Overview of the Space Environment

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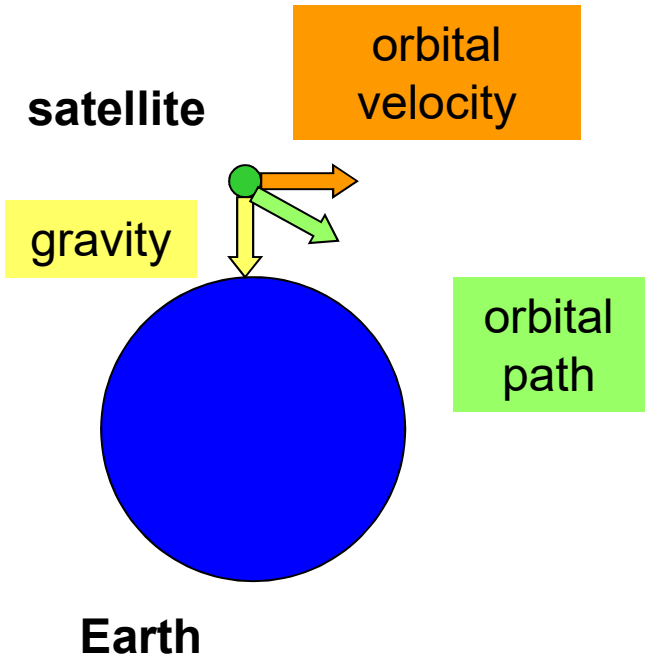
Oveview

- Basic physics of space
- National security uses of space
- Space debris
- Emerging and future security issues

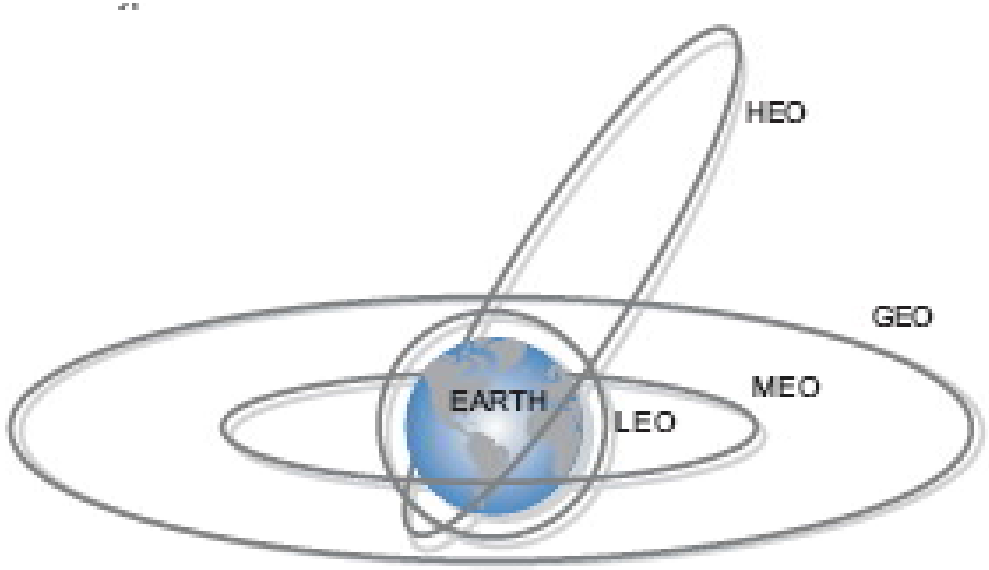
PHYSICS OF SPACE

Orbital mechanics 101



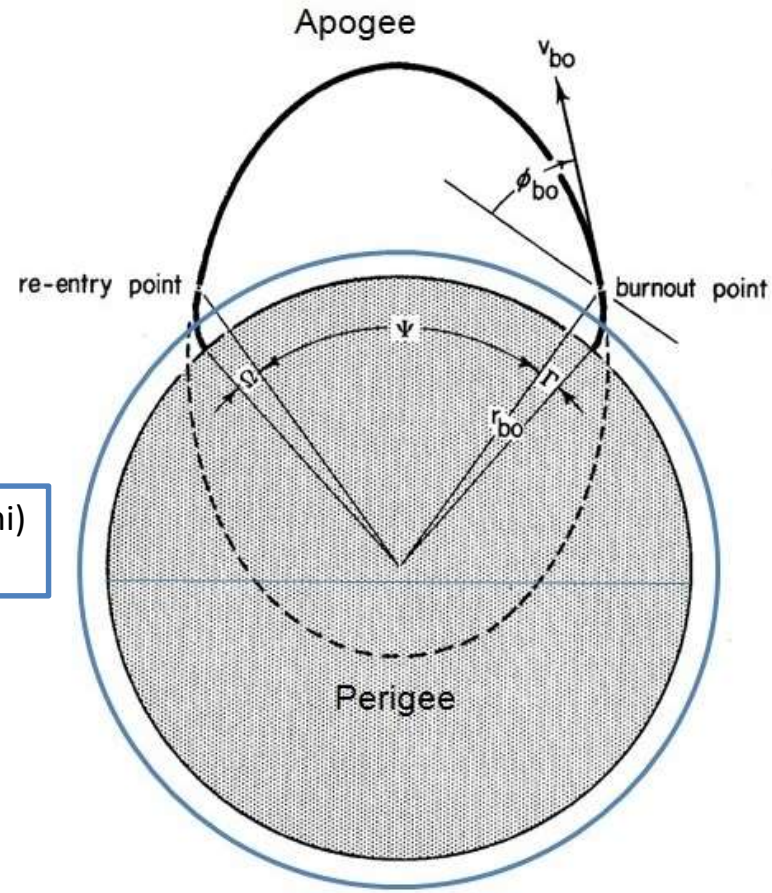
- Gravity exists in space!
  - Mass causes space-time to bend and objects to accelerate towards the mass, this acceleration is known as “gravity”
  - Objects in orbit are pulled towards the Earth but miss because of their orbital velocity (i.e. “freefall”)
- Rockets perform two functions
  - Lift payload to appropriate height (usually between 200km and 1000km for Near Earth)
  - Accelerates payload to the velocity needed to maintain orbit at that height (~7.6 km/s at 400km)

Basic Earth orbit typologies



	Name	Altitude	Inclination	Shape
LEO	Low Earth Orbit	250 - 2,000 km	Varies, many 80-100°	Mostly circular
MEO	Medium Earth Orbit	10,000 - 12,000 km	Varies	Circular
HEO	Highly Elliptical Orbit	1,000 km (perigee) 40,000 km (apogee)	63°	Elliptical
GEO	Geostationary Earth Orbit	36,000 km	Typically 0°	Circular

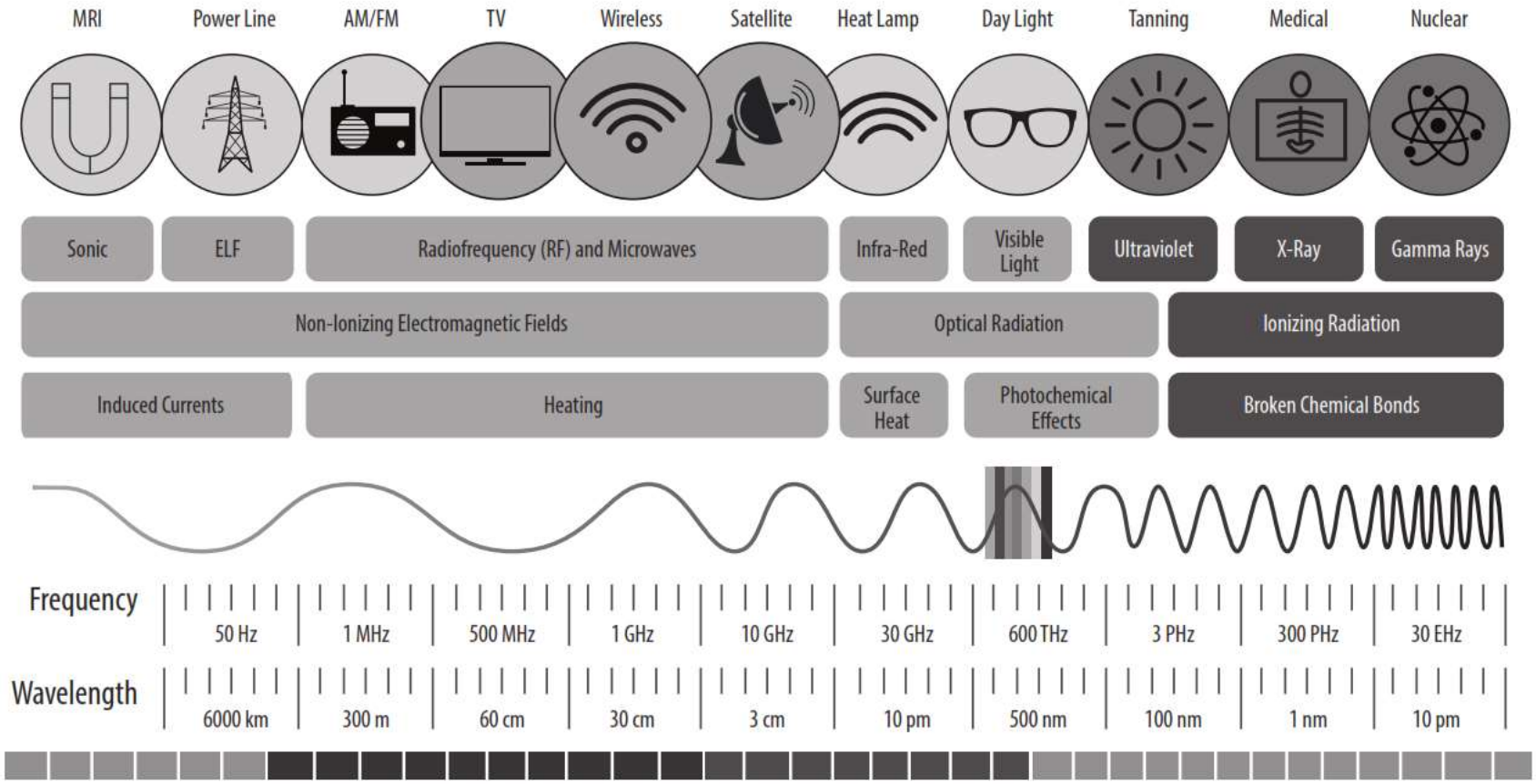
Ballistic vs orbital trajectories



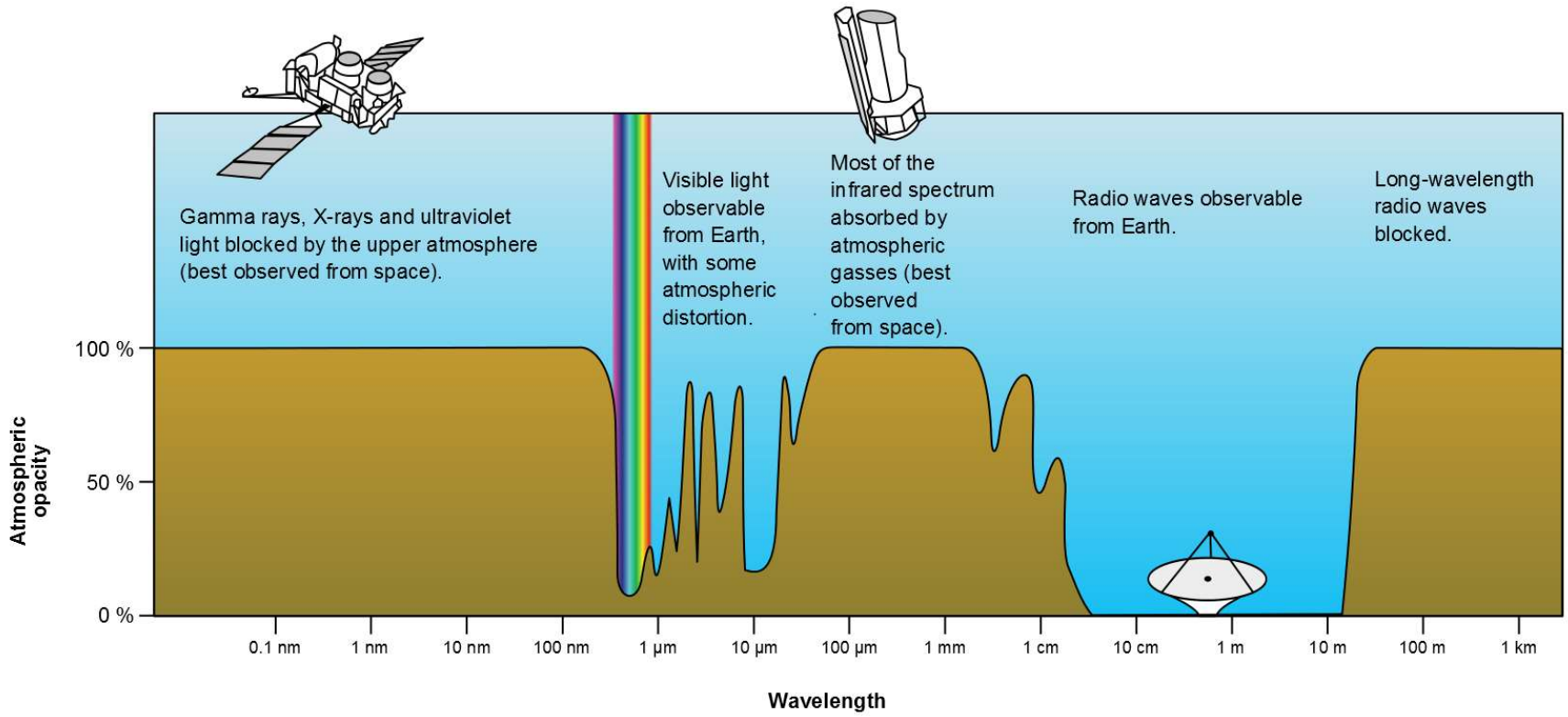
800 km (500 mi) circular orbit

Maximum altitude of a ballistic missile trajectory is roughly half the horizontal distance it will travel

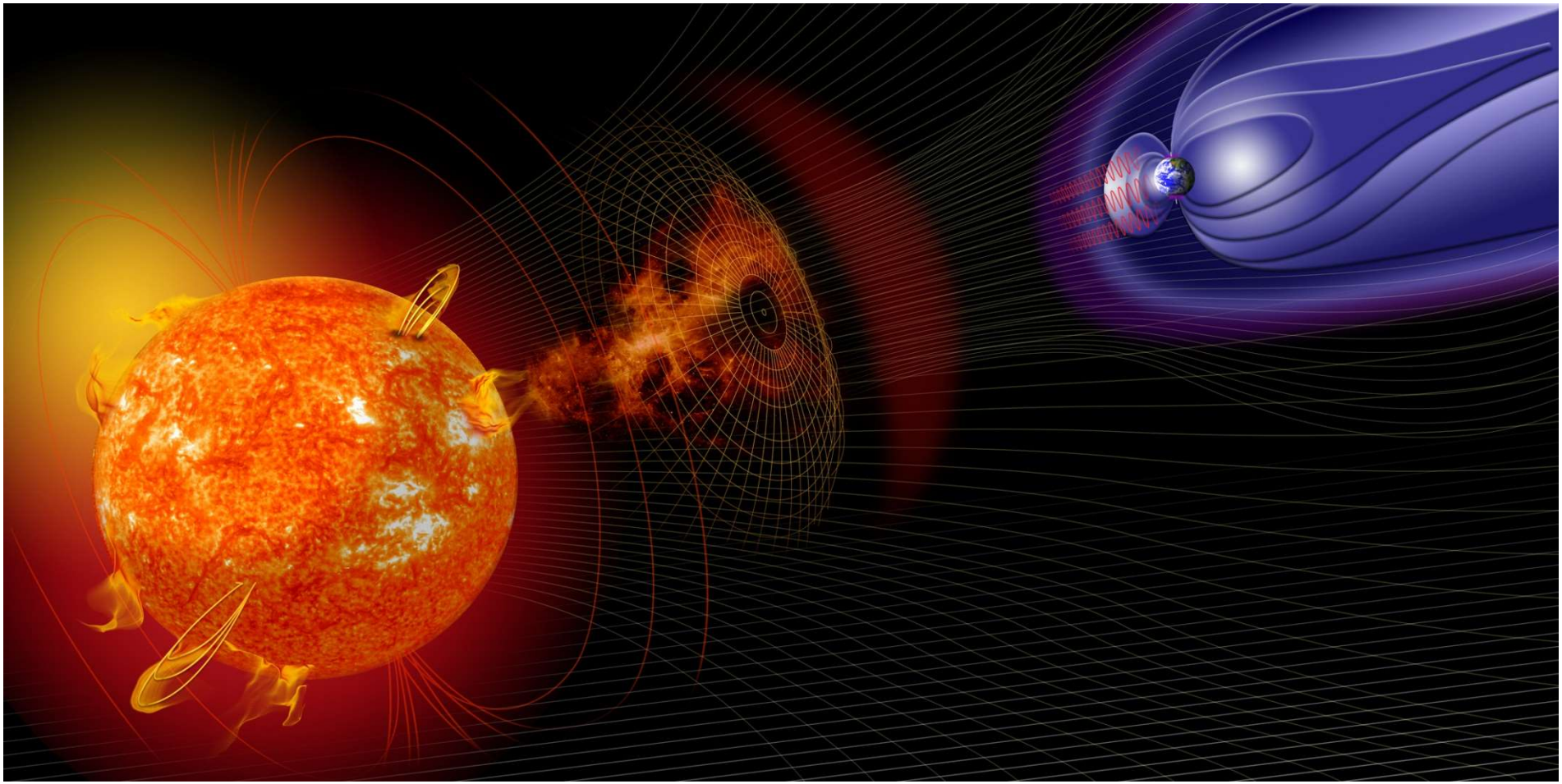
Electromagnetic (EM) spectrum



Atmospheric effects on EM spectrum



Space weather

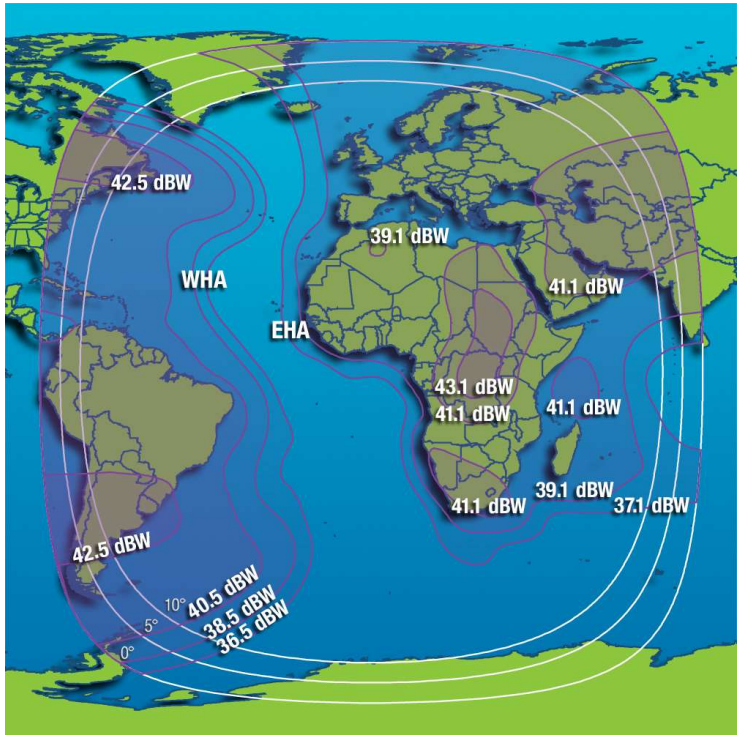


Implications

- Very small differences between long-range ballistic missiles and space launch vehicles
- Objects in Earth orbit need to be moving at relatively high speeds (typically 8-4 km/s) to stay in orbit, and require a lot of energy to change orbits
- There are specific orbits that are typically used for specific applications, but not hard limits
- There are specific parts of the EM spectrum that are best-suited for specific applications, and some hard limits to do otherwise
- Space weather can cause uncertainty in anomalies and malfunctions

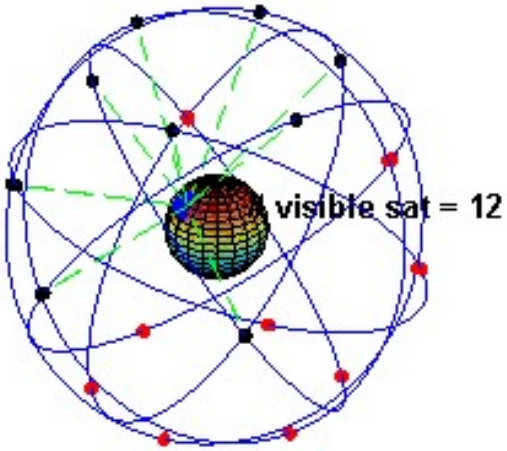
NATIONAL SECURITY USES OF SPACE

Major military uses of space



Field of view of a single geostationary satellite
Source: Intelsat

1-Meter Resolution Radar Image of the U.S. Capitol



GPS constellation

Elements of a space capability

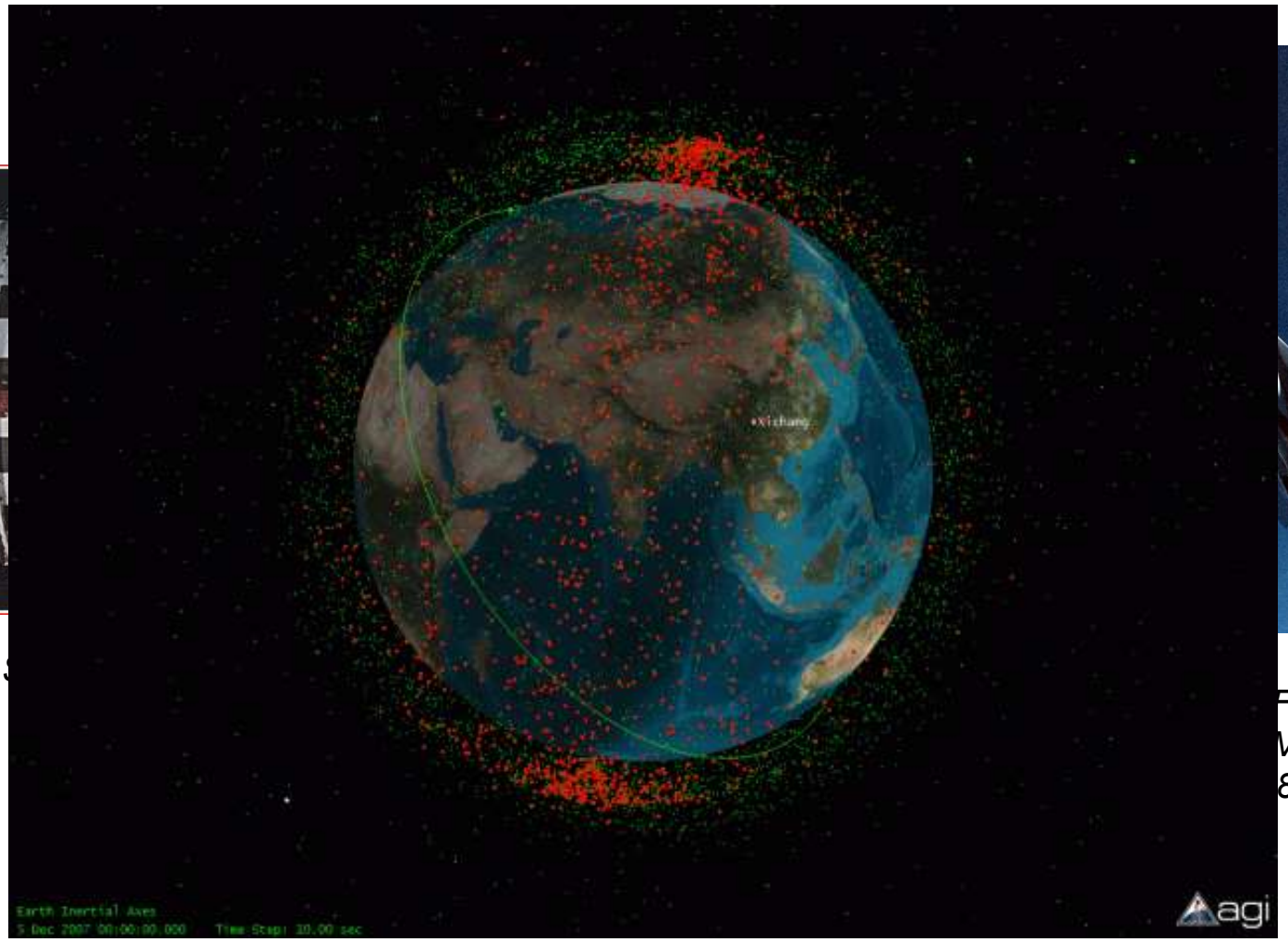
Space segment

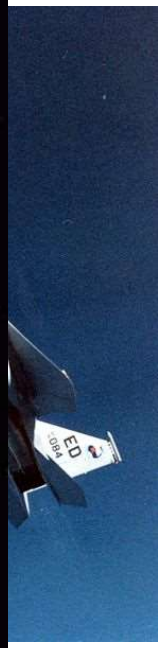
Ground segment

Internet

User segment

Kinetic attacks on satellites





F-15
M-135
8-1988)

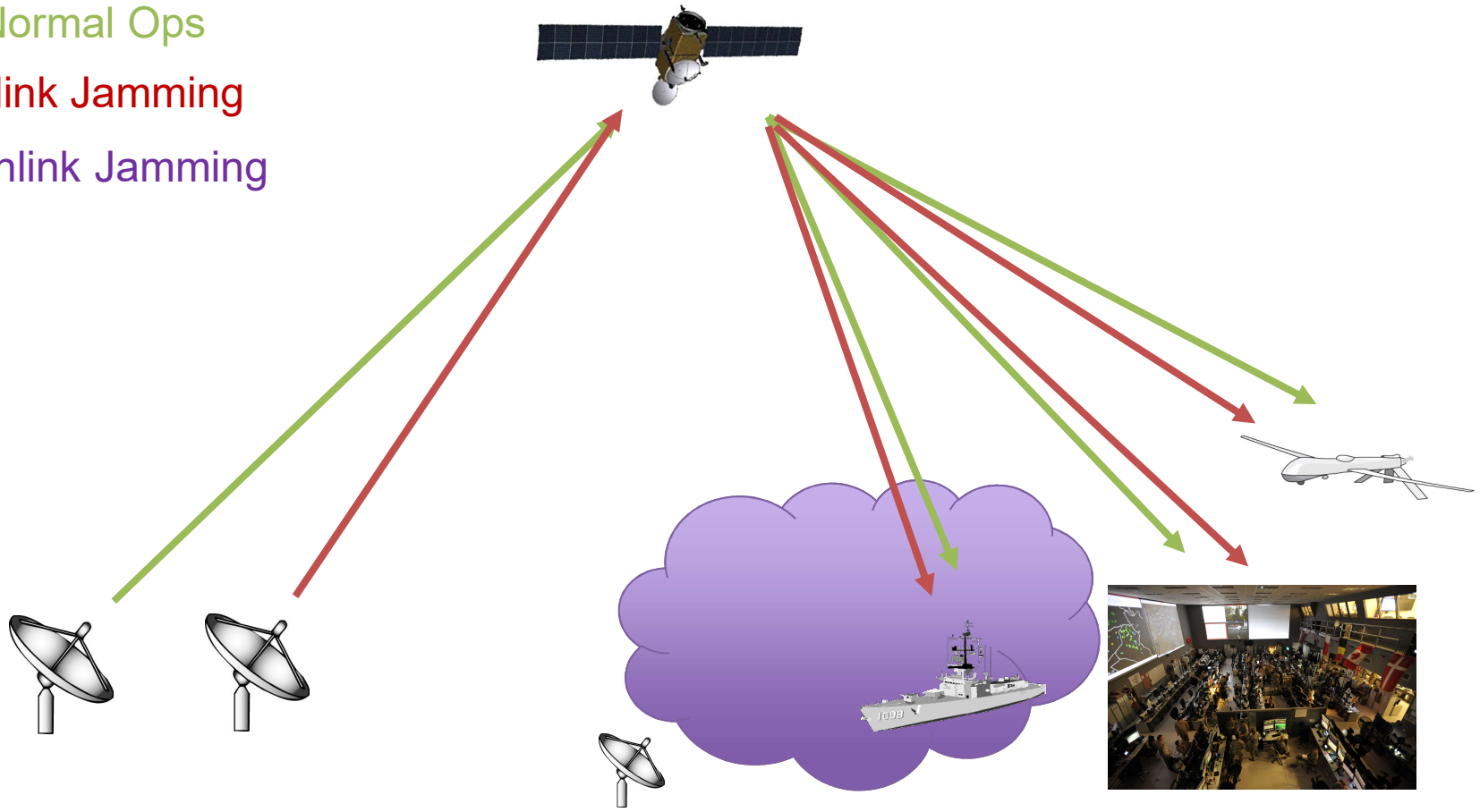
Debris from 2007 Chinese ASAT Test
(Source: Celestrak)

Satellite jamming

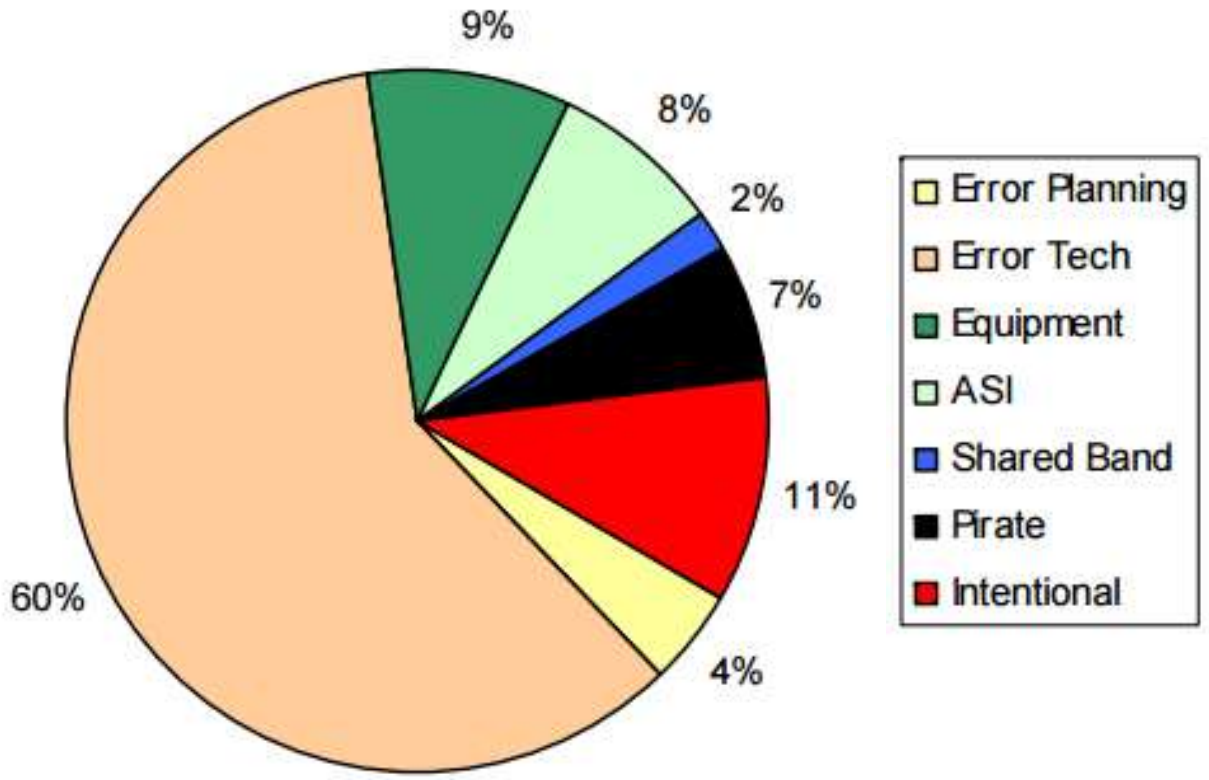
Normal Ops

Uplink Jamming

Downlink Jamming



Sources of interference



Source: Eutelsat briefing to the ITU (2013)

Space EW in Ukraine

At 13.01hrs and again at 13.19hrs the SMM UAV was subjected to serious electronic jamming while flying over "DPR"-controlled Chermalyk (40km NE of Mariupol). Initial analysis of the SMM UAV flight log data indicated that the SMM UAV was subjected to military-grade GPS jamming. The Ukrainian Air Operations Liaison Officer to the "Anti-Terrorism Operation" ("ATO") headquarters in Sector 'M', who was immediately contacted by the SMM UAV Team, told the SMM at 13.24hrs that there was no jamming by the Ukrainian forces. The SMM UAV left the area and landed safely. This is the third serious interference with the movement of the SMM UAV and is an impediment to the fulfilment of the Mission's mandate.

Source: Organization for Security and Cooperation in Europe

Russian R-330ZH Zhitel

Source: Ukrainian journalist Yaroslav Krechko

Non-state actors

$2,500 Phase-Coherent GPS Signal Synthesizer

Used to perform cyber attacks on GPS receivers using manipulated civil signals

Source: Nighswander, Ledvina, Diamond, Brumley, and Brumley (2012)

$85 million White Rose of Drachs

Successfully steered off course by UT grad students using homemade GPS spoofer

Source: UT Austin School of Engineering (2016)

Implications

- EM interference with satellite services is already commonplace
- Vast majority of interference is unintentional, but intentional is a big issue in specific regions
- Intentional EM interference with space capabilities has likely been part of every major conflict for last 10 years (or more)
- Technologies are proliferating to more state and non-state actors

SPACE DEBRIS

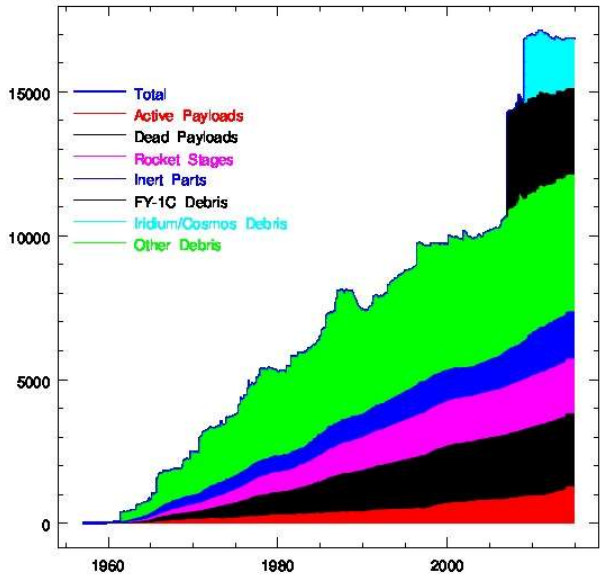
Current satellites on orbit

Total number of operating satellites: 1,419			
United States: 576	Russia: 140	China: 181	Other: 522
LEO: 780	MEO: 96	Elliptical: 37	GEO: 506

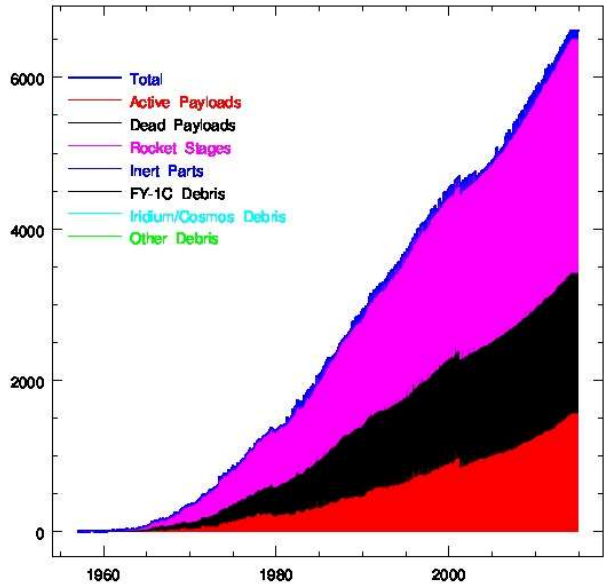
Total number of military satellites: 350					
Navigation	Weather	Communications	Missile Warning	Intelligence, Surveillance, & Reconnaissance	Technology Development
101	10	117	10	113	30

Source: Union of Concerned Scientists Satellite Database
(includes launches through 6/30/16)
http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database

Evolution of space objects orbiting Earth



Number of objects

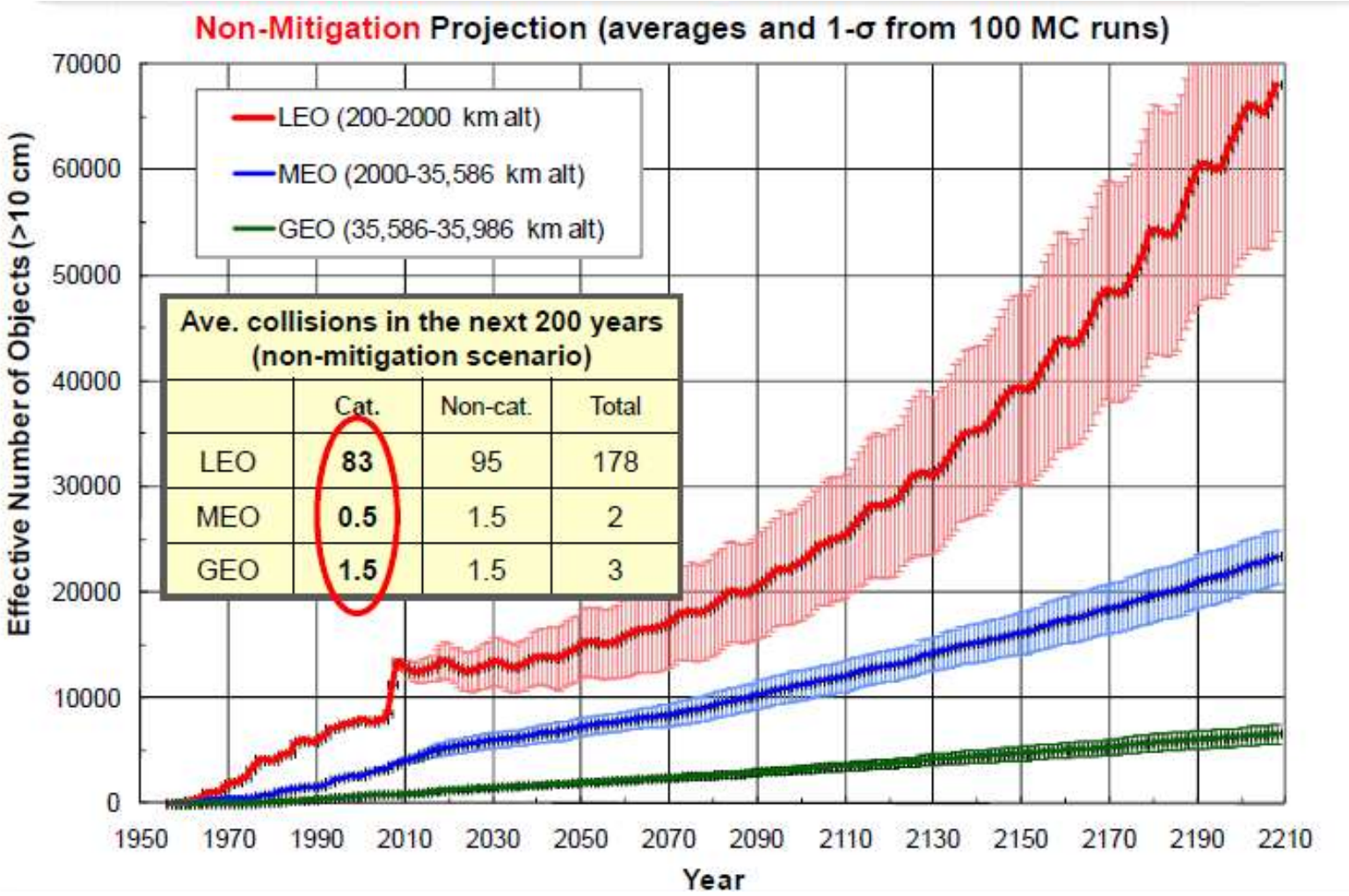


Mass of objects

Larger than 10 cm	~17,000	Sources of new debris
Between 1 and 10 cm	~500,000	Can cause major damage
Smaller than 1 cm	Many millions	Can cause minor damage

Data compiled from U.S. Strategic Command, NASA, and ESA
Graphs from Jonathan's Space Page http://planet4589.org/.

The next 200 years, if things stay the same

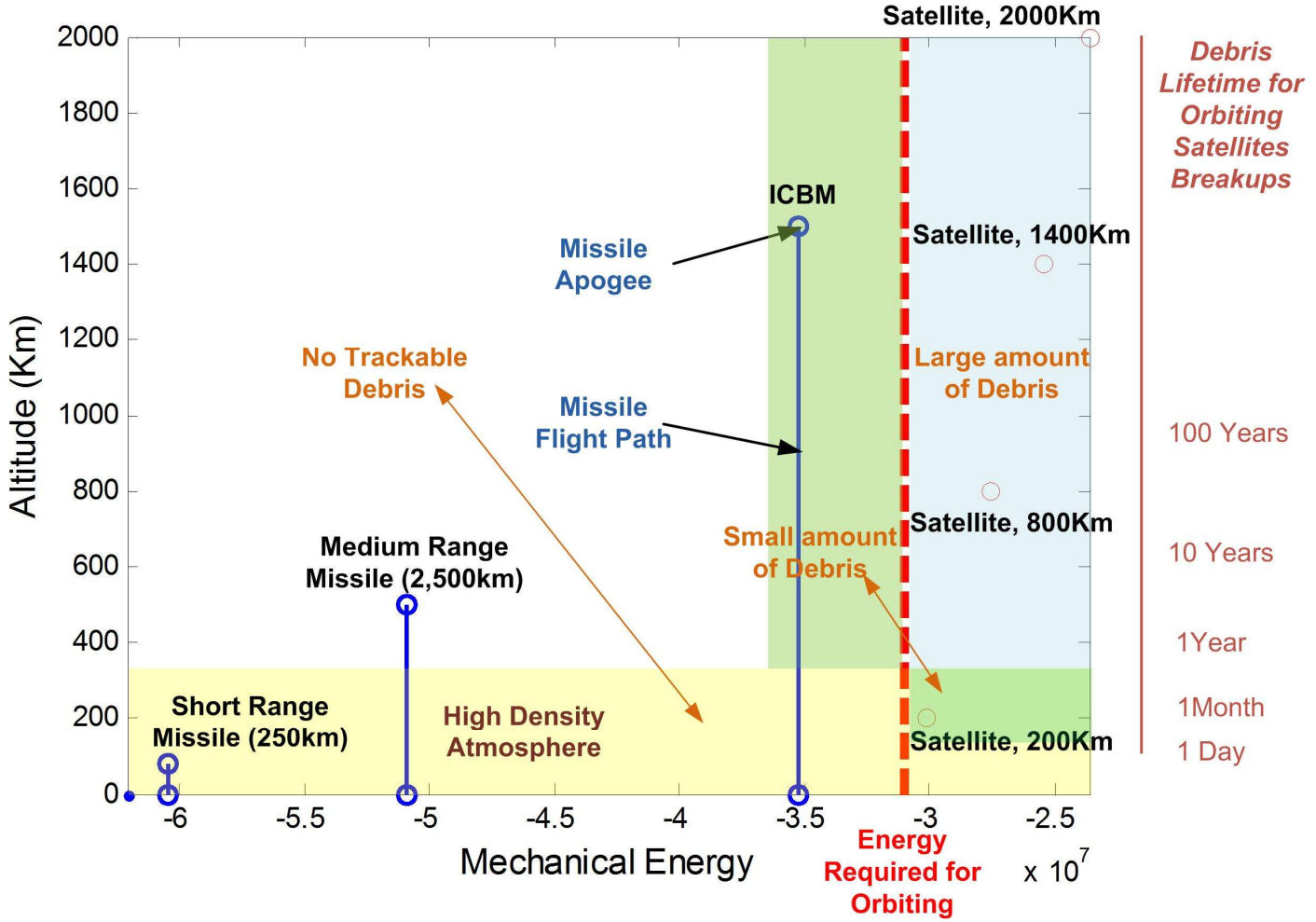


Ave. collisions in the next 200 years (non-mitigation scenario)

	Cat.	Non-cat.	Total
LEO	**83**	95	178
MEO	**0.5**	1.5	2
GEO	**1.5**	1.5	3

J-C Liou, NASA Orbital Debris Program Office (2009)

Missile defense intercepts and orbital debris



Implications

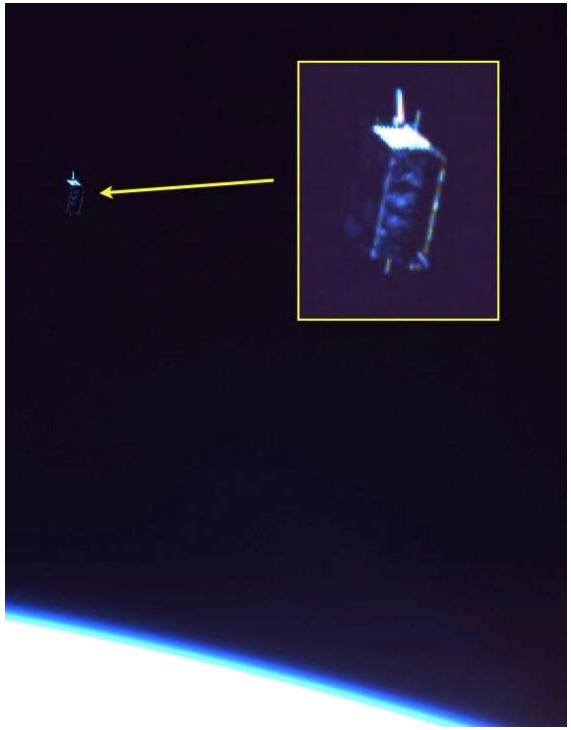
- Kinetic missile defense intercepts ***may*** generate space debris, depending on altitude and velocity of target
- Kinetic attacks on satellites ***will*** generate large amounts of space debris (thousands+ of pieces)
- Main consequence will be to ***raise the probability of collisions*** for other space objects
  - Biggest impact will be on objects in same/nearby orbits
  - But will spread to other orbits over time
- Duration of risk could be ***days/months/years/decades***, depending on the specifics of altitude and collision mechanics

EMERGING AND FUTURE ISSUES

Rendezvous and proximity operations (RPO)

Promoting Cooperative Solutions for Space Sustainability

"getting up close and (perhaps) touching another space object"



Swedish "Mango" satellite imaged by its partner, "Tango"

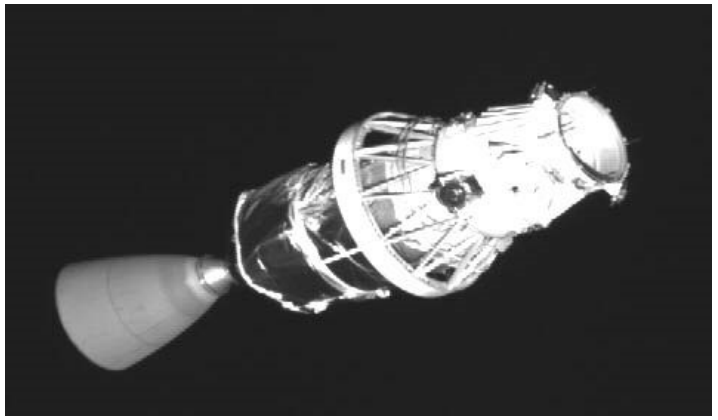
China remains silent on satellite rendezvous

BY STEPHEN CLARK
SPACEFLIGHT NOW
Posted: September 8, 2010

SHARE

The U.S. Air Force last week acknowledged tracking Chinese satellites secretly testing orbital rendezvous technologies, nearly two weeks after the spacecraft may have bumped into each other more than 350 miles above Earth.

A Department of Defense spokesperson confirmed numerous reports of two satellites deliberately flying in close formation.



Delta II rocket imaged by American XSS-10

Space-based missile defense

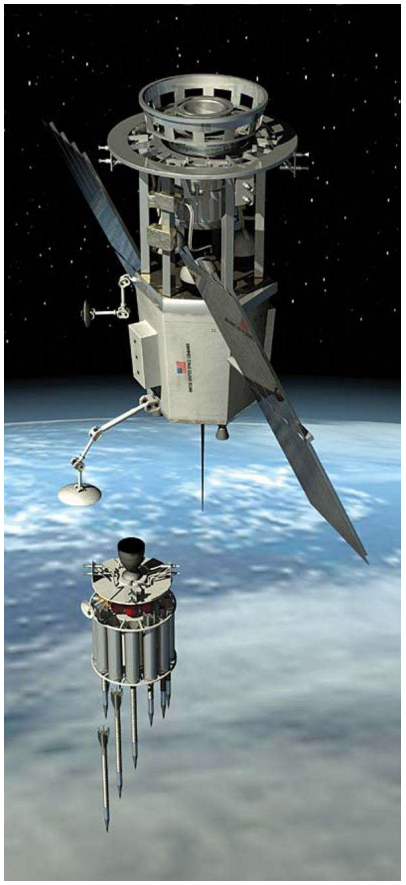
- Space-based missile defense interceptors have theoretical advantages over ground-, air-, or sea-based interceptors
  - Perform boost phase intercepts virtually anywhere in the world, at any time
- Nuclear-pumped X-ray lasers
  - Use a nuclear detonation to power an X-ray laser
- Kinetic kill satellites
  - Larger satellites releasing multiple kinetic-kill interceptors
  - 1,000 (or more) microsatellites interceptors
- Major challenges include high costs, inducing an arms race/instability, command and control, and increased congestion of LEO

Hypersonic weapons

- Goal: to be able to strike fleeting targets anywhere in the world
- Tech: ballistic missile to launch hypersonic glider with a conventional (non-nuclear) weapon on a non-ICBM trajectory

Space-to-earth force application

- Since the 1960s, military planners have considered satellites that can be used to attack targets on Earth
  - Analogous to strategic air bombardment
- Two main technologies
  - Re-entry of hyperkinetic "rods"
  - Space-based lasers
- So far air-, sea-, and ground-based capabilities have always proven to be more effective options



Artist's conception of "Rods from God"

Thank You.
Questions?

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