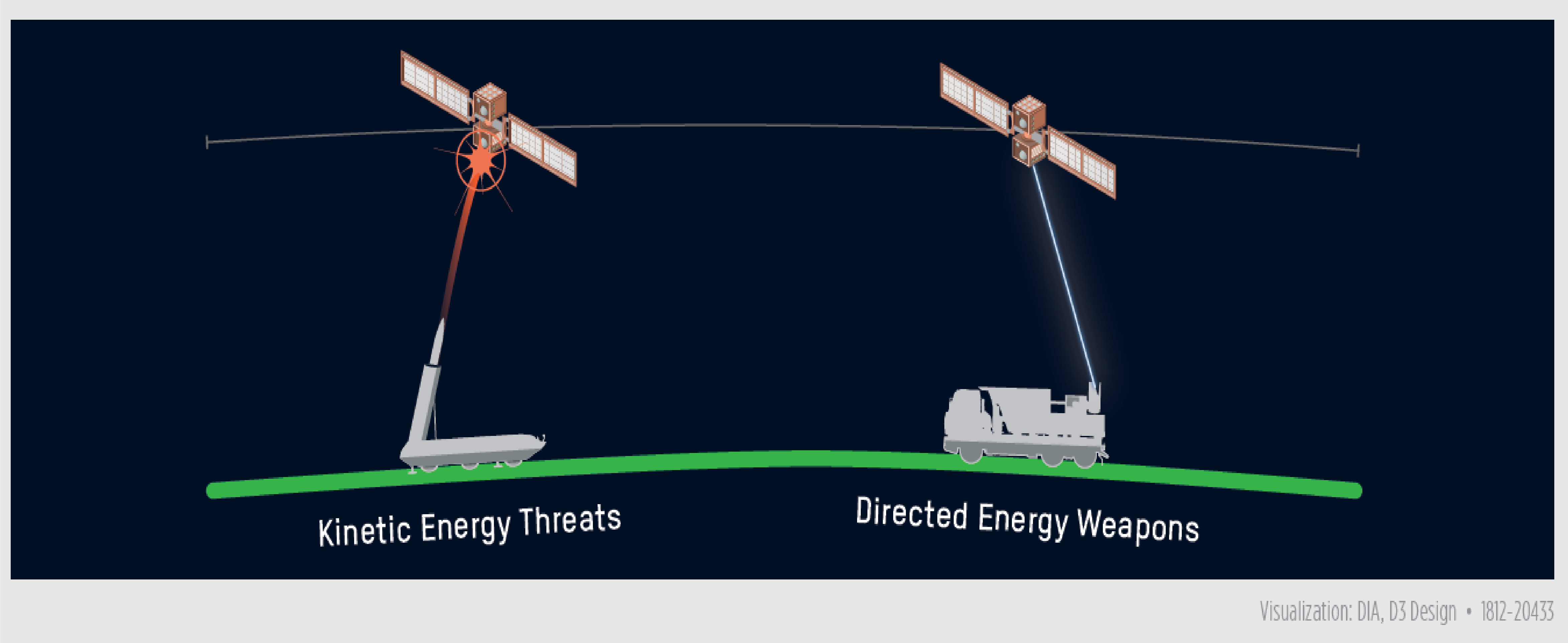




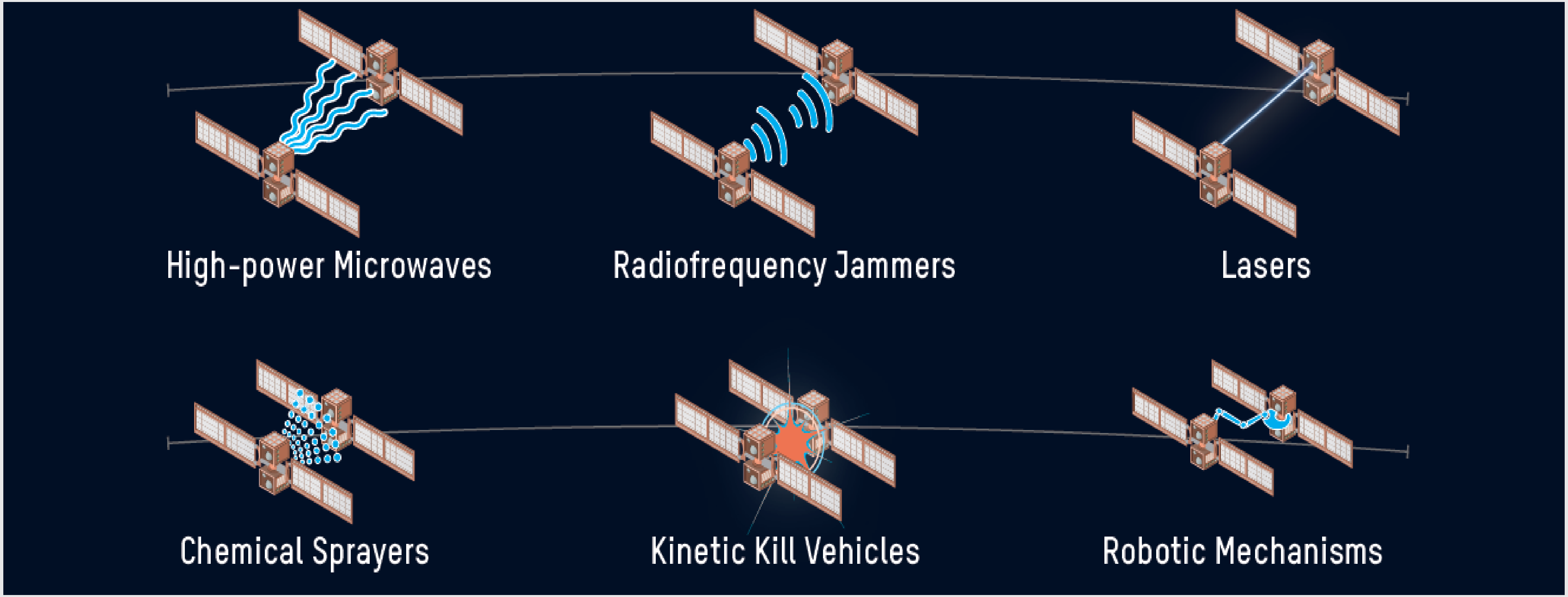
Midcourse phase
(ballistic)
Burnout altitude
Burnout angle
Burnout velocity
Reentry phase
Boost phase
Radius of earth = 6380 km


ASAT Tests By Country and Year
India
China
Russia
USA
0
2
4
6
8
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
Year

Minacce intenzionali ground based

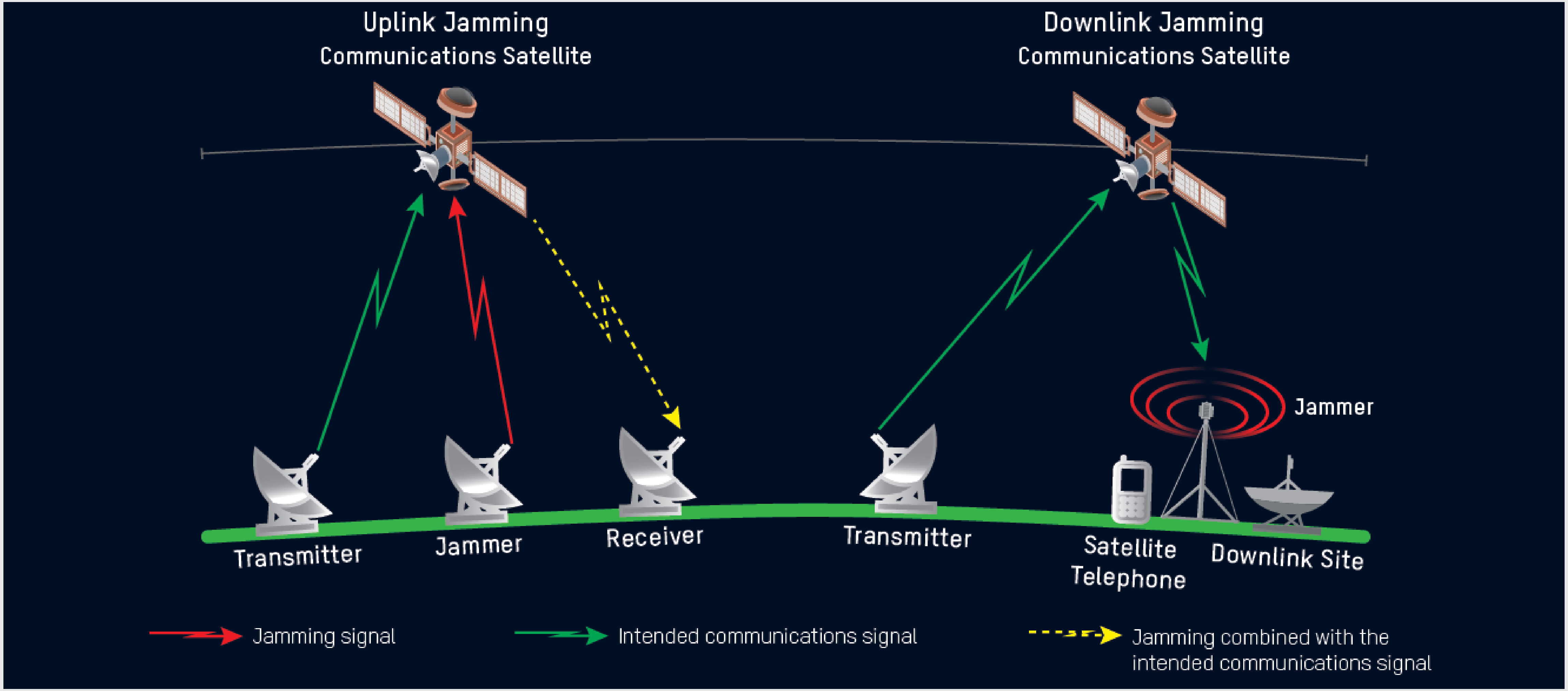


Minacce intenzionali space based HARD & SOFT



Visualization: DIA, D3 Design • 1812-20432

Minacce intenzionali
SOFT KILL



THE UNITED STATES

LEGEND: NONE (R) SOME (Y) SIGNIFICANT (G) UNCERTAIN "?" NO DATA "–"

	R&D	TESTING	OPERATIONAL	USE IN CONFLICT
LEO Direct Ascent	G	Y	–	R
MEO/GEO Direct Ascent	–	–	–	R
LEO Co-Orbital	Y	?	–	R
MEO/GEO Co-Orbital	Y	?	–	R
Directed Energy	G	Y	?	R
Electronic Warfare	G	G	G	G
Space Situational Awareness	G	G	G	G

FONTE : **SECURE WORLD FOUNDATION**

RUSSIA

LEGEND: NONE R SOME Y SIGNIFICANT G UNCERTAIN "?" NO DATA "–"

	R&D	TESTING	OPERATIONAL	USE IN CONFLICT
LEO Direct Ascent	G	Y	–	R
MEO/GEO Direct Ascent	Y	–	–	R
LEO Co-Orbital	G	G	–	R
MEO/GEO Co-Orbital	Y	–	–	R
Directed Energy	G	Y	?	R
Electronic Warfare	G	G	G	G
Space Situational Awareness	G	G	G	?

CHINA

LEGEND: NONE (R) SOME (Y) SIGNIFICANT (G) UNCERTAIN "?" NO DATA "–"

	R&D	TESTING	OPERATIONAL	USE IN CONFLICT
LEO Direct Ascent	G	G	G	R
MEO/GEO Direct Ascent	Y	Y	–	R
LEO Co-Orbital	Y	?	–	R
MEO/GEO Co-Orbital	Y	–	–	R
Directed Energy	G	Y	–	R
Electronic Warfare	G	G	G	?
Space Situational Awareness	G	G	G	?

LA SSA/SST VISTA DA ALTRE PROSPETTIVE QUALCHE ULTERIORE SPUNTO

- LE PROSPETTIVE DEL MONDO DELLE ASSICURAZIONI
- NUOVE CAPACITA DI IN-SERVICE ORBITALE
- NUOVI SCENARI ECONOMICI
  - *DIFESA DEGLI INTERESSI ECONOMICI LEGATI AL SETTORE CISLUNAR E ALLE MISSIONI PLANETARIE*

IL PUNTO DI VISTA SETTORE ASSICURATIVO

- IL RISCHIO DI COLLISIONE IN LEO MINACCIA ASSETTI DI VALORE PARI A CIRCA **38 MILD $** (SOTTOSTIMATO E NON CONSIDERA ISS E RITORNI LEO)
  - *SOLO 8% DI QUESTI ASSETTI SONO ASSICURATI*
  - *LE IMPRESE CONSIDERANO QUESTA **PRINCIPALE MINACCIA AL BUSINESS***
  - *ALCUNE AZIENDE SI SONO RITIRATE DAL SETTORE ASSICURATIVO*
- UN EVENTO DI COLLISIONE DI UN ASSETTO ASSICURATO DI VALORE SIGNIFICATIVO POTREBBE AVERE **CONSEGUENZE GRAVI** SUL MERCATO ASSICURATIVO SPAZIALE
- PER LE SOCIETA ASSICURATIVE LE PROSPETTIVE NON SONO INCORAGGIANTI
  - *LANCIATORI PIU PICCOLI - SATELLITI PIU PICCOLI ⇒ PIU RISCHI*
  - *MAGGIORE PRESENZA COMMERCIALE ⇒ PIU RISCHI*

NECESSARIO SSA/SST EFFICACE E AFFIDABILE

LA SSA / SST VISTA DA ALTRA PROSPETTIVA

- LE PROSPETTIVE DEL MONDO DELLE ASSICURAZIONI
- NUOVE CAPACITA   DI IN-SERVICE ORBITALE
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  - *DIFESA DEGLI INTERESSI ECONOMICI LEGATI AL SETTORE CISLUNAR E DELLE MISSIONI PLANETARIE*

TOMORROW

IN-ORBIT SERVICING

THE NEXT MARKET

We believe the combination of **existing D-Orbit technology**, the scalability of the **ION platform** and **advanced robotics** will enable D-Orbit to provide in-orbit servicing to satellite operators

- TRANSPORTATION
- REFUELING
- PHASING

Scalable and modular

In-orbit servicing active debris removal

- MAINTENANCE
- EMERGENCY
- DISPOSAL

01	02	03	04
Move existing satellites from one orbit to another new orbit	Extend the life of satellites	Rescue satellites launched or drifting to the wrong orbit	Dispose of satellites properly at the end of their life (active debris removal)

D-Orbit has already won a contract with a major satellite operator for studying and delivering in-orbit servicing (active debris removal)

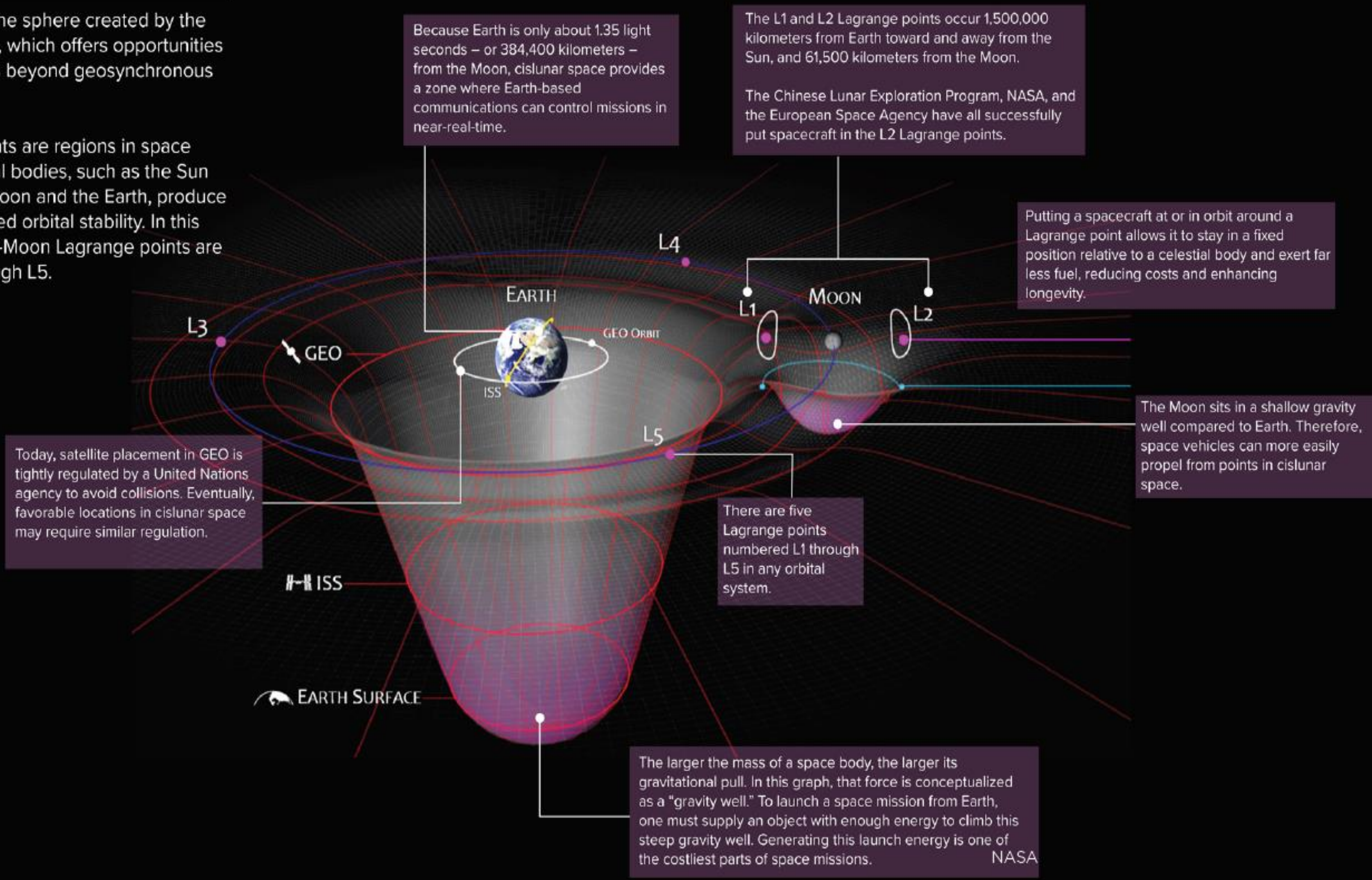
LA SSA / SST VISTA DA ALTRA PROSPETTIVA

- LE PROSPETTIVE DEL MONDO DELLE ASSICURAZIONI
- NUOVE CAPACITA DI IN-SERVICE ORBITALE
- NUOVI SCENARI ECONOMICI
  - *DIFESA DEGLI INTERESSI ECONOMICI LEGATI AL SETTORE CISLUNAR E ALLE MISSIONI PLANETARIE*

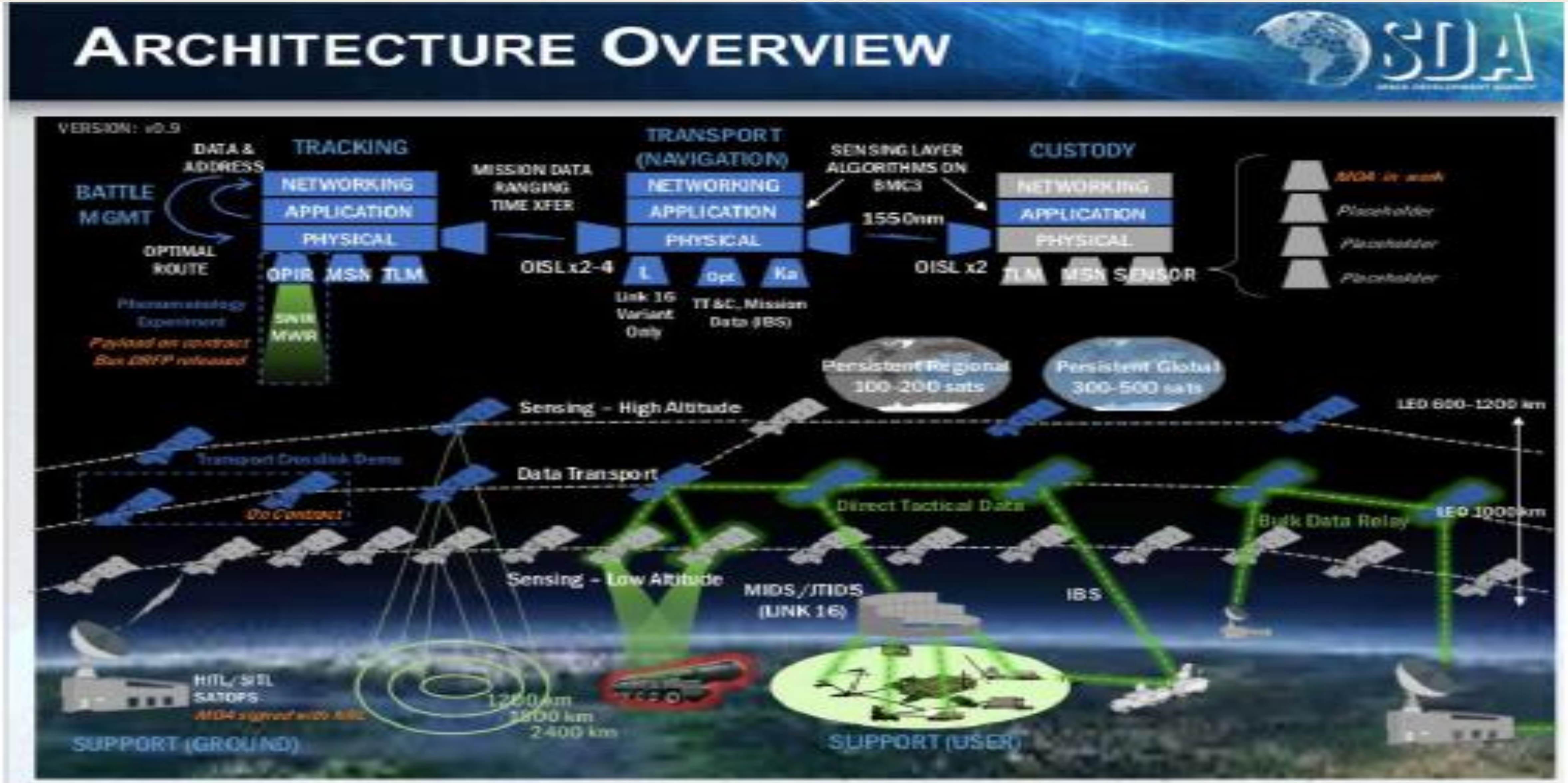
Map of Cislunar Space

Cislunar space is the sphere created by the Earth-Moon radius, which offers opportunities to extend activities beyond geosynchronous Earth orbit (GEO).

The Lagrange points are regions in space where two celestial bodies, such as the Sun and Earth or the Moon and the Earth, produce regions of enhanced orbital stability. In this diagram, the Earth-Moon Lagrange points are numbered L1 through L5.



USA – UNA RISPOSTA ALLA SPACE SECURITY

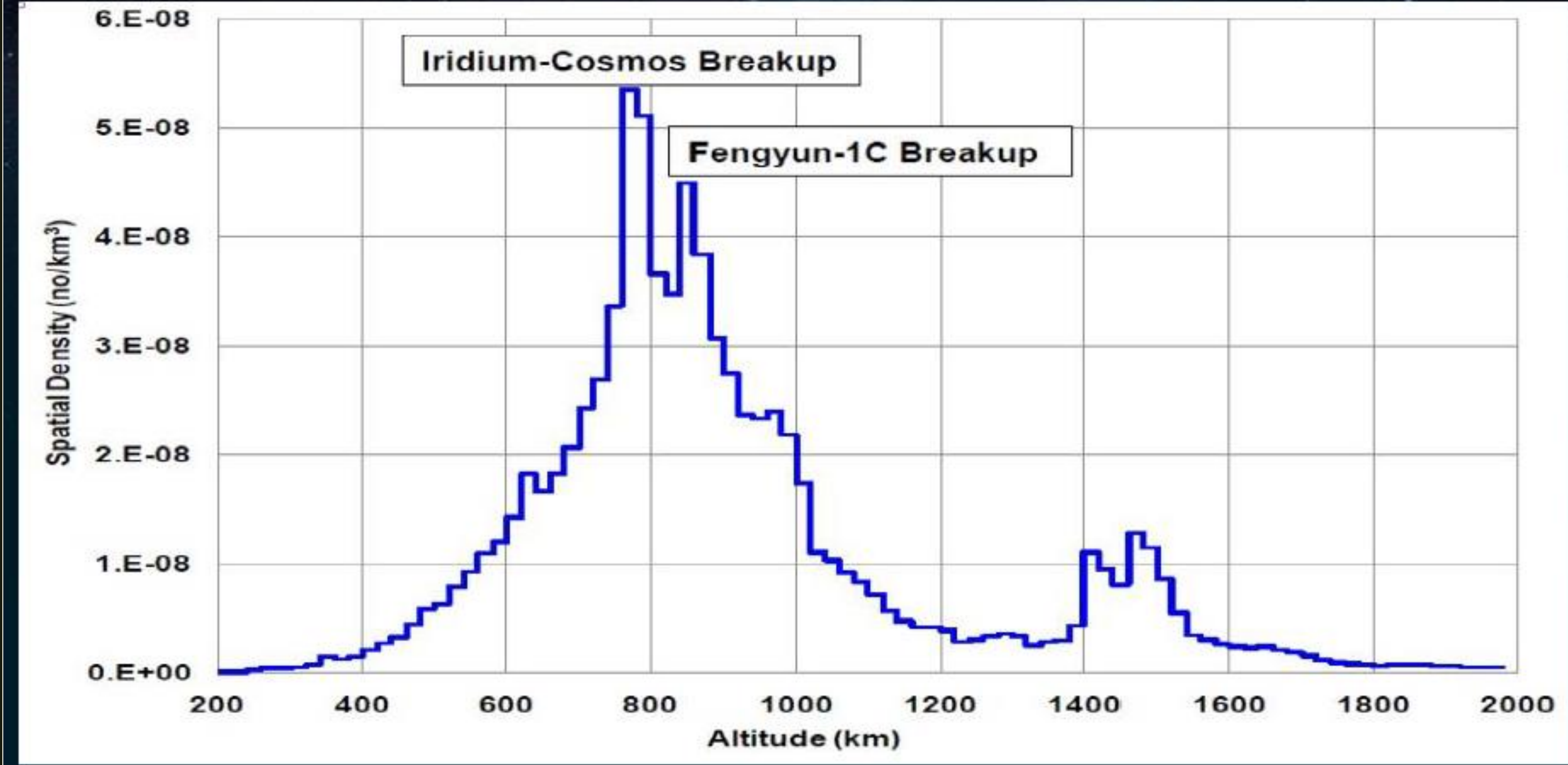


Architettura resiliente di piccoli Sat su (5+2) livelli

- **Space Transport Layer:** Global, persistent, low-latency data and communications proliferated "mesh" network to provide 24×7 global communications (200-300 sat)
- **Tracking Layer:** Indications, warning, targeting, and tracking of advanced missile threats (200 sat)
- **Custody Layer:** 24×7, all-weather custody of all identified time-critical targets (200-300 sat).
- **Deterrence Layer: Space Situational Awareness (SSA) of, and rapid access to, the cislunar volume (X37 ….) , LUNINT (intel on moon)**
- **Navigation Layer:** Alternate Positioning, Navigation and Timing (PNT) for GPS-denied environments (100-150 sat)
- **Battle Management Layer:** Distributed, artificial intelligence-enabled Battle Management Command, Control and Communications (BMC3
- **Support Layer:** Mass-producible ground command and control capabilities, user terminals, and rapid-response launch services (small- to medium-class).

LO SPAZIO CHE SI AFFOLLA - SPACE SITUATION AWARNESS E SPACE SURVEILLANCE AND TRACKING (SSA/SST)

Where Is All This Junk?



Orbital Perturbations

- Planetary and satellite motion at a high level can be described by Keplerian motion
- Simplifications and assumptions in Kepler's theory do not account for most real-world effects
- These effects, called perturbations, alter the trajectory of a satellite from its nominal path.

- Conservative Perturbations
  - Non-Spherical Earth
  - Third-body Effects
  - Solar Radiation Pressure*
- Non-conservative Perturbations
  - Drag

** In theory SRP is a conservative fo[illegible] between photons and*

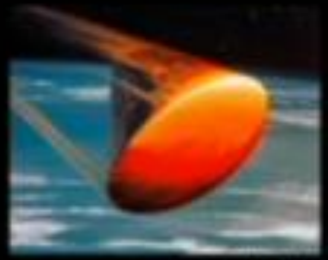
- **Non-Spherical Earth**
  - Earth is not perfectly spherical, but rather an approximate oblate spheroid
  - The centrifugal effect, caused by Earth's rotation, produces a bulge near the equator
  - Affects RAAN and arg. of perigee

Credit: NASA/ JPL Caltech [8]

- **Third-Body Effects**
  - Kepler's equation assumes only one massive body in the system, but the gravitational effect of the Sun and other planets perturb a satellite's orbit from the path predicted by Kepler.

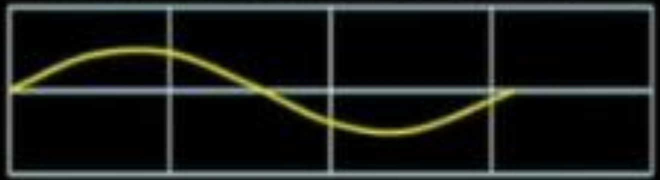
Credits: NASA/JPL Caltech [9]

- **Drag**
  - A result of Earth's atmosphere
  - Varies with solar activity/cycle
  - Additionally, interactions between solar wind and Earth's magnetic field during geomagnetic storms can increase short term drag effects
  - Significant for LEO satellites below 700-1000 km
  - Affects SMA and eccentricity



Credit: NASA [10]

- **Solar Radiation Pressure**
  - Force of solar photons impacting satellite
  - The typical SRP effect on a satellite's orbit is a long-term sinusoidal variation in eccentricity



Credit: NASA [11]

Current and planned constellation projects	# of satellites	Satellite mass (kg)	Altitude	Project status
Amazon Kuiper	3,236	unspecified	590-630 km	Development
Astrocast	80	3/6U CubeSats	500-600 km	Demonstration
Boeing V-band	2,956	unspecified	1,200 km	Development
Globalstar 2	24	700 kg	1,410 km	In operation
Hongyan	320	unspecified	1,100 km	Demonstration
Hongyun	156	250 kg	1,000 km	Demonstration
Iceye	18	80 kg	587 km	Deployment
Iridium-NEXT	72	860 kg	780 km	In operation
Kepler	140	3U CubeSats	575 km	Development
LeoSat	108	1.000 kg	1,432 km	Suspended operations
OneWeb	648	147 kg	1,200 km	Deployment
Planet	150	3U CubeSats	370-430 km	In operation
SpaceX Starlink	4,425 (init.) (+7,518)	260 kg	1,100-1,325 km 340 km (add. sats)	Deployment
Spire	175	3U CubeSats	385-650 km	In operation
Swarm	150	0.25U CubeSats	300-550 km	Demonstration
Telesat LEO	117	unspecified	1,000 km	Development
Theia	120	unspecified	800 km	Development

Table 1: Selection of current and planned constellation projects in Low Earth Orbit (source: ESPI compilation)