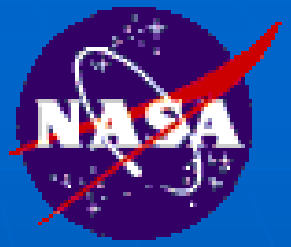


Will the Commercial Sector Overtake the Government's Lead in Mitigation and Remediation Policy?

Stephen Garber

11/14/18

Outline

I. Mitigation Guidelines, Waivers

II. Commercial Developments

- A. Cubesats, Large LEO constellations
- B. SSA Capabilities

III. SPD-3

IV. Remediation technology

V. Summary

U.S. AIR FORCE

Orbital Debris Mitigation
Standard Practices

"Consistent with mission requirements and cost"

1 - Control Release of Debris
During Normal Operations

- *No Debris greater than 5mm that will remain on-orbit for more than 25 years)*

2 - Accidental Explosion
Minimize During and After Mission Operations

- *Demonstrate no credible failure mode, if so limit*
- *Deplete stored energy sources - Passivation*

3 - Assess and Limit Collisions
Safe Flight Profile and Operational Configuration

- *Limit collision with large objects*
- *Limit collision with small objects less than 1 cm that could prevent post-mission disposal maneuvers*

4 - Post-Mission Disposal

- *Disposal Orbits*
  (between LEO/MEO, MEO/GEO, above GEO)
- *LEO: deorbit within 25 years*
- *Re-entry Casualty Expectation*
  Ec less than 1 in 10,000

Exceptions to National Space Policy require approval of the agency head (SECDEF) and notification to the Secretary of State.

NATIONAL SPACE POLICY
of the
UNITED STATES *of* AMERICA

I. Waivers

- potential, perceived conflict of interest
- AF didn't need any waivers one year but still hard to build sets of sats differently
- Other bureaucratic options?
- Other financial incentives?

- II. A. Changing Environment
  - Cubesats
  - Large LEO constellations

  Will existing guidelines suffice?

LEO & MEO Broadband Constellations

At least 15 companies have declared their intent to develop broadband satellite constellations in low Earth orbit (LEO) or medium Earth orbit (MEO), according to Northern Sky Research. Most of these companies intend to have their first-generation systems deployed within five years. O3b, which is nearing completion of a 20-satellite constellation begun in 2013, will add seven mPower second-generation broadband satellites starting in 2021.

PROGRESS KEY

- Constellation builder selected
- Launcher(s) identified
- Prototype satellite(s) launched
- Operational satellite(s) in orbit

Source: Northern Sky Research

SPACENEWS

Viasat
Satellites: 24
Altitude (km): 8,200

O3b
Satellites: 27
Altitude (km): 8,000

Astrome Technologies
Satellites: 600
Altitude (km): 1,400

OneWeb
Satellites: 900
Altitude (km): 1,200

SpaceX Starlink
Satellites: 4,425
Altitude (km): 1,100-1,325

Xinwei
Satellites: 32
Altitude (km): N/A

Laser Light
Satellites: 12
Altitude (km): 10,000

LeoSat
Satellites: 108
Altitude (km): 1,432

Telesat LEO
Satellites: 117
Altitude (km): 1,000

Hongyan
Satellites: 300
Altitude (km): 1,100

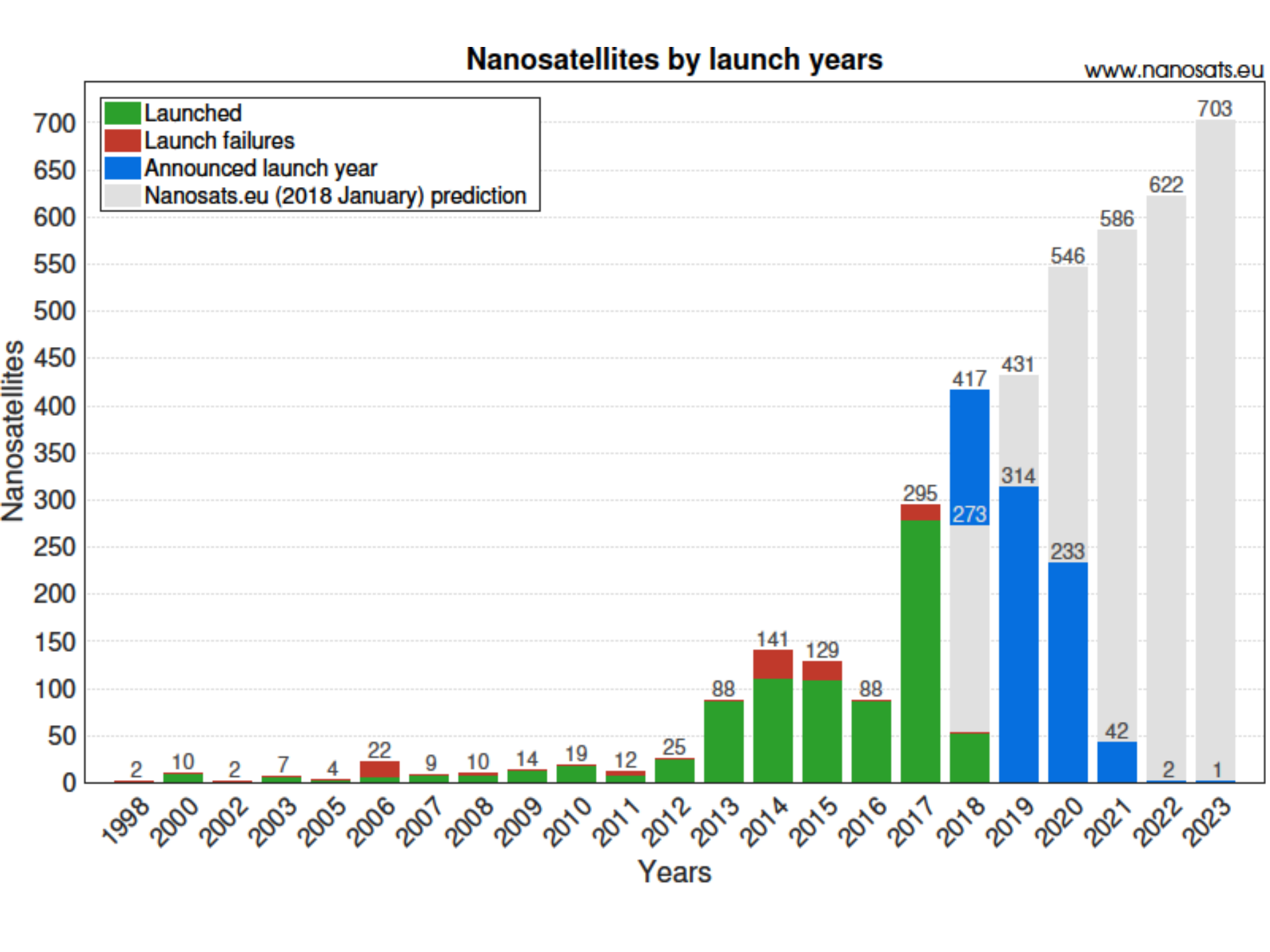
Boeing V-band
Satellites: 2,956
Altitude (km): 1,030-1,080

Samsung
Satellites: 4,600
Altitude (km): 1,500-2,000

Lucky Star
Satellites: 156
Altitude (km): 1,000

Yaliny
Satellites: 135
Altitude (km): 600

Commsat
Satellites: 800
Altitude (km): 600


Nanosatellites by launch years
www.nanosats.eu
Launched
Launch failures
Announced launch year
Nanosats.eu (2018 January) prediction
Nanosatellites
Years
0
50
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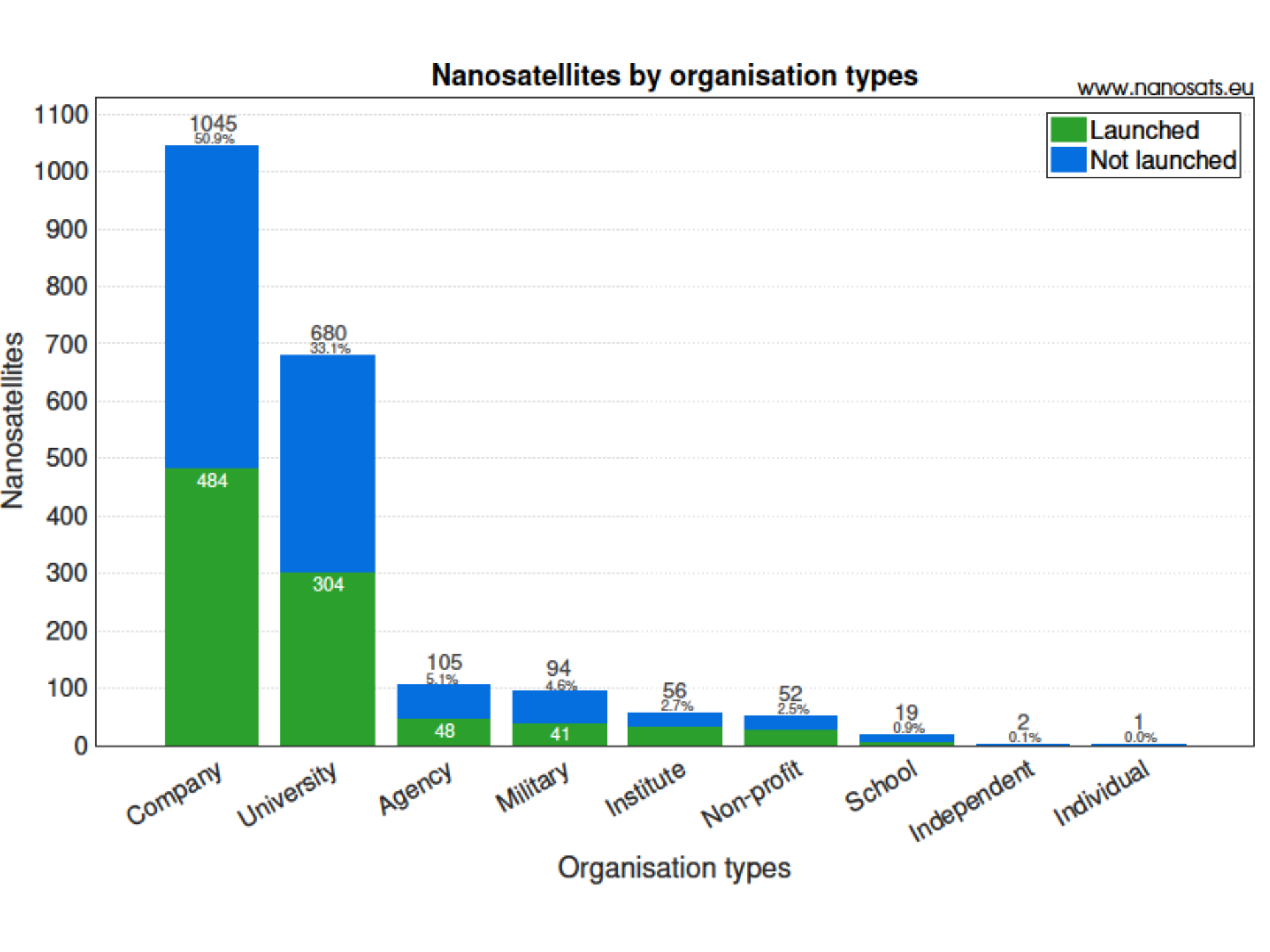
Nanosatellites by organisation types
www.nanosats.eu
Launched
Not launched
Nanosatellites
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680
33.1%
304
105
5.1%
48
94
4.6%
41
56
2.7%
52
2.5%
19
0.9%
2
0.1%
1
0.0%
Company
University
Agency
Military
Institute
Non-profit
School
Independent
Individual
Organisation types

Big Constellations of Small Cubesats

Good	Bad	TBD
One Web, Planet, SpaceX very proactive	Potentially many s/c	Assumed PMD is key
Low mass, volume s/c	Secondary payloads	Cheap to build, ok to lose some
NASA cubesats undergo ODAR review	No propulsion (but maneuverability is double-edged sword)	Lifetimes lengthen > 700 km (edge of LEO)
	Hard to track	If there's a design flaw in one s/c…
	Quick obsolescence	

II. B. Changing Environment

Commercial SSA Capabilities

- Space Data Association
- AGI's ComSpOC
- Other companies

USG SSN is good…

-JSpOC, SSA Sharing, Space Fence

No single comprehensive catalog

II.B. Changing Environment

- SSA Sensor Types
  - Radar
    - Accurate and good for LEO but big, complex, and expensive
  - Optical
    - Cheaper; ground-based good for LEO, MEO, GEO but clouds obscure (fine for space-based)
  - RF
    - Good for LEO, MEO, GEO

II. B Changing SSA Capabilities

- Why Commercial>Gov't Capabilities?
  - Transparency?
  - Algorithms, data fusion
  - Sensors
  - Realistic error portrayal in all orbits
  - Responsiveness

  *Commercial capability can free up Gov't resources for specialized tasks

III. SPD-3

- "pursue and utilize both Government and commercial sector technologies to track and monitor space debris"
- Update USG ODMSP
- SSA/STM
  - Continue sharing basic SSA data free
  - DoD maintain authoritative catalog, DoC disseminate data

Sample of Debris Removal Concepts

Debris Removal Technique	Altitude Regime	Debris Size Regime
Ground-based Laser/Directed Energy	LEO	< 10 cm
Airborne Laser/Directed Energy	LEO	< 10 cm
Space-based Laser/Directed Energy	LEO, MEO, GEO	< 10 cm
Space-based Magnetic Field Generator	LEO	< 10 cm
Drag Augmentation Device	LEO	> 10 cm
Solar Sail	LEO, MEO, GEO	> 1 m
Magnetic Sail	LEO, MEO, GEO	> 1m
Momentum Tethers	LEO, GEO	> 10 cm
Electrodynamic Tethers	LEO	> 10 cm
Capture/Orbital Transfer Vehicle	LEO, MEO, GEO	> 1 m
Attachable Deorbit/Reorbit Module	LEO, MEO, GEO	> 1 m
Sweeping/Retarding Surface (balloon, film, foam ball, etc.)	LEO	< 10 cm

IV. Remediation projects

- ISS RemoveDEBRIS
- Swiss Clean Space One
- ESA e.deorbit

- RPO/satellite servicing

V. Summary

- Update mitigation guidelines?
- Update USG waiver procedures?
- Likely lots more cubesats coming
- Improving operational commercial SSA capabilities
- No single comprehensive catalog
- ADR tech advancing but…