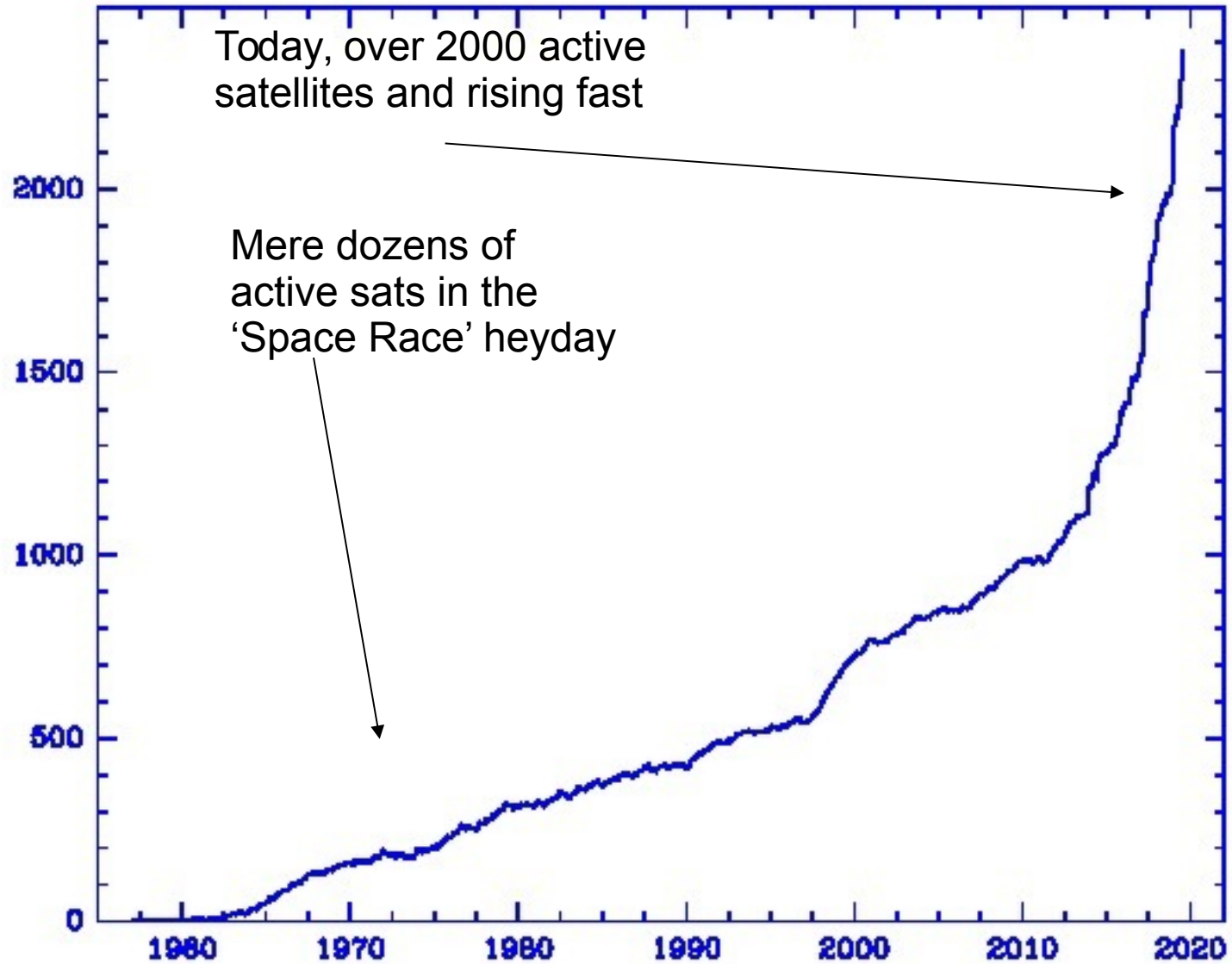


Part I:

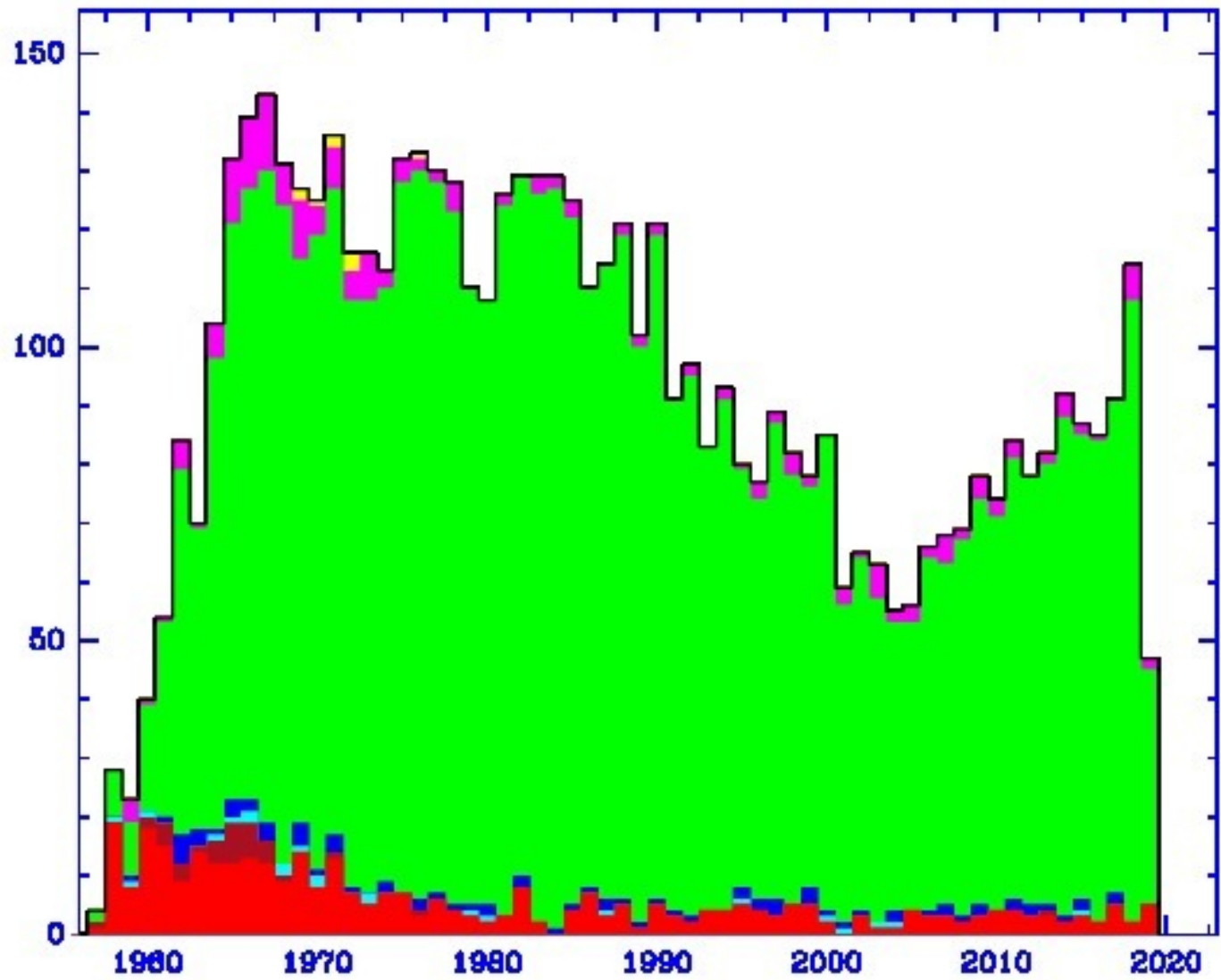
Space is getting crowded

Active Satellites 1957-2019



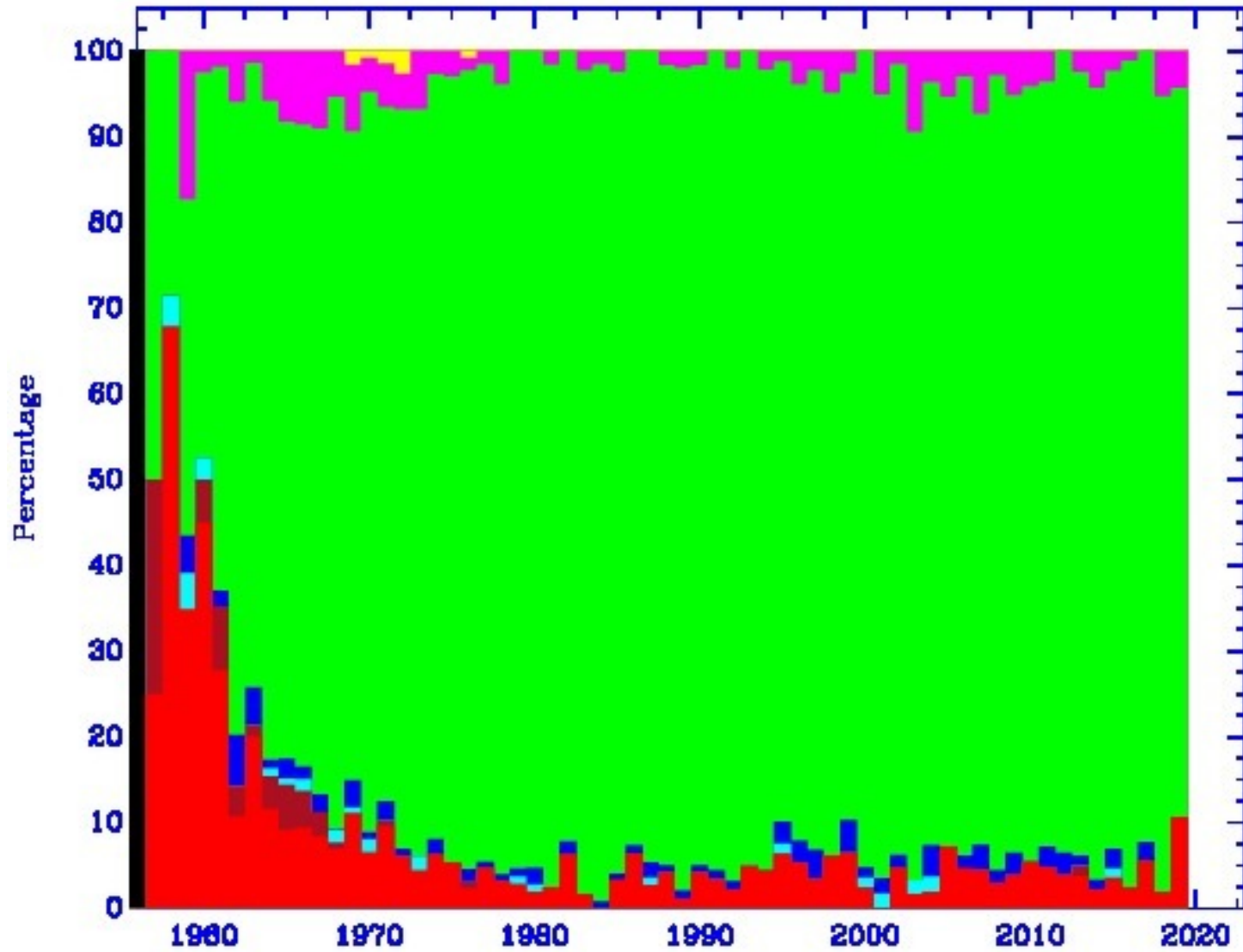
Orbital Launches

- Total
- AT Launch
- Deep Space
- Orbital
- Orb LVFail
- Orb Marginal
- Orb Energy
- Failed to Orbit



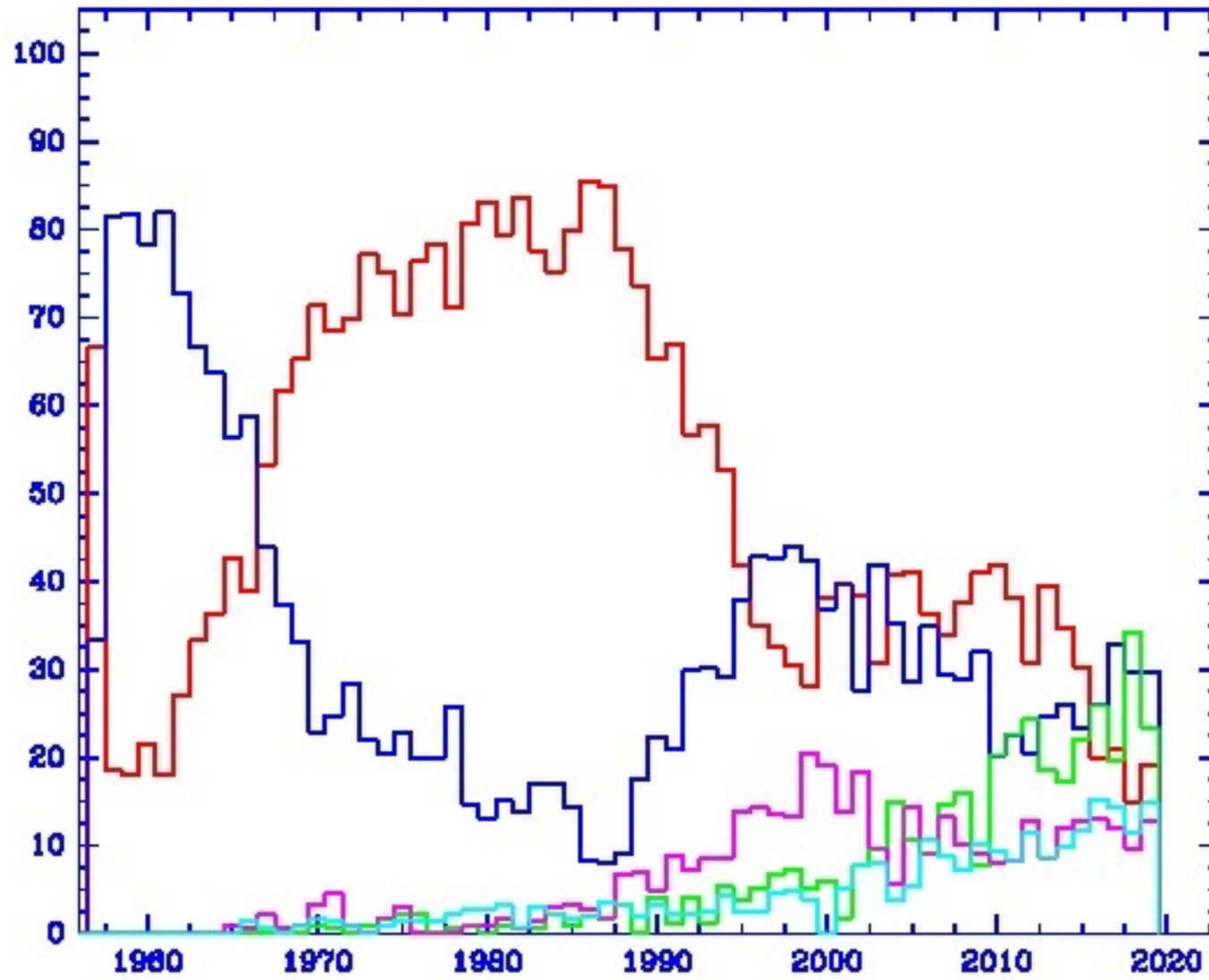
Orbital Launches and Failures

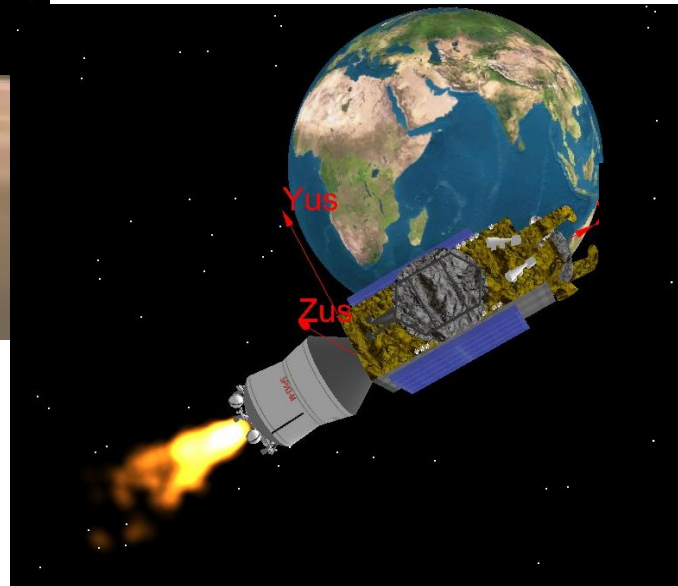
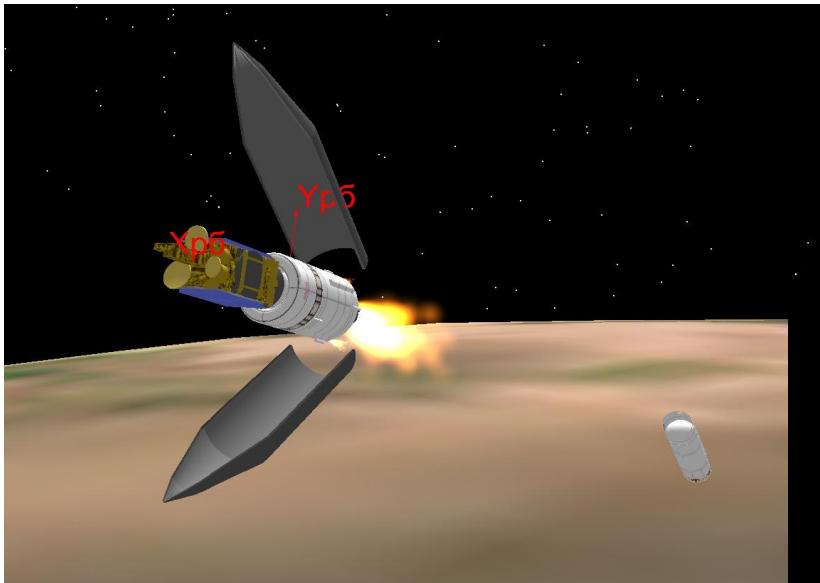
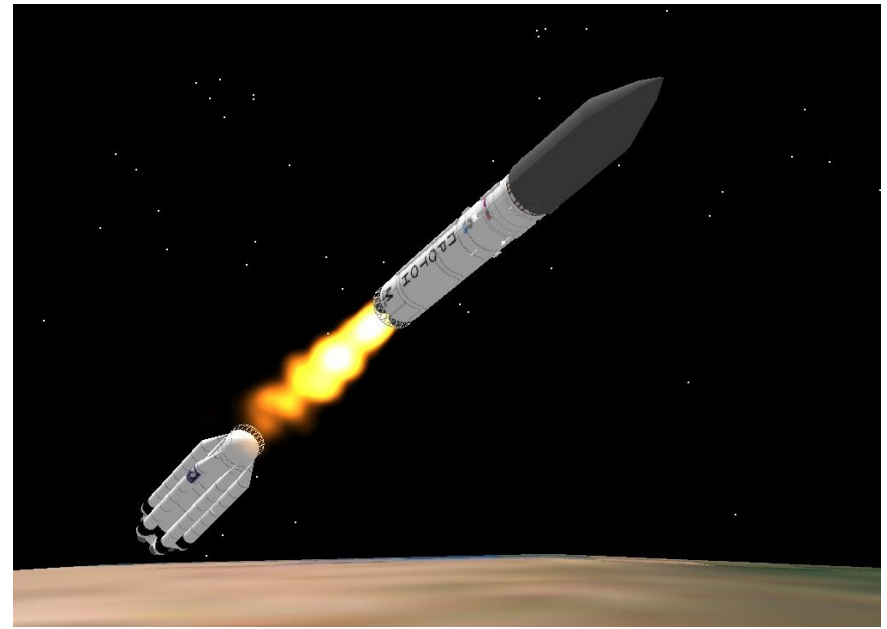
- Total
- RT Launch
- Deep Space
- Orbital
- Orb LVFail
- Orb Marginal
- Orb Energy
- Failed to Orbit



Percentage of Launches

- USSR
- USA
- China
- Europe
- Other

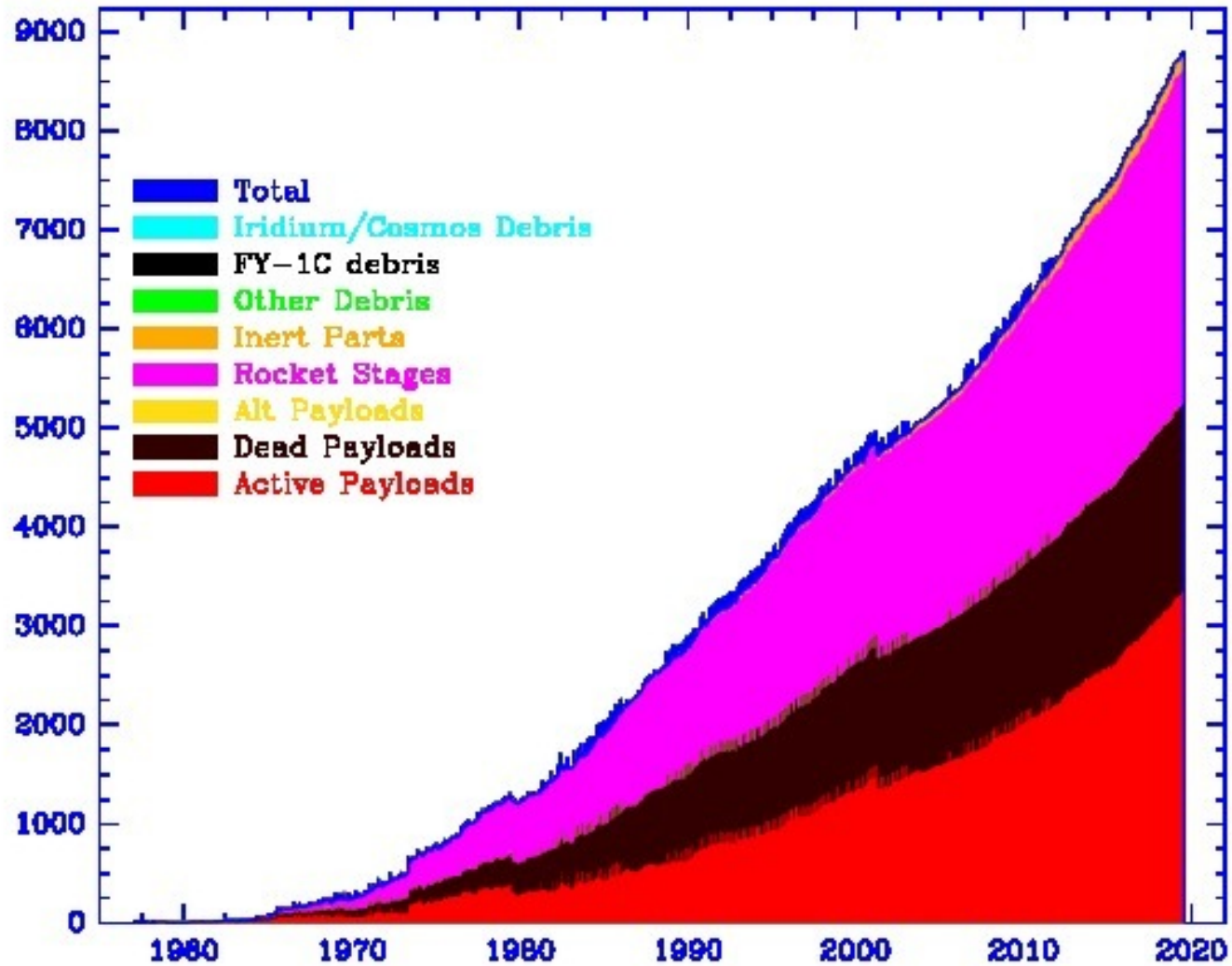




A typical satellite launch ends up with at least two objects in orbit – the satellite and the last piece (“stage”) of the rocket that got it there

Space Junk - mass in metric tons

Orbital Tonnage



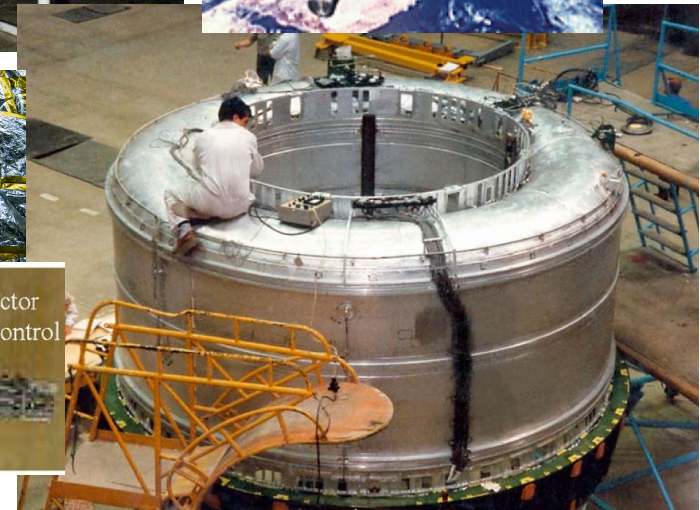
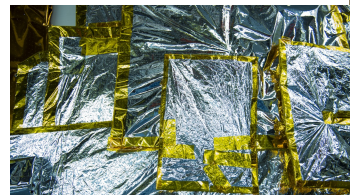
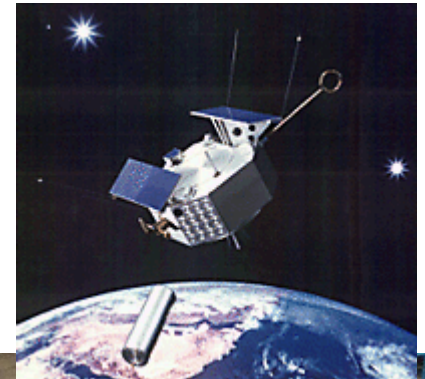
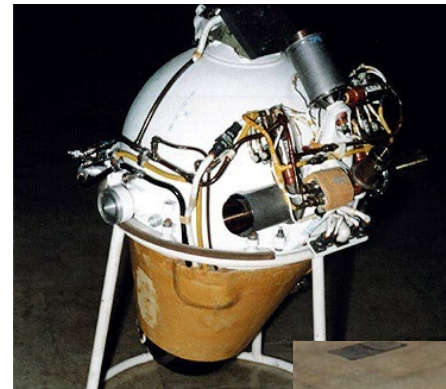
A Census of Space Debris

as of 12 Apr 2017 (including 172 objects cataloged yesterday evening!)

Total objects cataloged	42661	
Objects still in Earth orbit	18296	
Active payloads	1500?	
Dead payloads	2796?	
Rocket stages	1930	
Adapters, jettisoned objects	1652) 10417
2007 Chinese ASAT debris	2855	
2009 collision	1443	
Other debris	6119	

Covers, fairings	300
Jettisoned motors and tanks	170
Multi-payload adapters	141
Despin devices	131
Deployment canisters	38
Insulation blankets	36
Nuclear reactor cores	14
Misc	28
Unknown pieces	794

Residual fuel explosions	3826
Antisatellite weapon tests	3247
Accidental collision	1458
Battery explosion	1315
NaK Reactor coolant blobs	53
Insulation, Destruct, Other	518

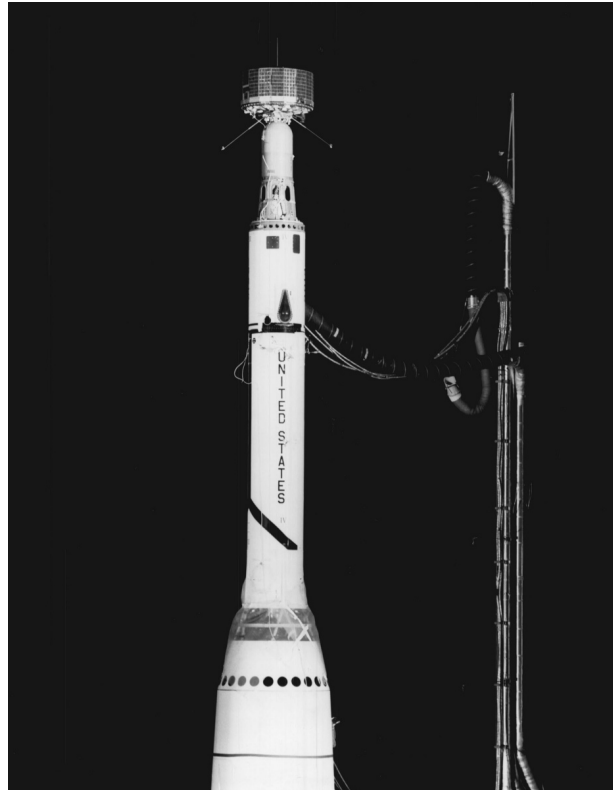
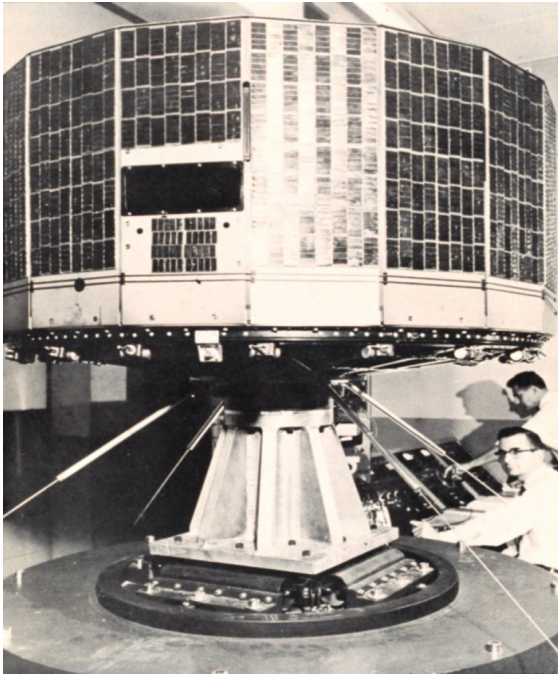


Part II:

New players in space

- Internationalization
- Commercialization
- Globalization
- Democratization

The 1960s – the superpower era in space



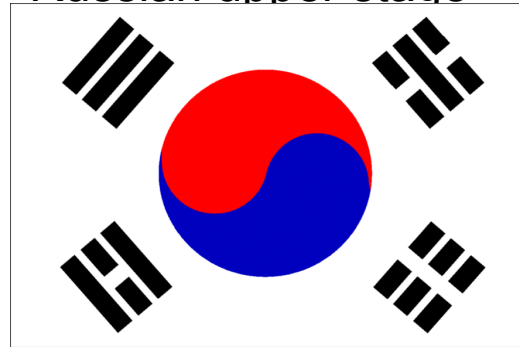
New Jersey-built satellite on California-built rocket orbited from Florida launch pad, mission control in Maryland



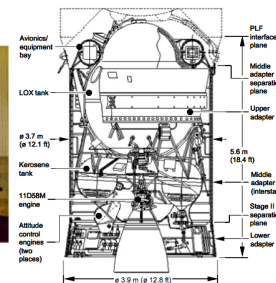
But it's not like that any more!

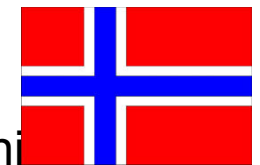
An example modern (2006) satellite:

South Korea's Koreasat-5 satellite takes shape in the Thales Alenia factory in Cannes, in the south of France
Launched on a Ukrainian rocket with Russian upper stage



Block DM-SL (without interstage)

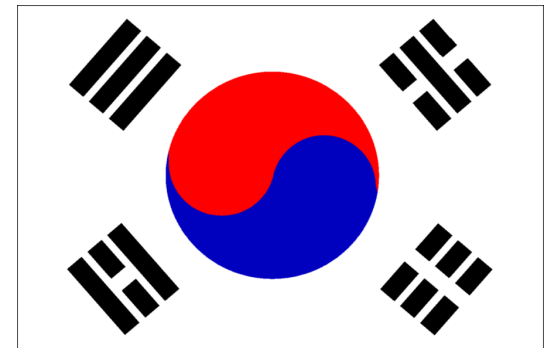
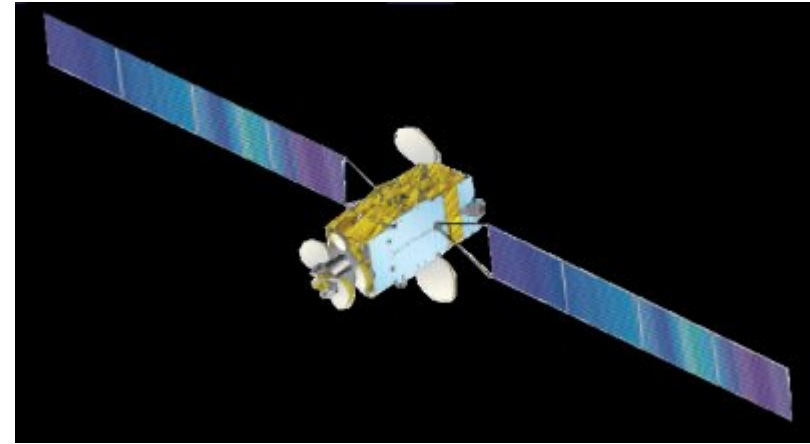




At Sea Launch home port in Long Beach, California, the satellite and Zenith rocket are loaded on the Norwegian-built floating launch platform

The platform then sails out in the Pacific to the Equator – in international waters

The Zenit rocket puts the Koreasat-5 in orbit where it is operated via the mission control center in S Korea with support from engineers in France

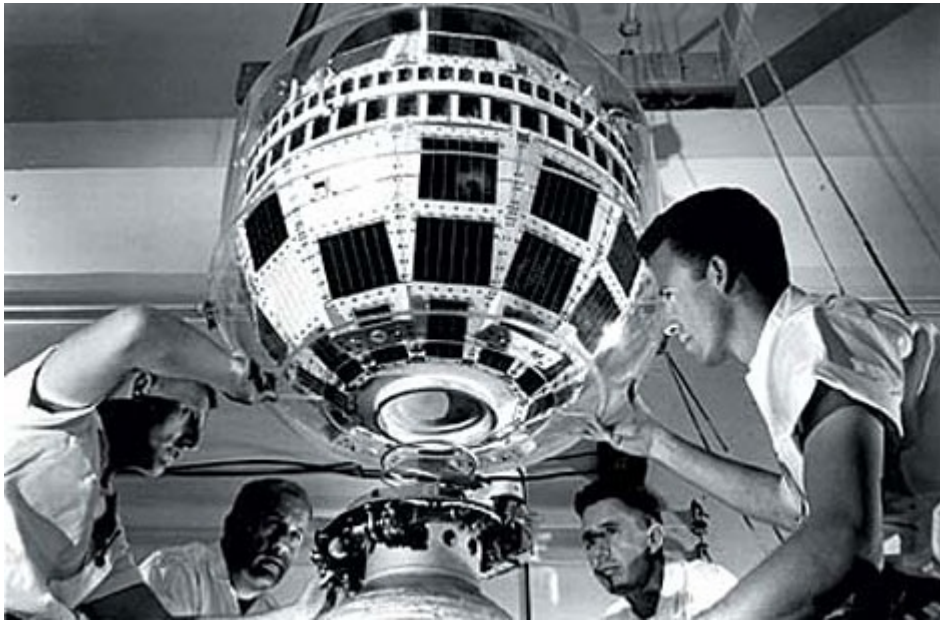


The rocket launch is carried out by Energia Logistics (US), a US subsidiary of RSC Energiya. The launch is sold to the satellite owner by Sea Launch AG of Bern

I count this as a US launch!



The commercialization of space

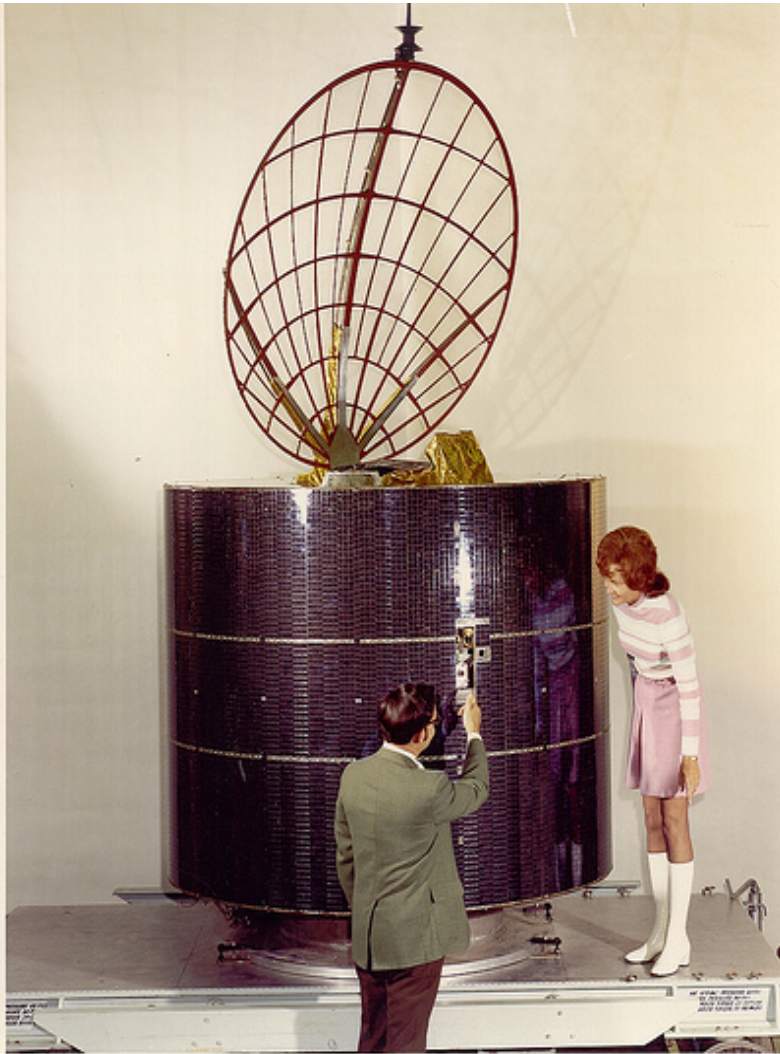


1939

1962-1963

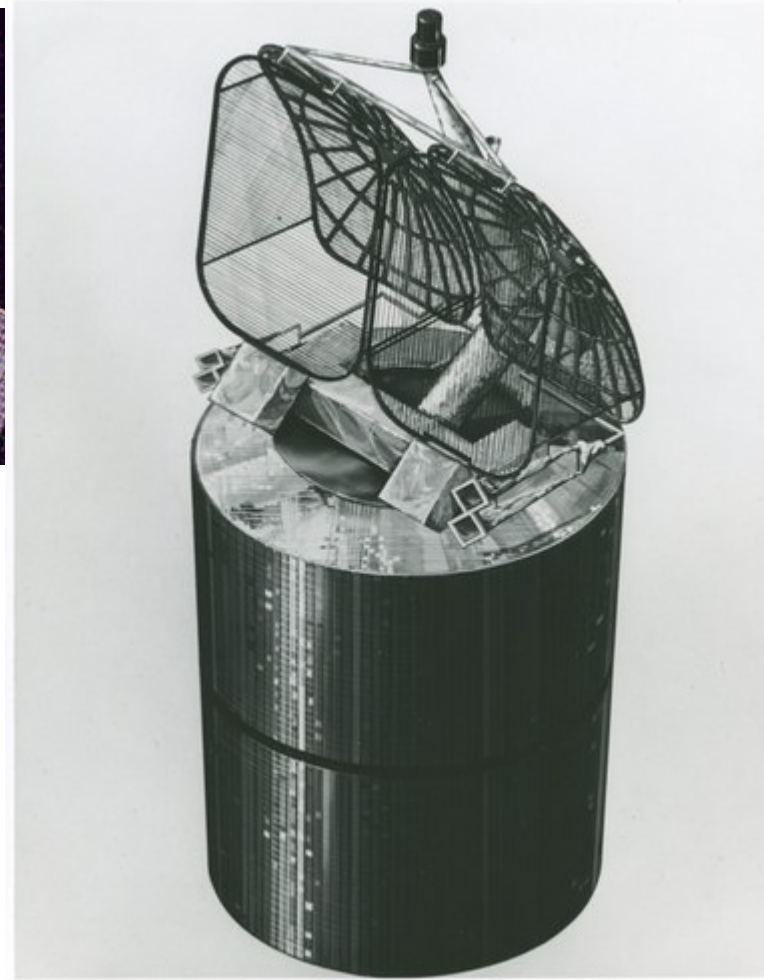
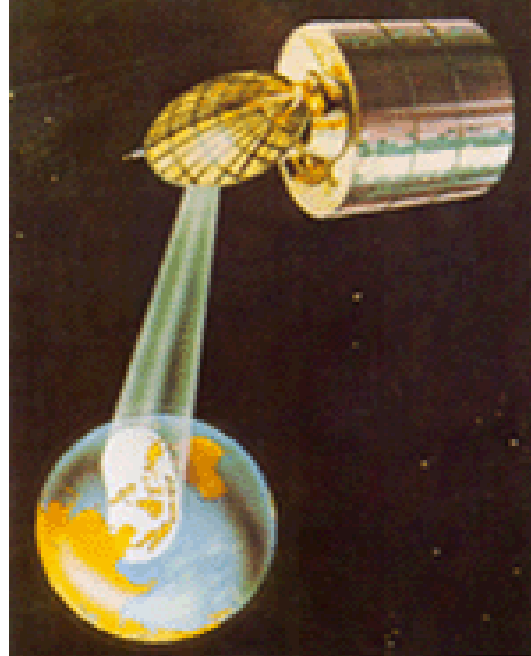
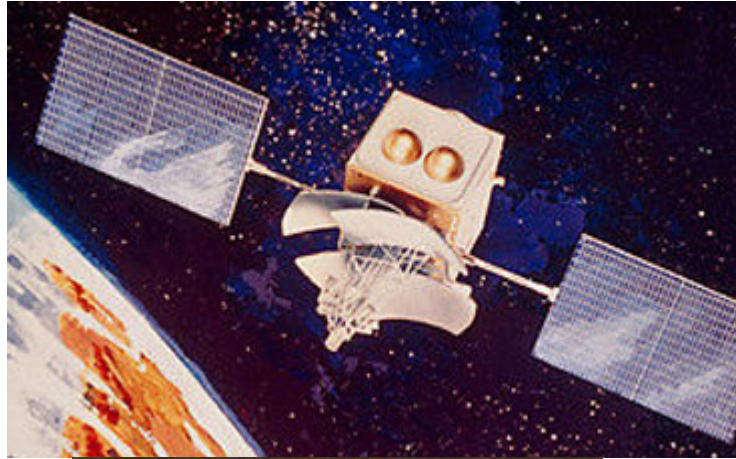
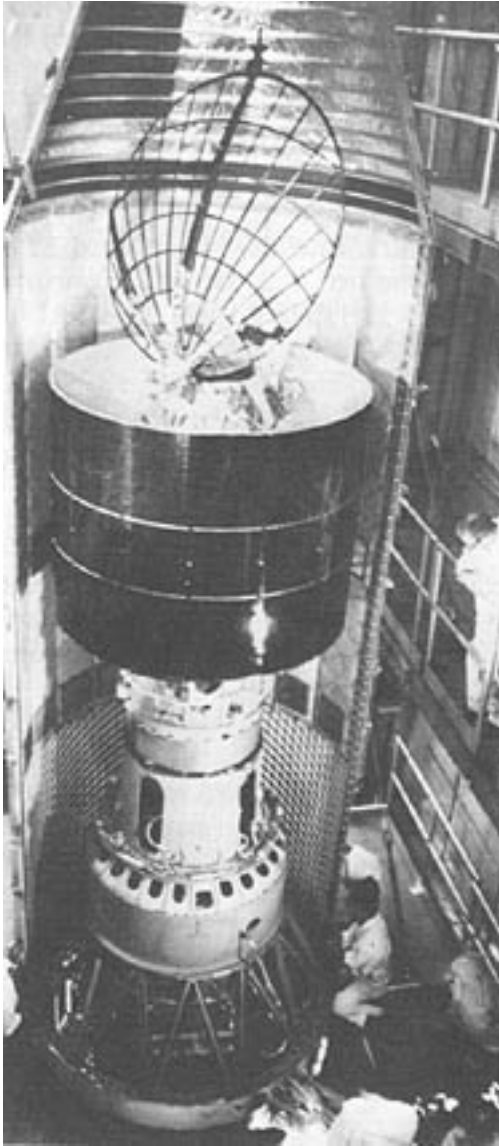
Telstar 1 and 2 – AT&T funded the first commercial communications satellites and paid NASA to launch them





Telstar was not followed up – the next commercial satellite system had to wait for geostationary satellites to be mature.

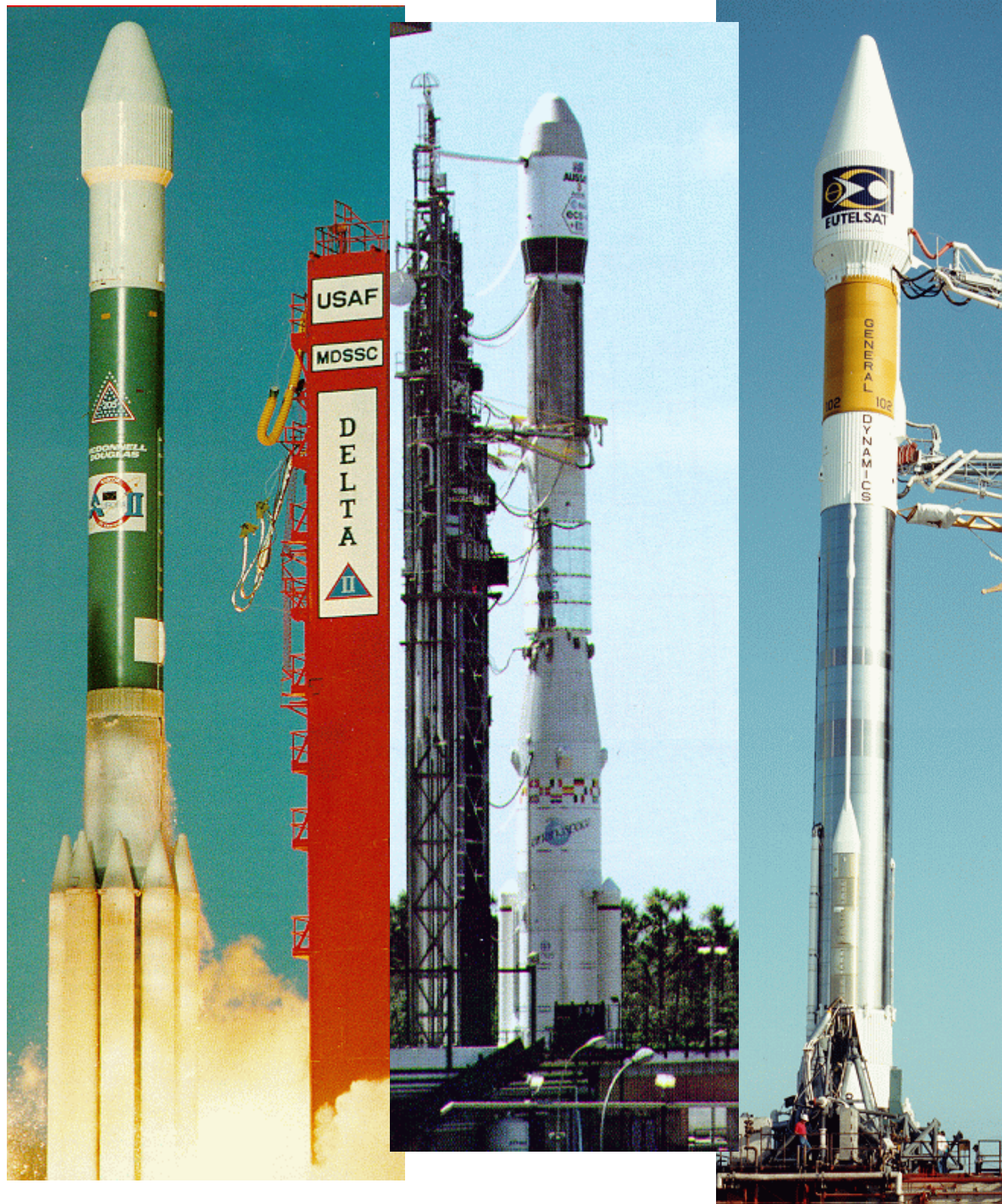
In 1972 the Canadian company Telesat was established as a commercial enterprise by the Canadian government
The 'Anik' system was the first of a rush of first-generation commercial communications satellites built by Hughes and RCA



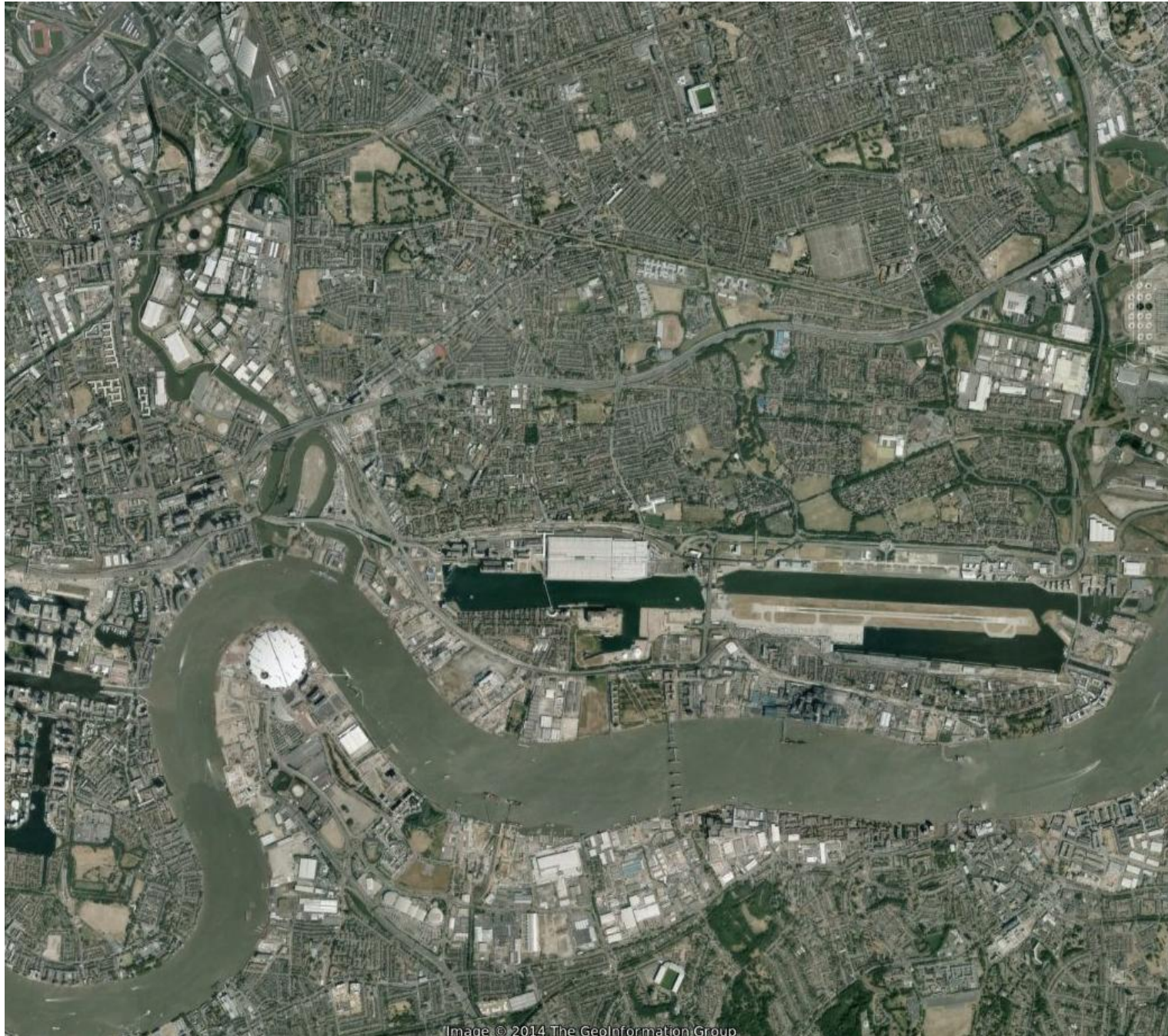
- 1974: Western Union's Westar
- 1975: RCA Globcom's Satcom
- 1976: Comsat General's Marisat and Comstar
- 1976: Perumtel of Indonesia's Palapa

In the 1980s government civilian orbital launches by NASA and ESA were replaced by commercial launch services by McDonnell Douglas (now Boeing), General Dynamics (now Lockheed Martin) and Arianespace

Apart from the Space Shuttle, NASA hasn't launched a satellite itself since 1994



Today commercial imaging satellites are familiar thanks to Google maps!





In the 2010s, commercialization began to extend to human spaceflight
SpaceX's Dragon cargo ship at the Station on 2013 Mar 3

With the globalization of corporations, space commercialization becomes space globalization

SES (Societe Europeene des Satellites)

- Based Luxembourg, 1985 (first satellite 1988)
- Absorbed RCA Americom (New Jersey) 2001
(Absorbed GTE Spacenet 1994)
- Absorbed GE Capital (Gibraltar) 2001
- Absorbed Nordic Satellite (Stockholm) 2005
- Absorbed New Skies (The Hague) 2006
(spun off from INTELSAT in 1998)
- Stake in Nahuelsat (Argentina), Quetzsat (Mexico)
- Former stake in Asiasat (Hong Kong) and Star One (Brazil), etc.

As of 2014, 46 SATS OPERATING IN GEO – 10% of total
Activities in many countries; satellite control centers in US and Lux.
Which country do the SES satellites belong to?



SES  **ASTRA**
An SES GLOBAL Company

Another effect of globalization and mergers:
buying and selling satellites in space

1985: Satellite Business Systems sells 4 sats to MCI Corp

1992: BSkyB sells its two satellites to Telenor (Norway) and Sirius (Sweden)

– more sales here and there in 1990s, but in 2000s see whole in-orbit
fleets change hands

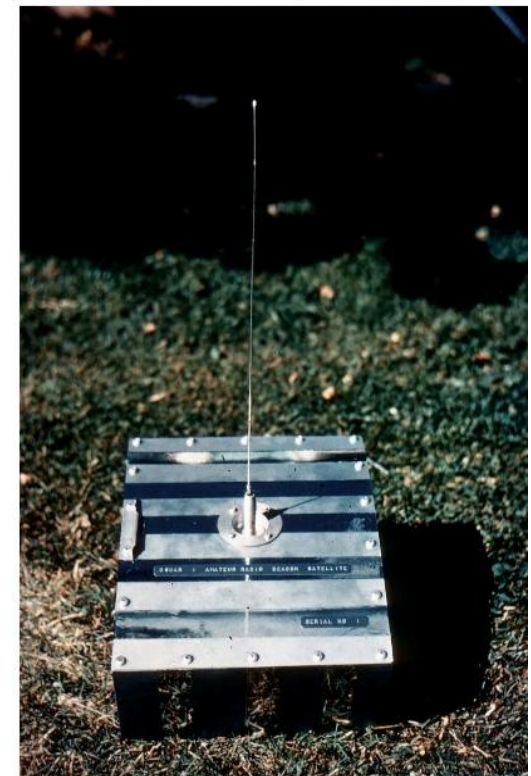
2004 - 4 Loral Telstars become Intelsats

2006-2007 – 21 Panamsat satellites (PAS and Galaxy) sold to Intelsat

2006 - New Skies fleet sold to SES



The Democratization of Space



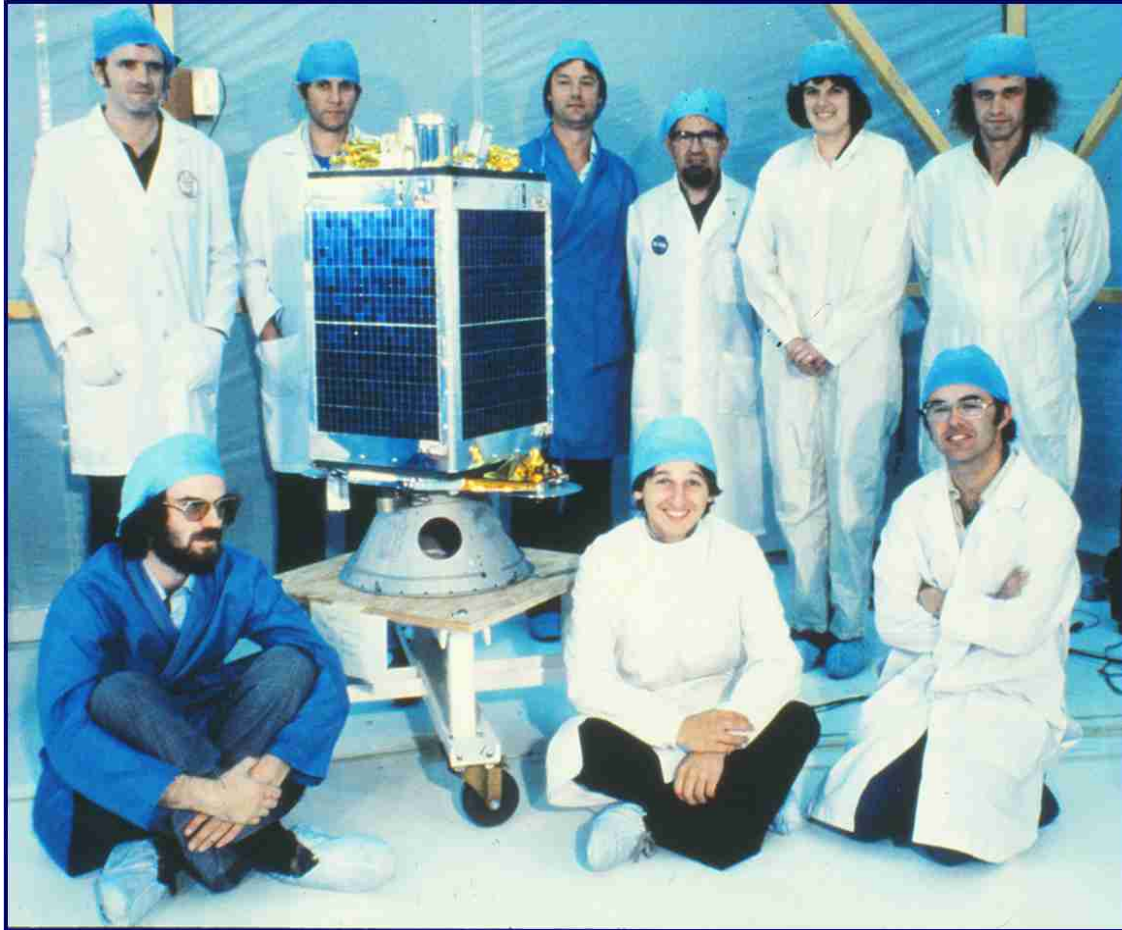
Dec 1961 – the first amateur satellite
Built by radio amateurs in California
Hitched a ride strapped to the side of a spy
satellite rocket

OSCAR – Orbiting Satellite Carrying Amateur
Radio



Guildford, 1981: University of Surrey team (under Martin Sweeting) builds amateur radio satellite UoSat-1

It becomes the basis of a series of cheap commercial satellites affordable by developing countries





Alsat (Algeria) 2002

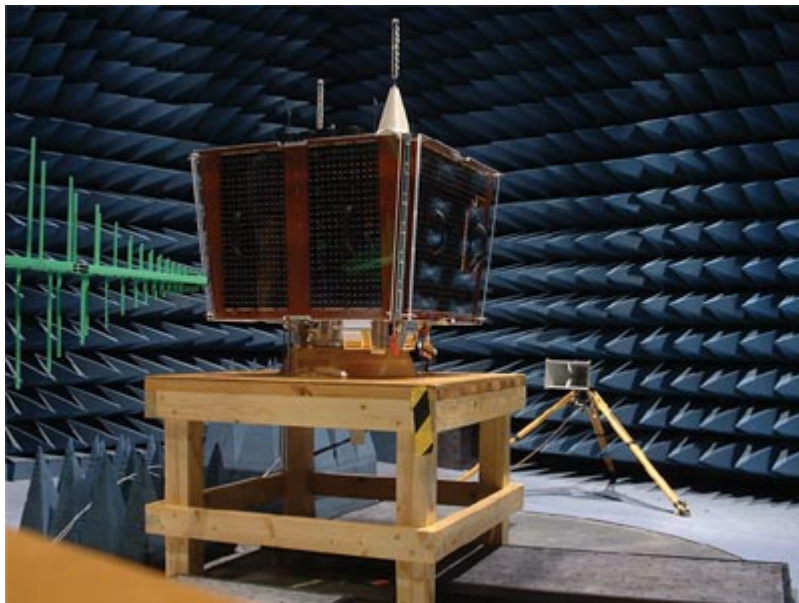


Tiungsat (Malaysia) 2000

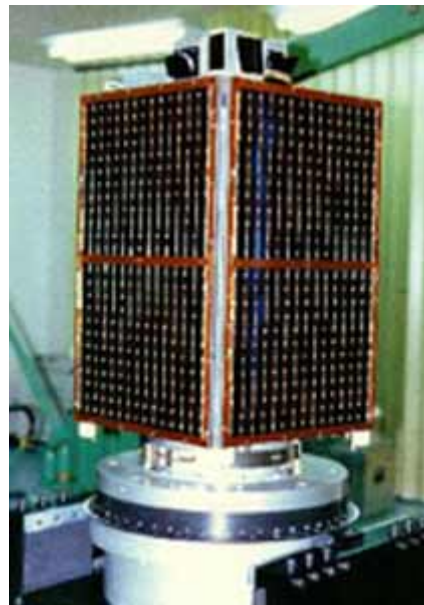


Fasat (Chile) 1998

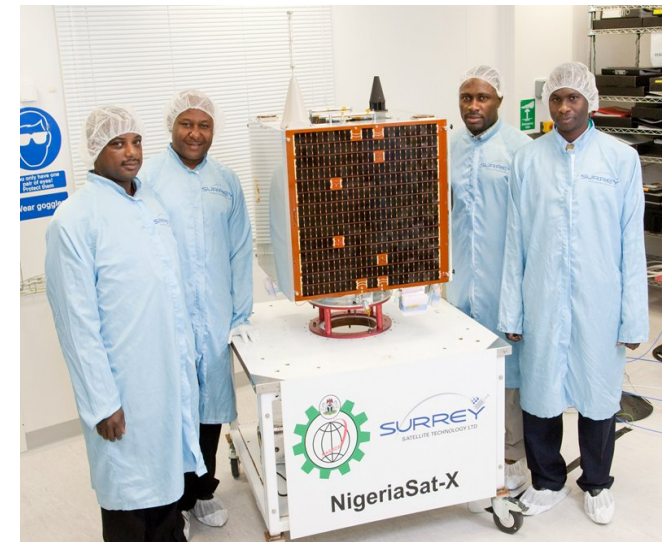
Posat
(Portugal)
1993



Bilsat (Turkey) 2003

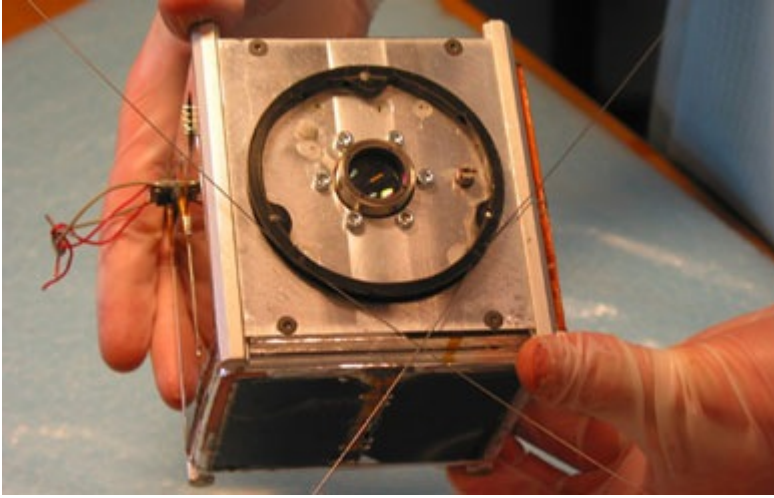


Uribyol
S Korea 1992

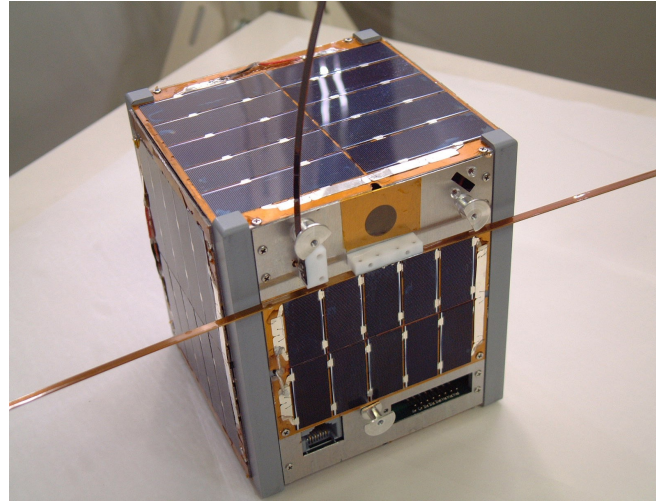


Nigeriasat-2 2011

Cubesats: 1 kg, 10 cm (2 lb, 4 in for the metric impaired)
Standard kit for universities to make students build sats in engineering courses
Can also make '3U' cuboids 30 x 10 cm
97 Cubesats launched 2003-Feb 2013 by 66 organizations in 20 countries



Aalborg U. 2003



Univ. of Tokyo, 2003



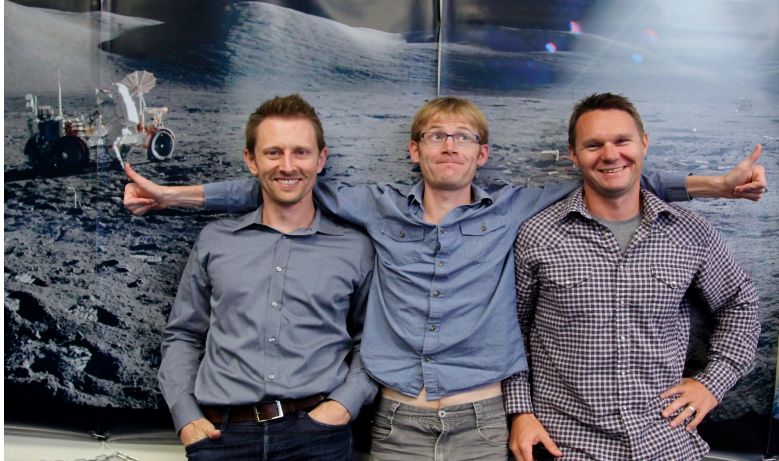
Cubesat deploy from ISS,
2012



Triple-cube Quakesat, Stanford
2003

2013: CUBESAT EXPLOSION!

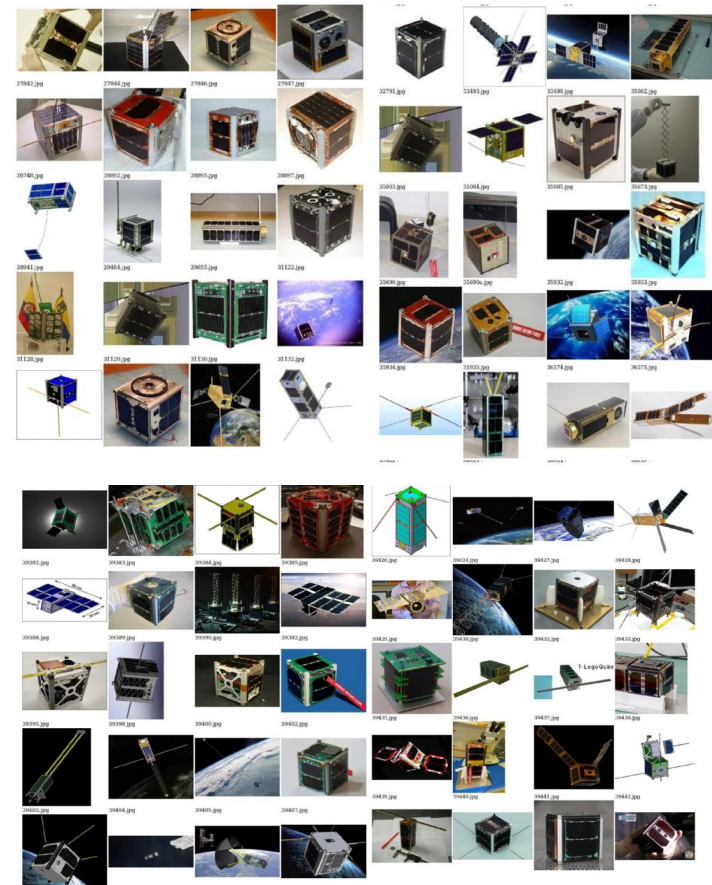
99 Cubesats launched Jun 2003-Feb 2013 by 63 organizations in 20 countries
120 Cubesats launched Mar 2013 – Feb 2014 by 57 organizations in 18 countries
(Cumulative: 219 Cubesats by 108 orgs in 28 countries)



Chris, Will and Robbie left NASA to found PlanetLabs in a San Fran office building – 71 satellites launched since 2013, first big Cubesat constellation

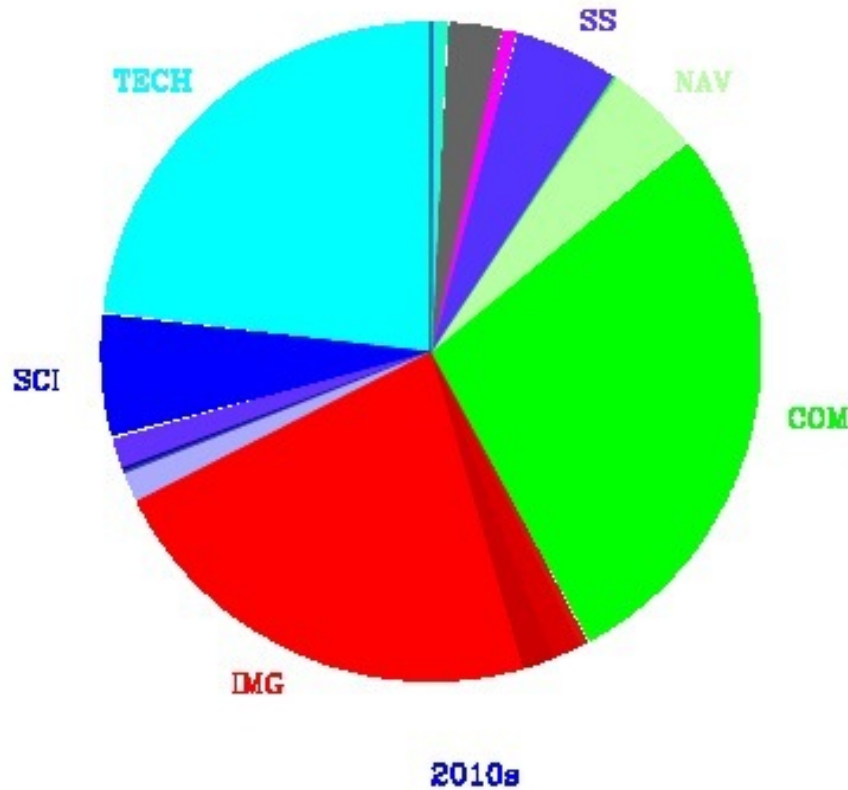
TOTAL 66 COUNTRIES:

USA 816
China 45
Japan 40
Germany 26
S Korea 17
Russia 16
Denmark , UK 12
Australia 10
Spain 9
Singapore, France, Italy 8
Canada, Netherlads 7
India 6
Turkey, Israel 5
,Belgium,Finland,Poland,Switzerland,S Africa, Brazil 4
Norway,Peru,Ecuador,SwedenKazkahstan, Lithuania,
Czechia 3
Vietnam,Greece, UAE, Ukraine, Thailand, Malaysia,
Argentina, Egypt, Colombia, Austria, Estonia 2
Uuruguay, Sri Lanka, Nepal, Jordan, Bhutan,
Bulgaira, Costa Rica, Kenya, Slovakia, Bangladesh,
Mongolia, Ghana, Phillipines, Hungary, Romania,
Chile,Pakistan, Belarus, Mexico, Taiwan, Nigeria, Algeria 1



PART III - SATELLITE DEMOGRAPHICS

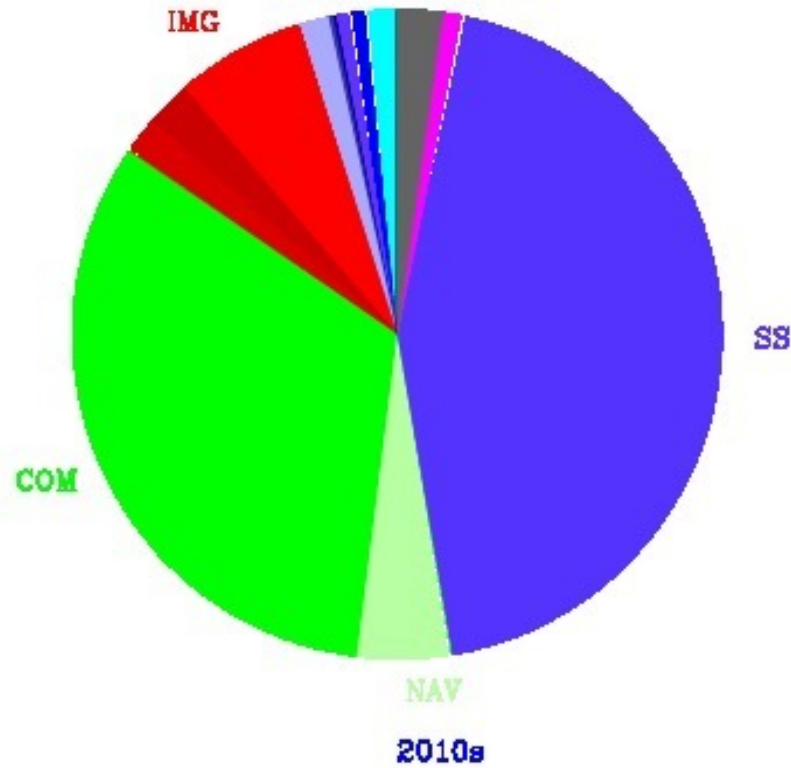
Satellite Categories



SS =
Spaceship/Human
Spaceflight

In the 2010s, most sats are either communications or imaging; technology development (including student satellites) also a big sector

Tonnage by Category



By mass however, human spaceflight dominates – comms still next
Tech/student satellites vanish, they are mostly little cubesats which don't weigh much

Satellite Categories

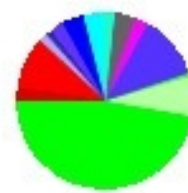
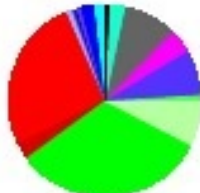
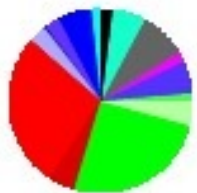


Decade by decade:
[by number of sats]

Imaging dominated
in cold war (spy
sats)

1950s

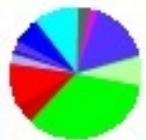
1960s



1970s

1980s

1990s



2000s

2010s

Decade by decade:

Red:
Imaging (spy sats) don
in cold war

Purple:
Human spaceflight ton
huge in 1990s (100 ton
each Shuttle)

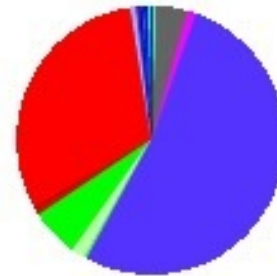
Green:
Steady growth of
communications sector

Tonnage by Category



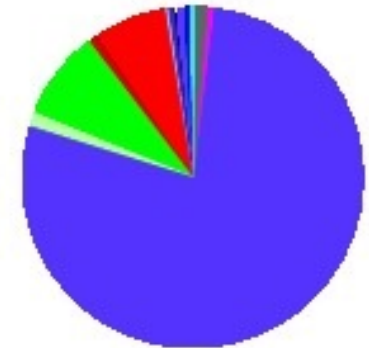
1950s

1960s

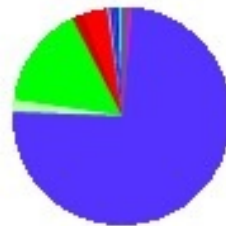


1970s

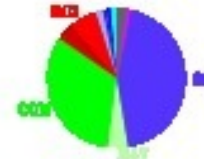
1980s



1990s

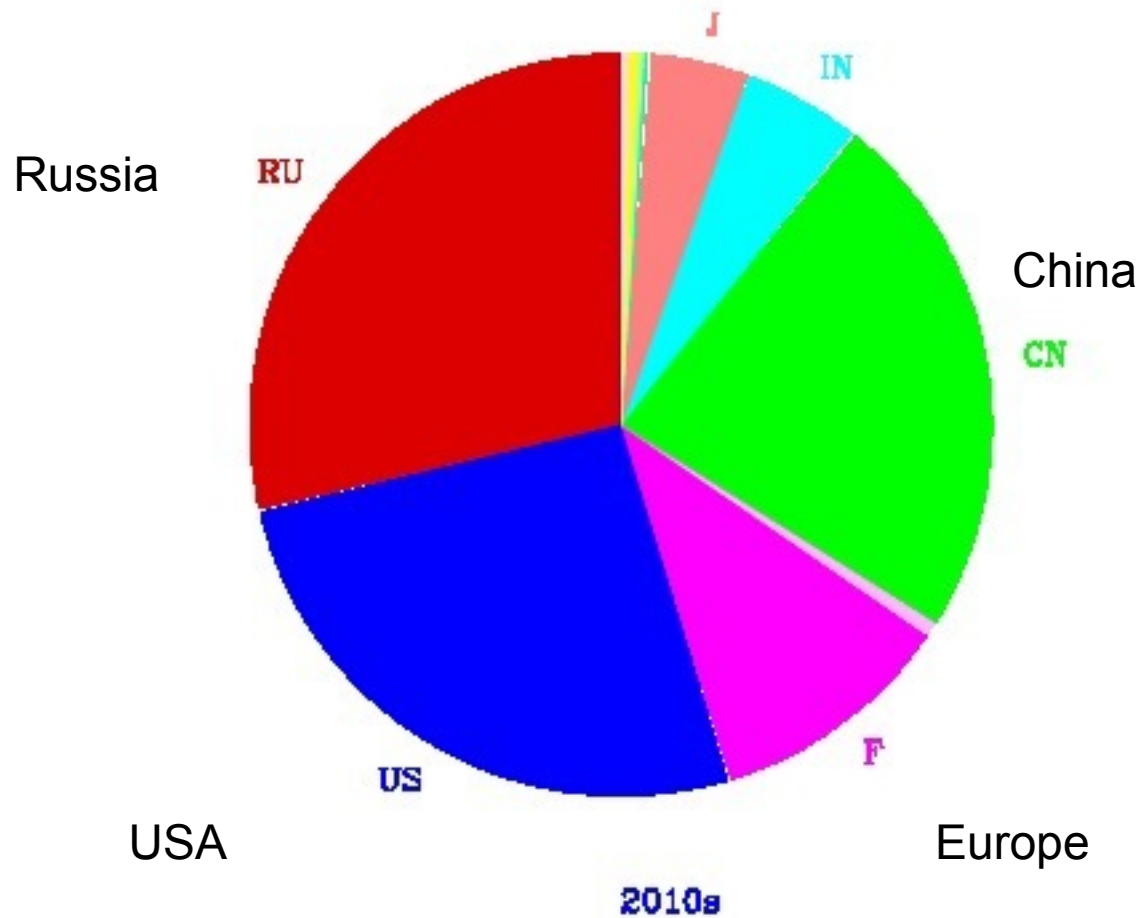


2000s



2010s

Global Space Launches



Today the space launch market has many more players

In 2012 China had as many orbital launch attempts as the US

Russia led for decades but now plummeting

12 countries plus ESA/Arianespace have launched satellites; Brazil has also tried but failed.

North and South Korea are the latest members of the club

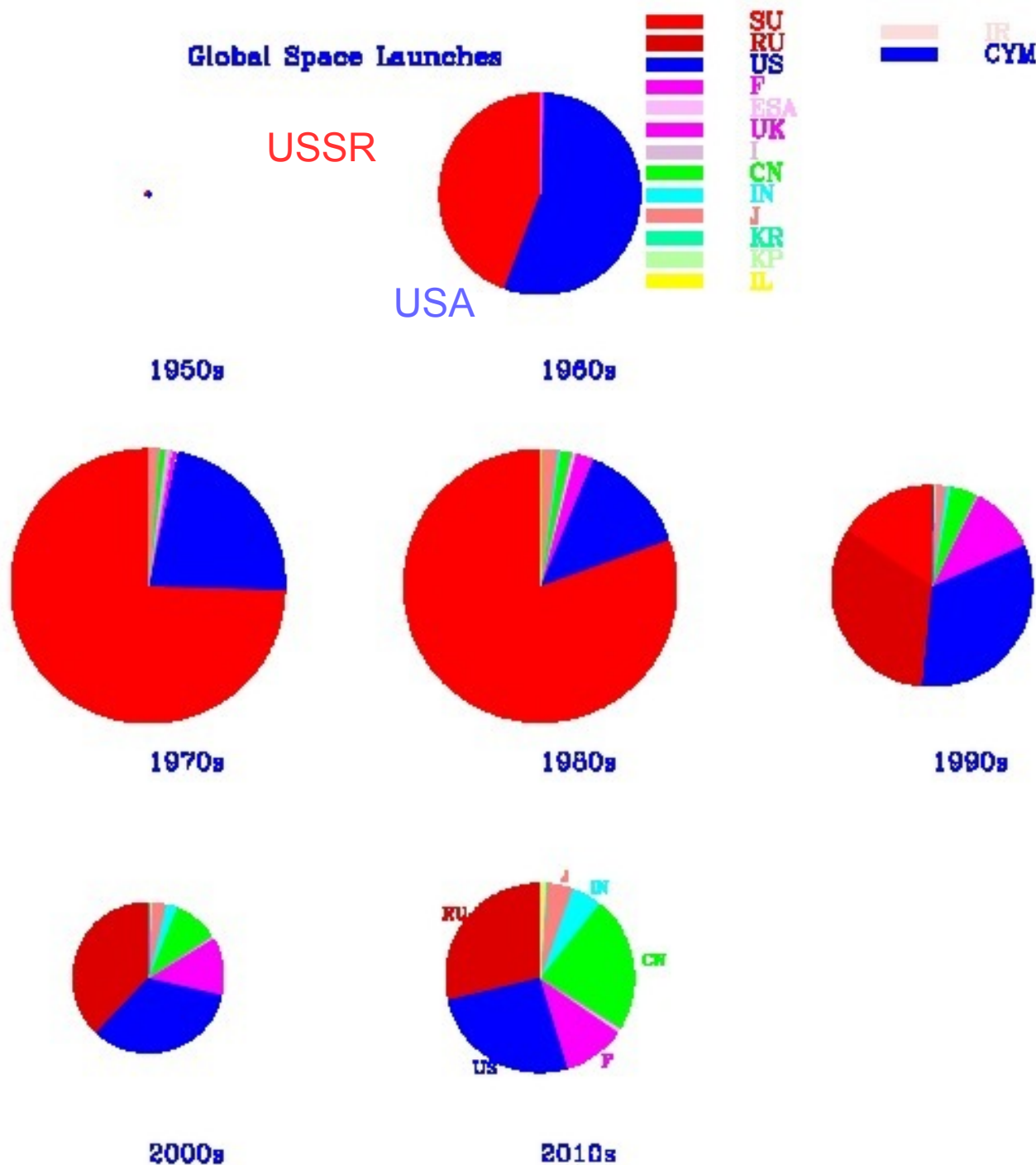
Decade by decade
 Size of circle = total launches

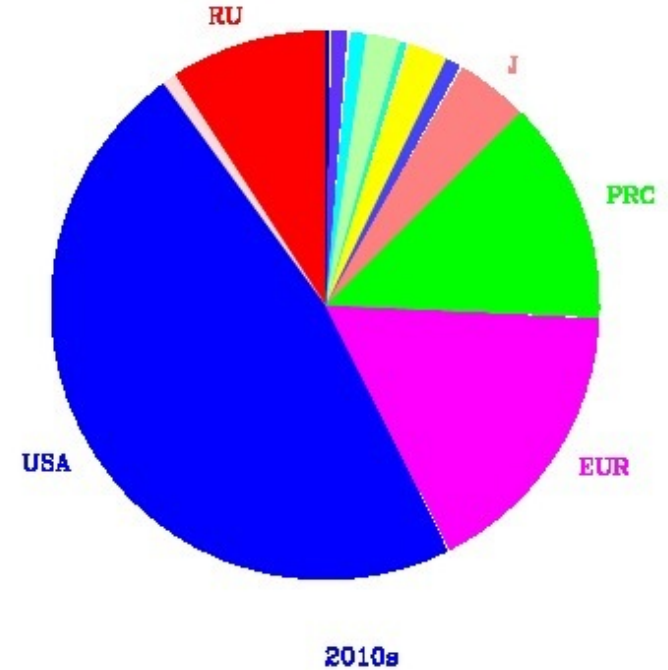
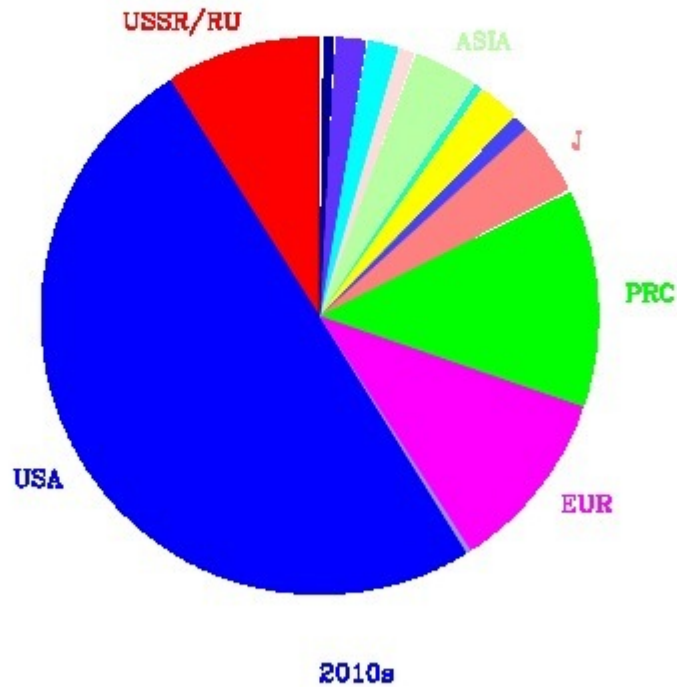
Soviet launches (red)
 dominated in 1970s and
 1980s – many satellites but
 each one didn't last long

US (blue) – fewer launches
 but the payloads were long
 lived

China (green) got serious
 about space in the 2000s

Europe (magenta) was in 3rd
 place, dropped to 4th in 2010s

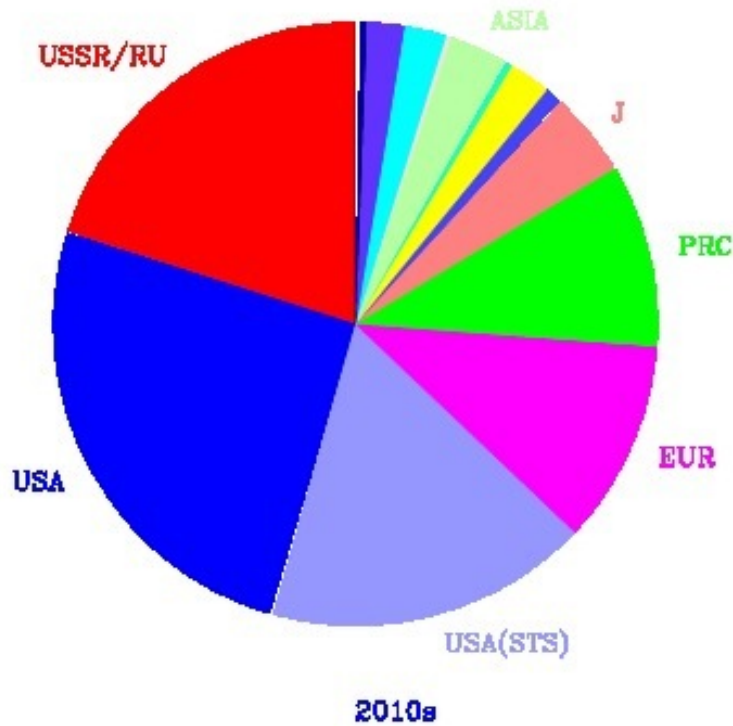




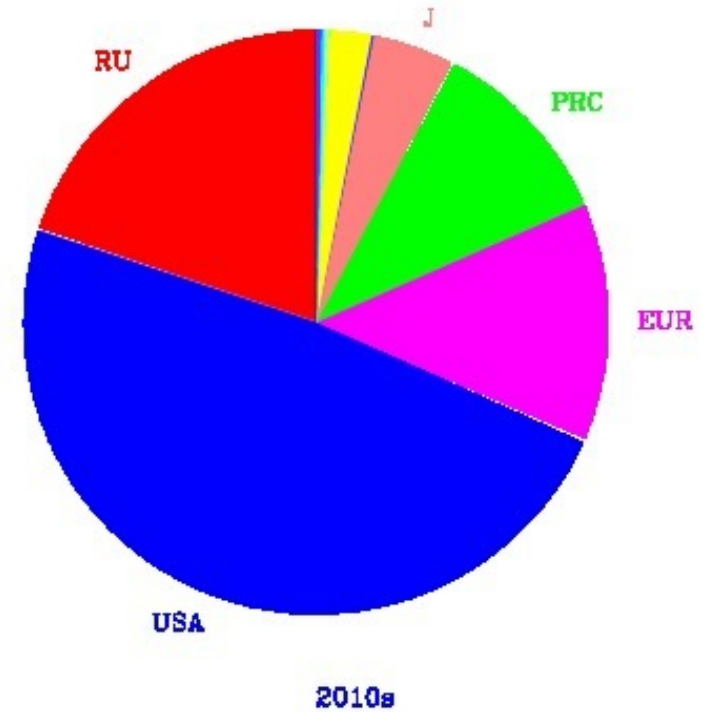
Lots of countries OWN satellites – too many to show on the chart, so I grouped together E. Europe (pink), Africa (black), Latin America (dark purple), and Asia-other-than-China/India/Japan (light green)

Russia, US, W. Europe and China dominate; next Japan (orange), and India (yellow)

Satellite Tonnage by Region

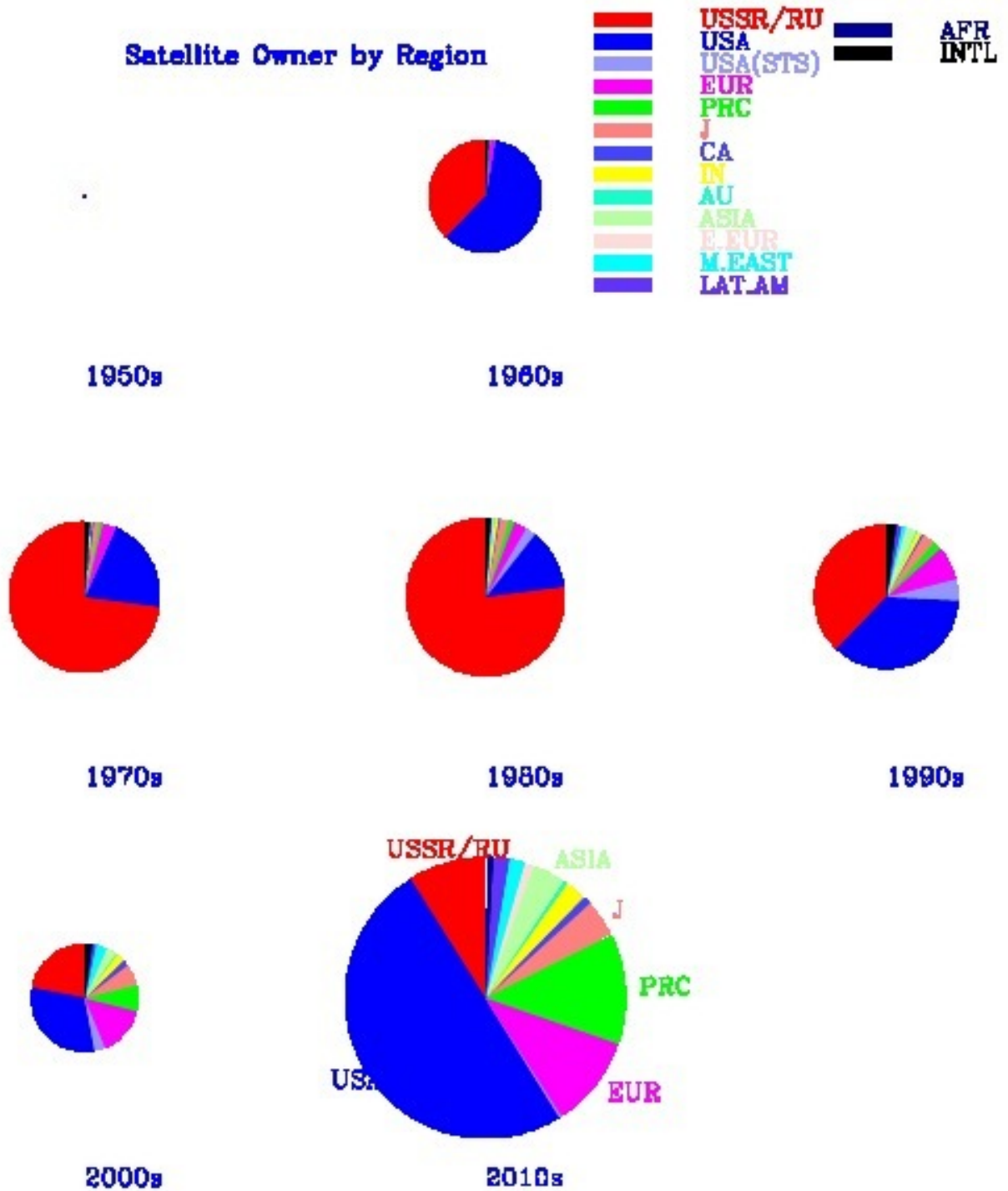


Satellite Tonnage by Manu. Region



The 'other' countries almost vanish when considering tonnage -
 Their satellites are usually tiny cubesats

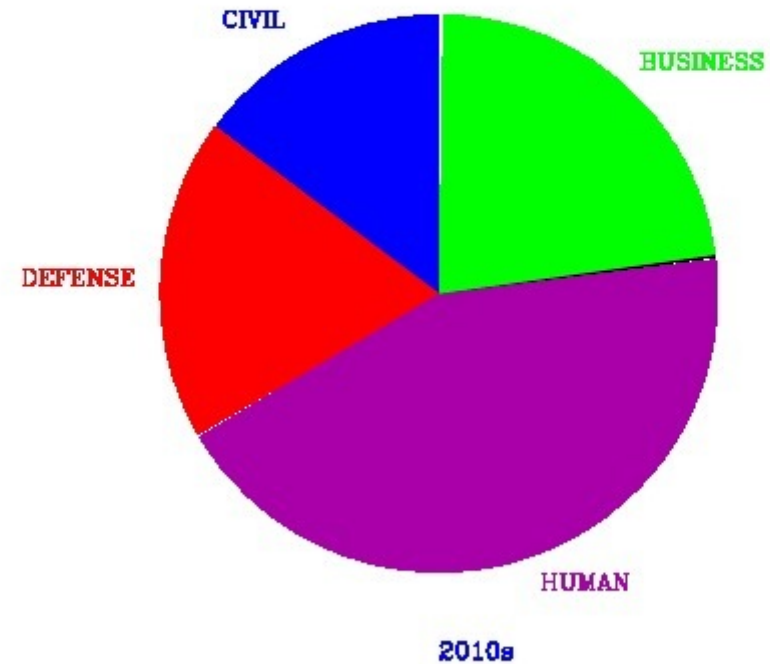
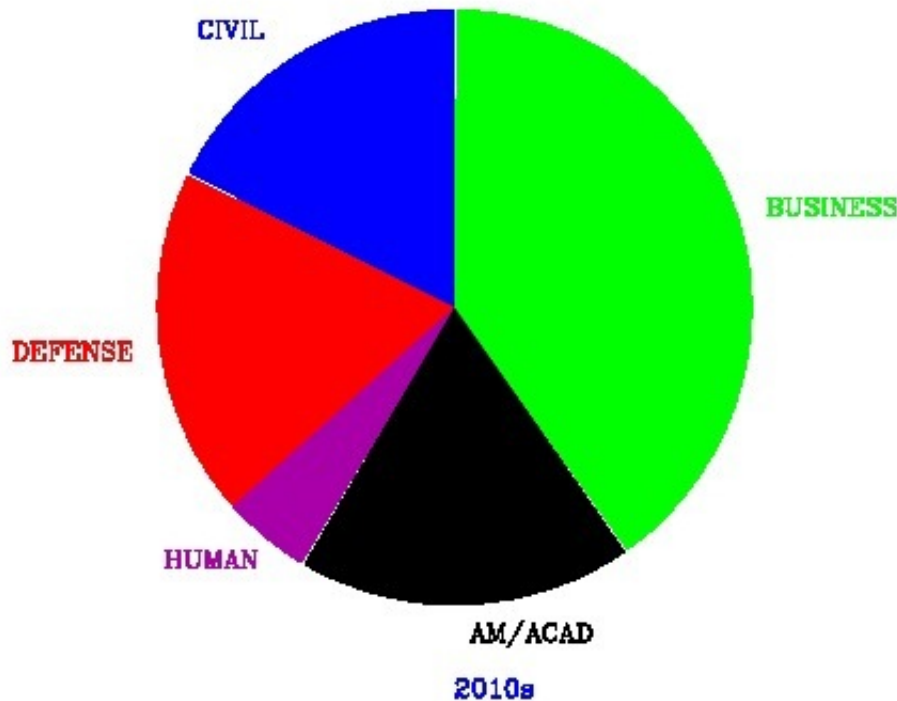
Check out the steady increase in internationalization over the decades



Satellite Classes



Satellite Tonnage



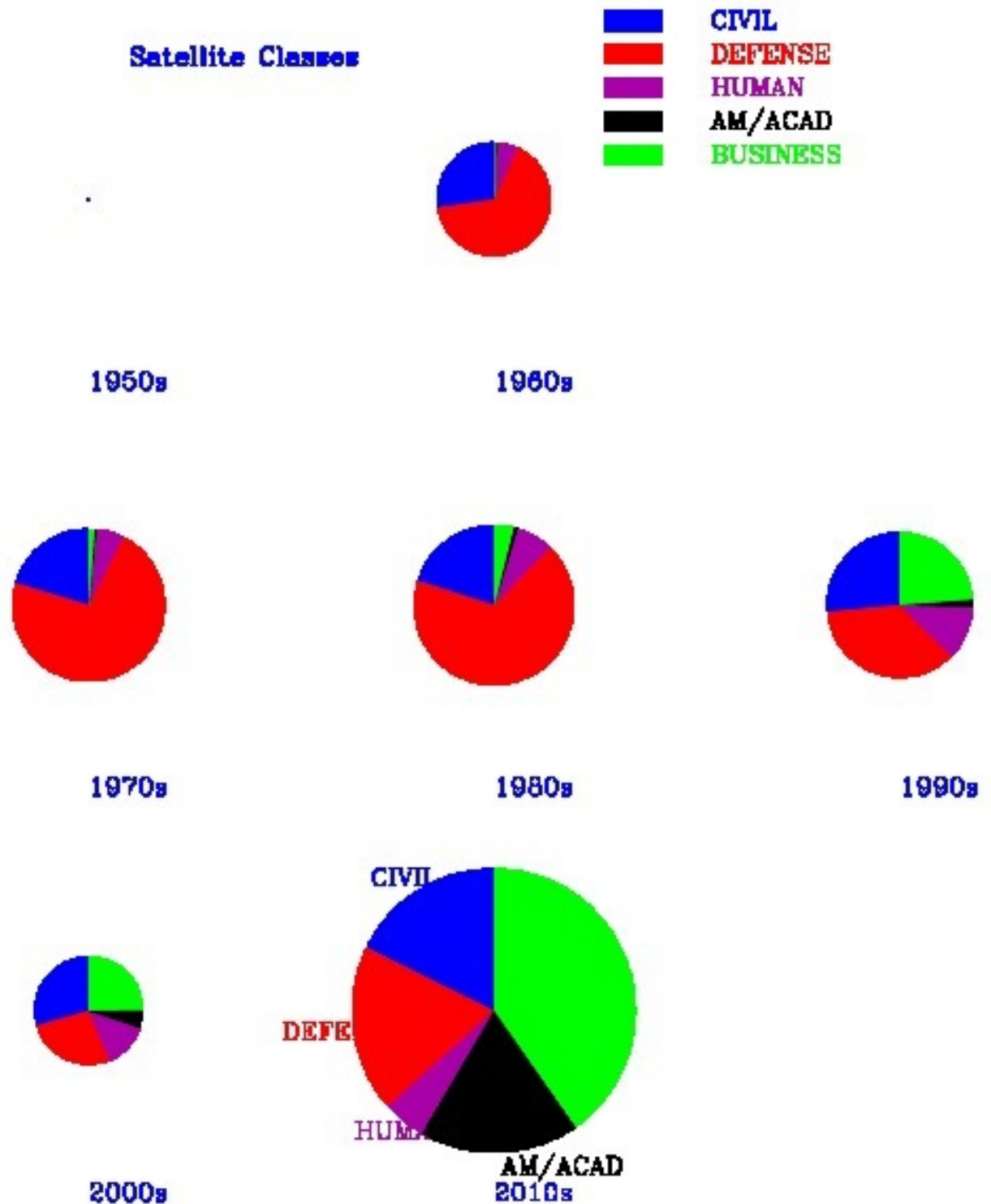
Lump all countries together – division between military, civilian and commercial is about even if you exclude human spaceflight (most of the tonnage, and money)

Non-profit an important sector by number of satellites, but tonnage is negligible

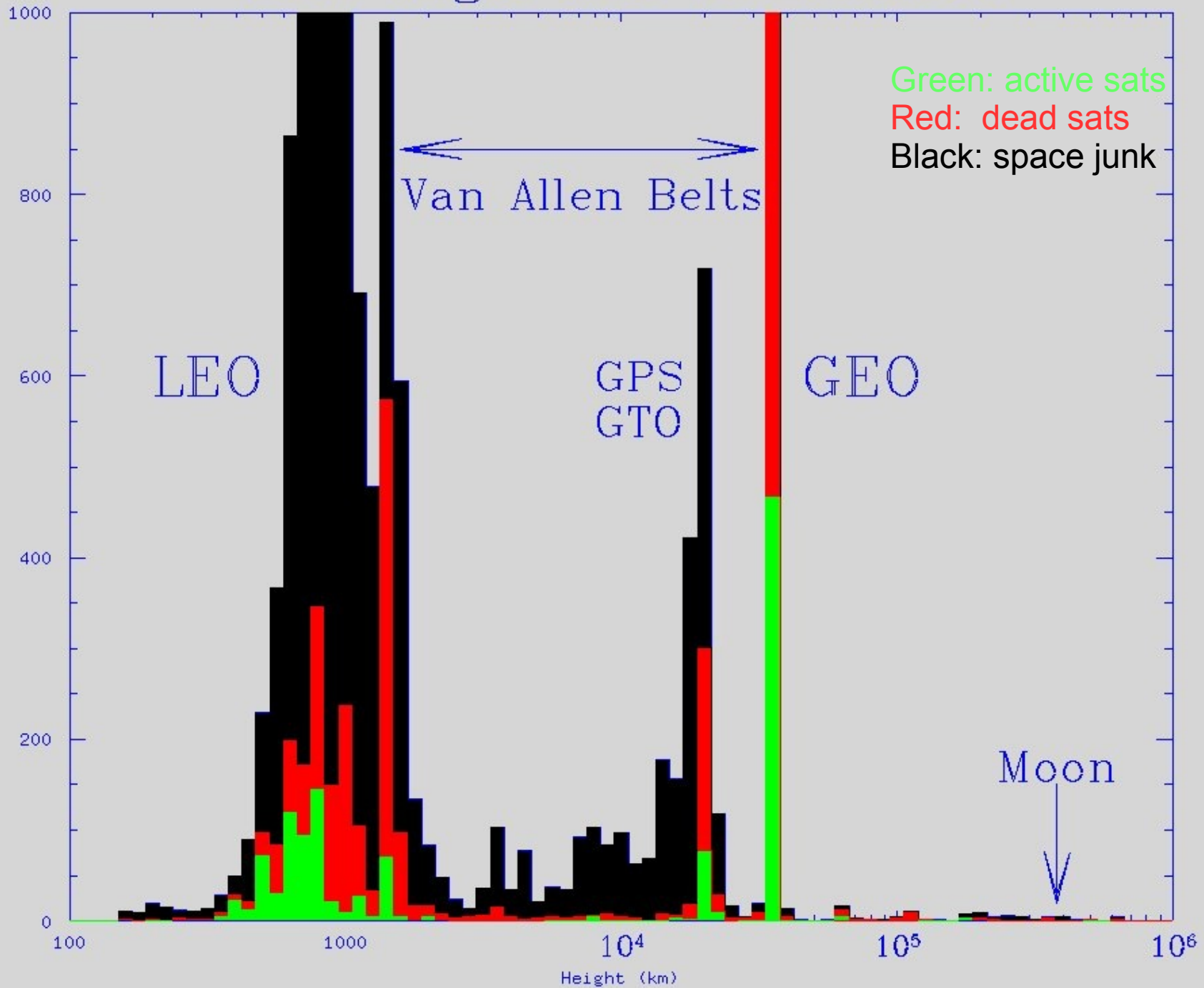
The defense sector (red) shrunk after the cold war

Commercial sector became important in 1990s

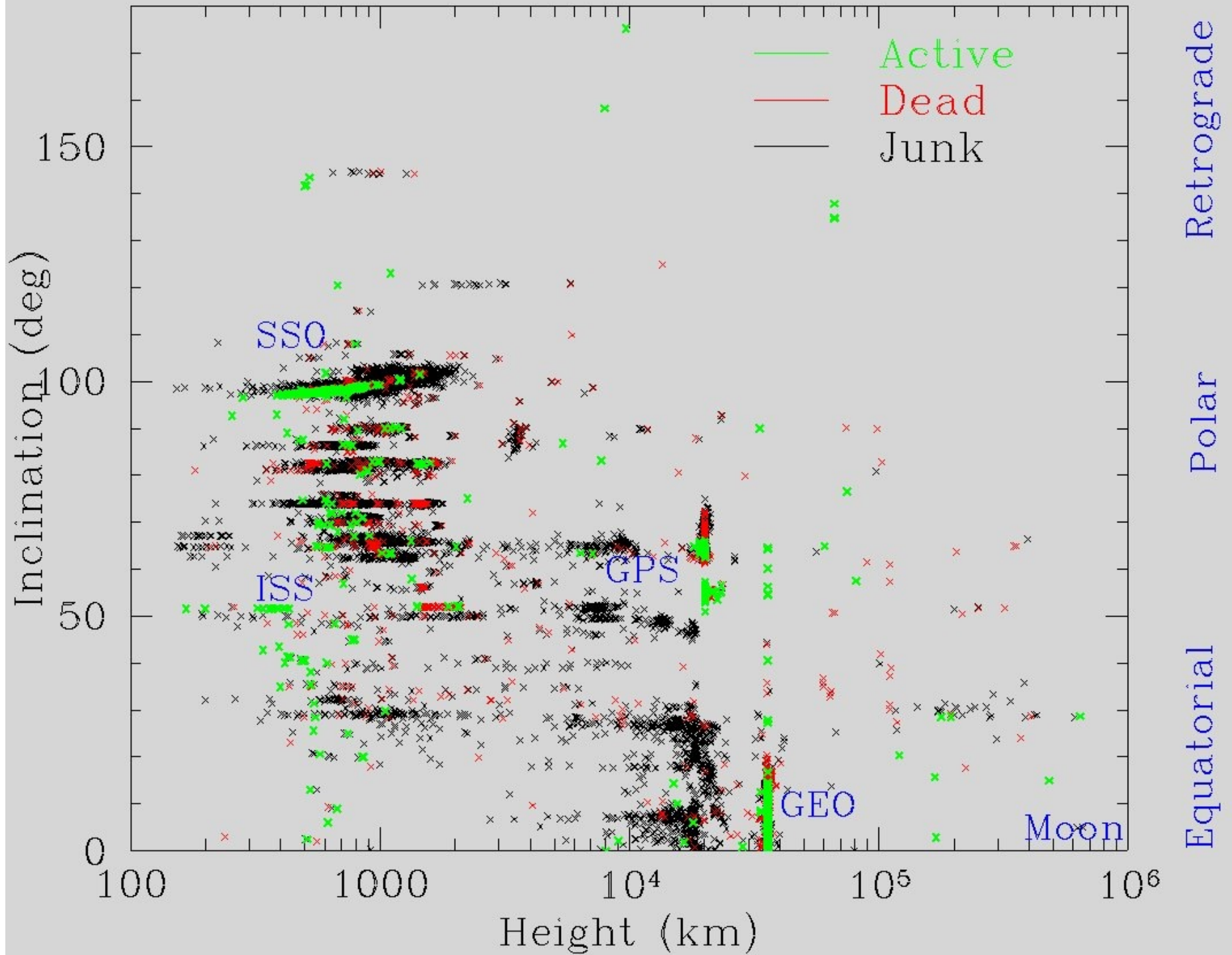
Non-profit sector is a factor starting in 2010s



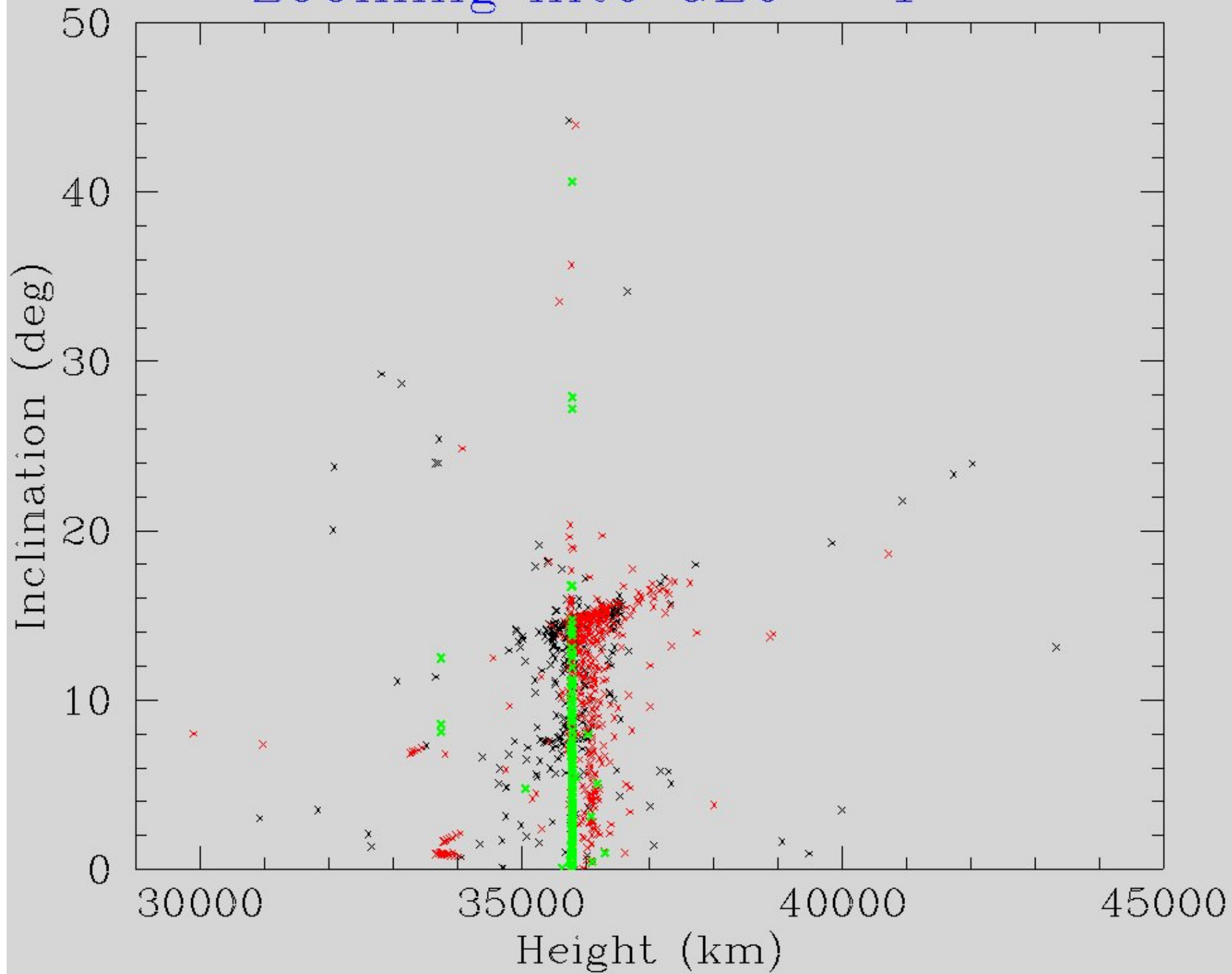
How high are satellites?



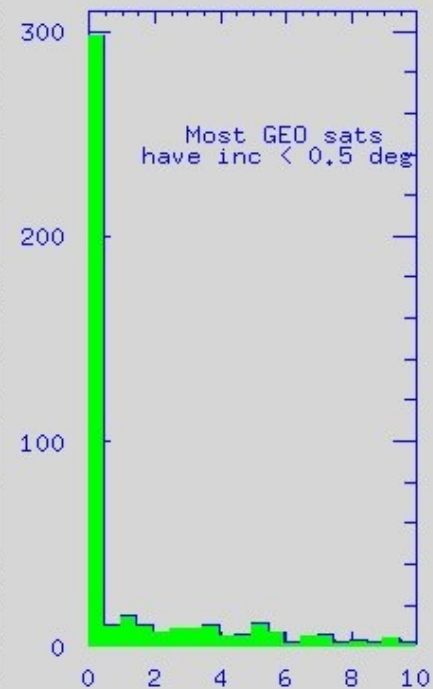
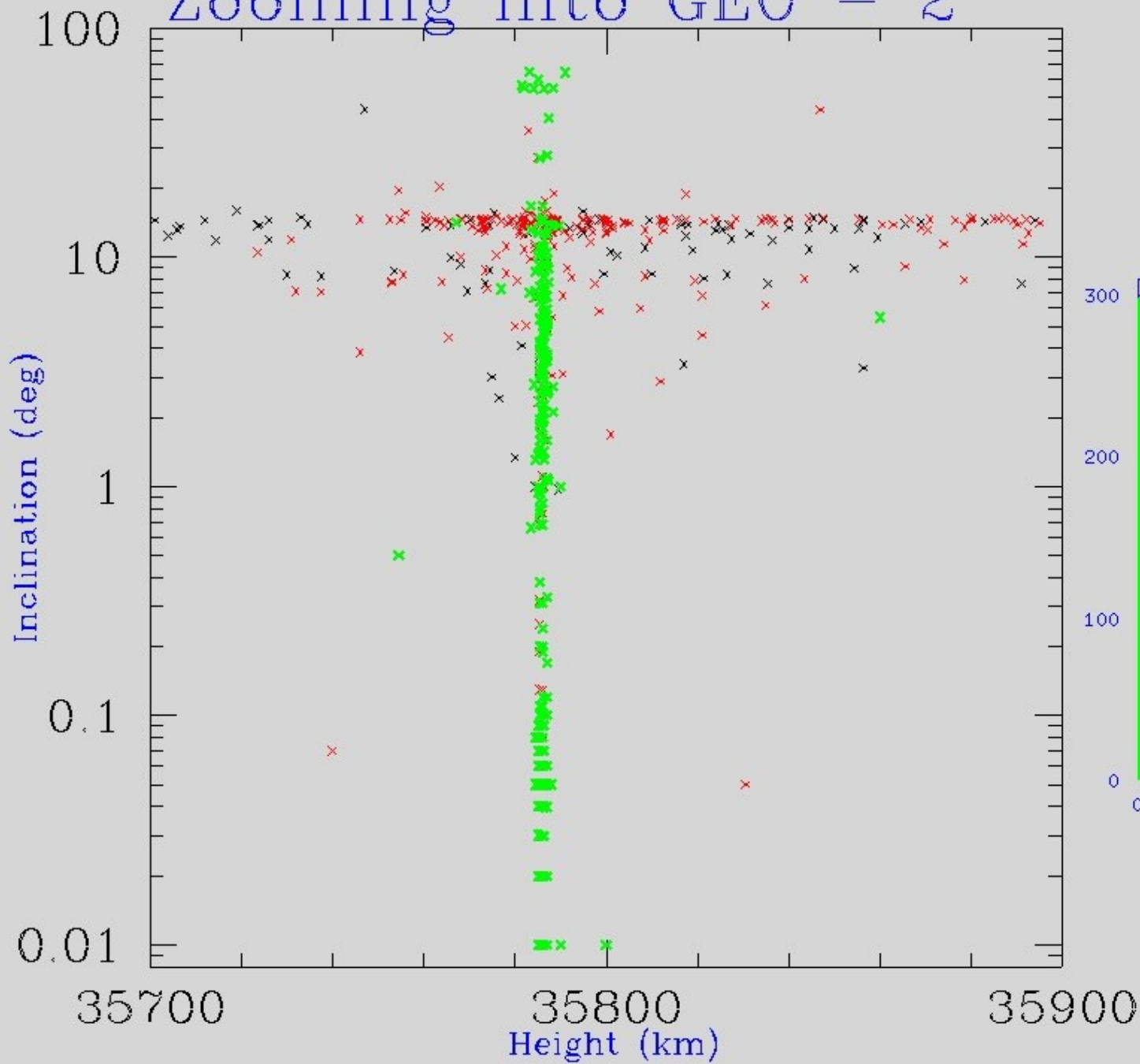
A Map Of Earth Orbit



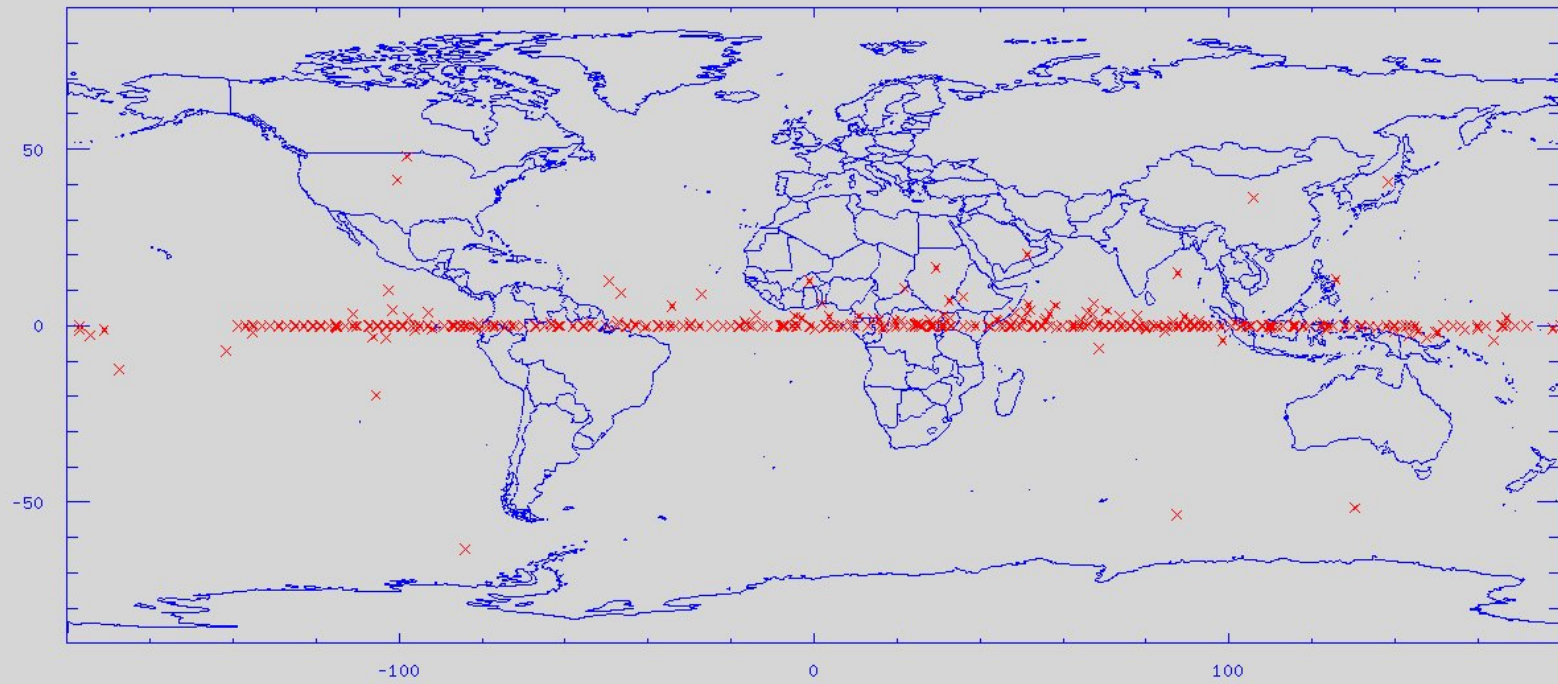
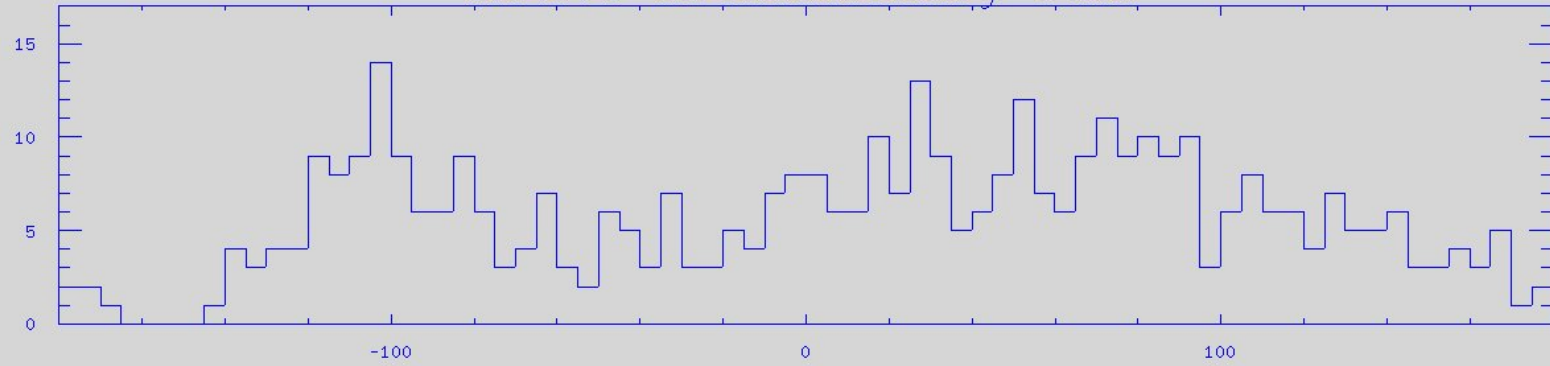
Zooming into GEO - 1



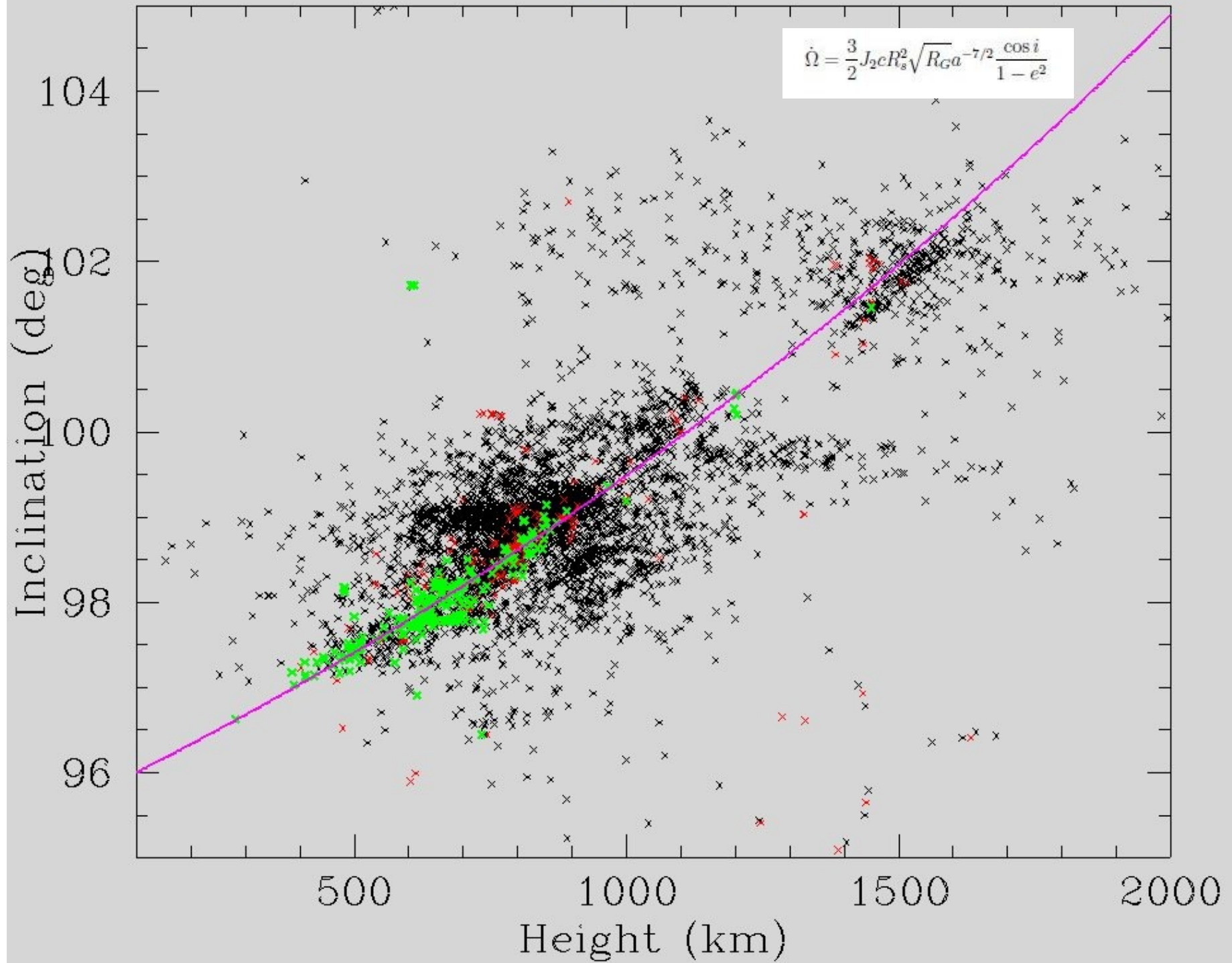
Zooming into GEO - 2



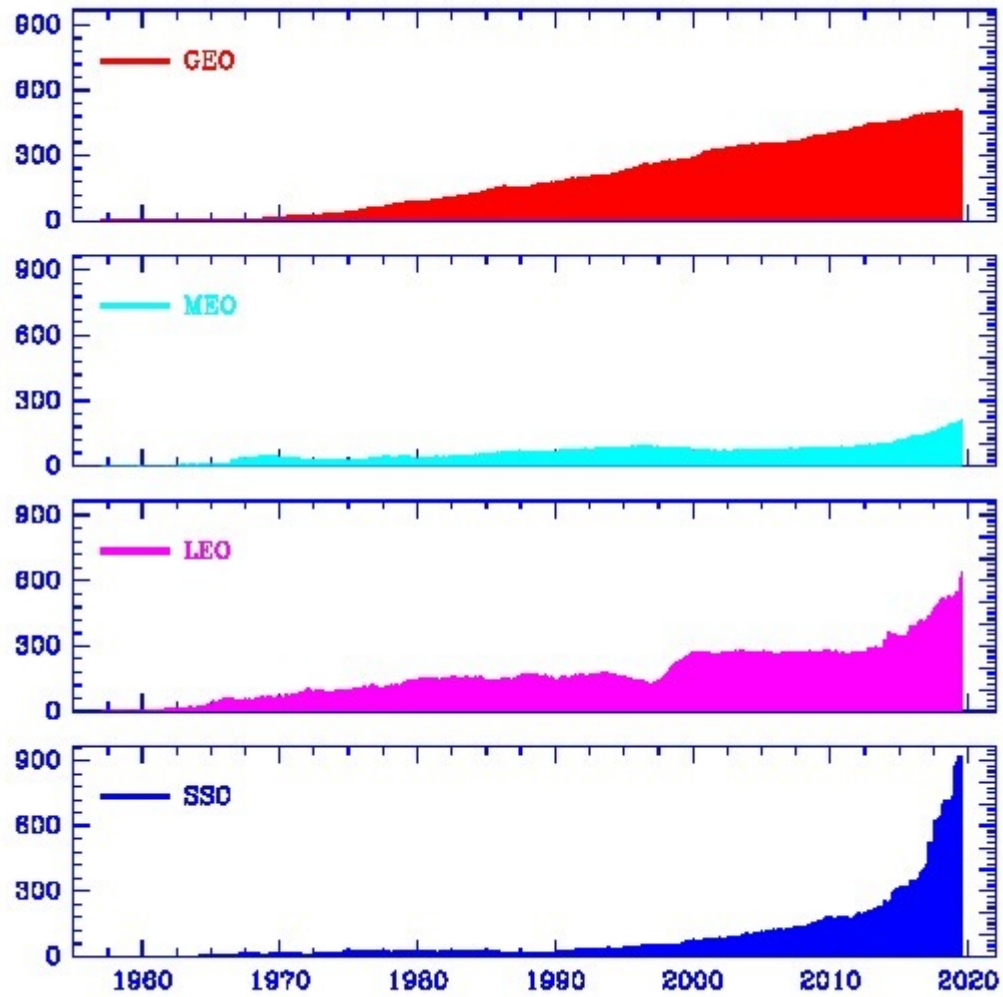
Active Geostationary Sats



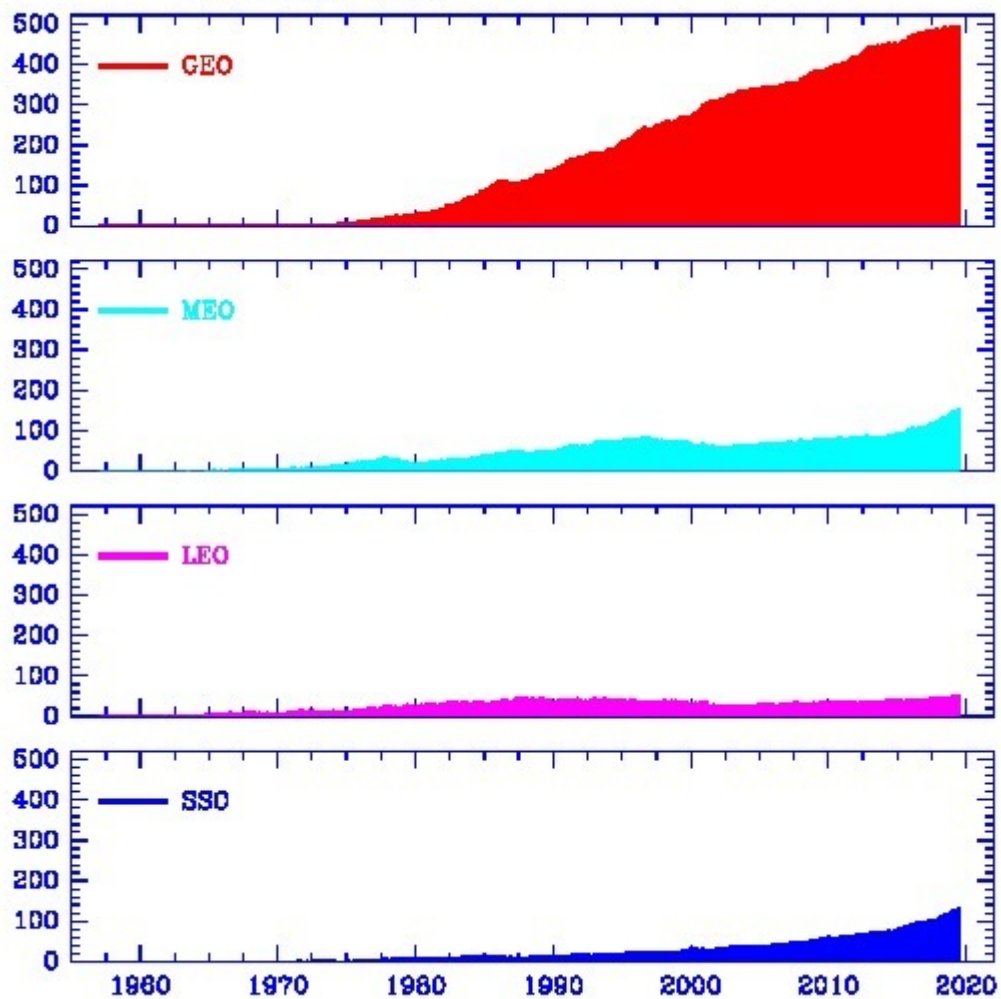
Zooming into SSO



Active Sats

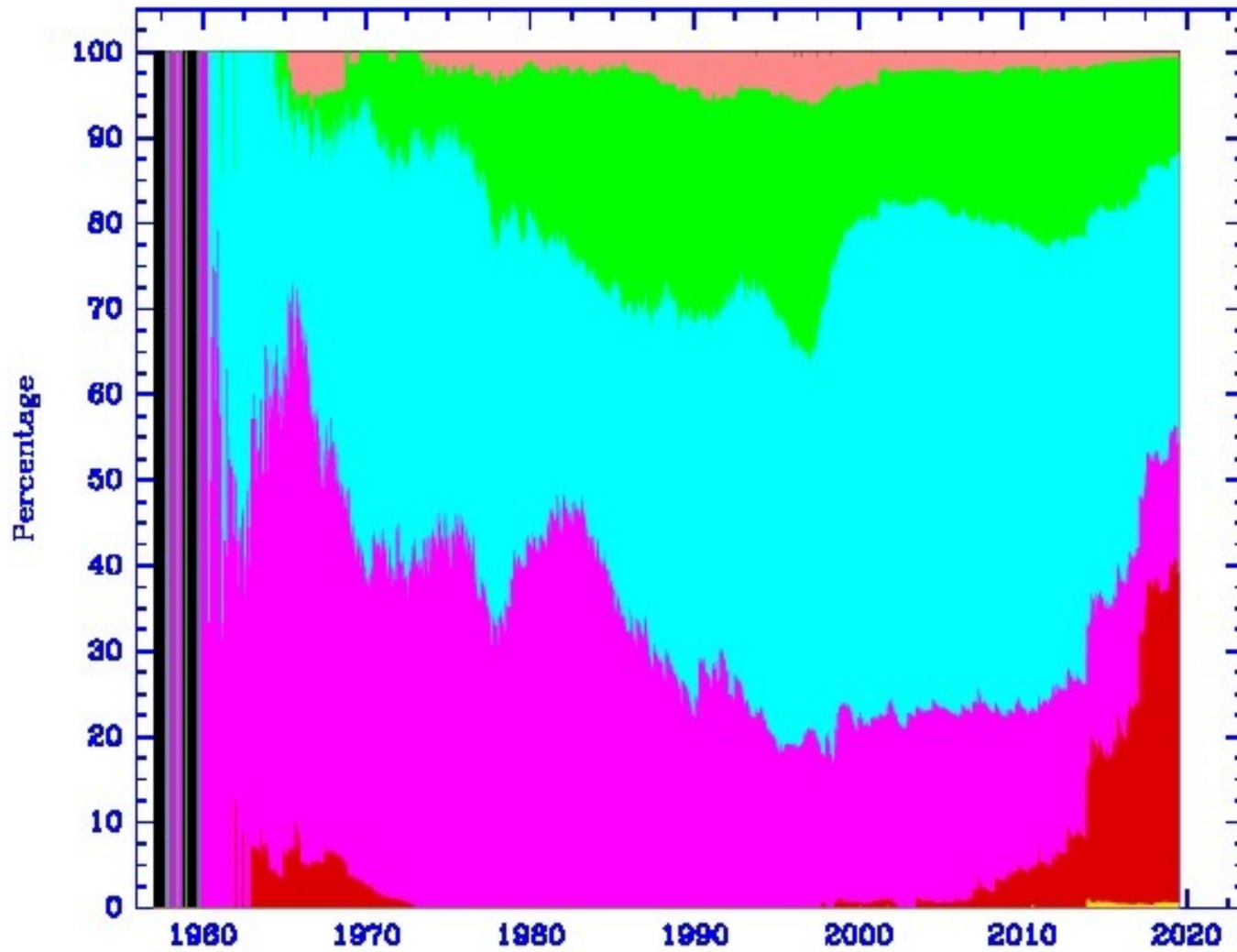


Active Sats > 100 kg

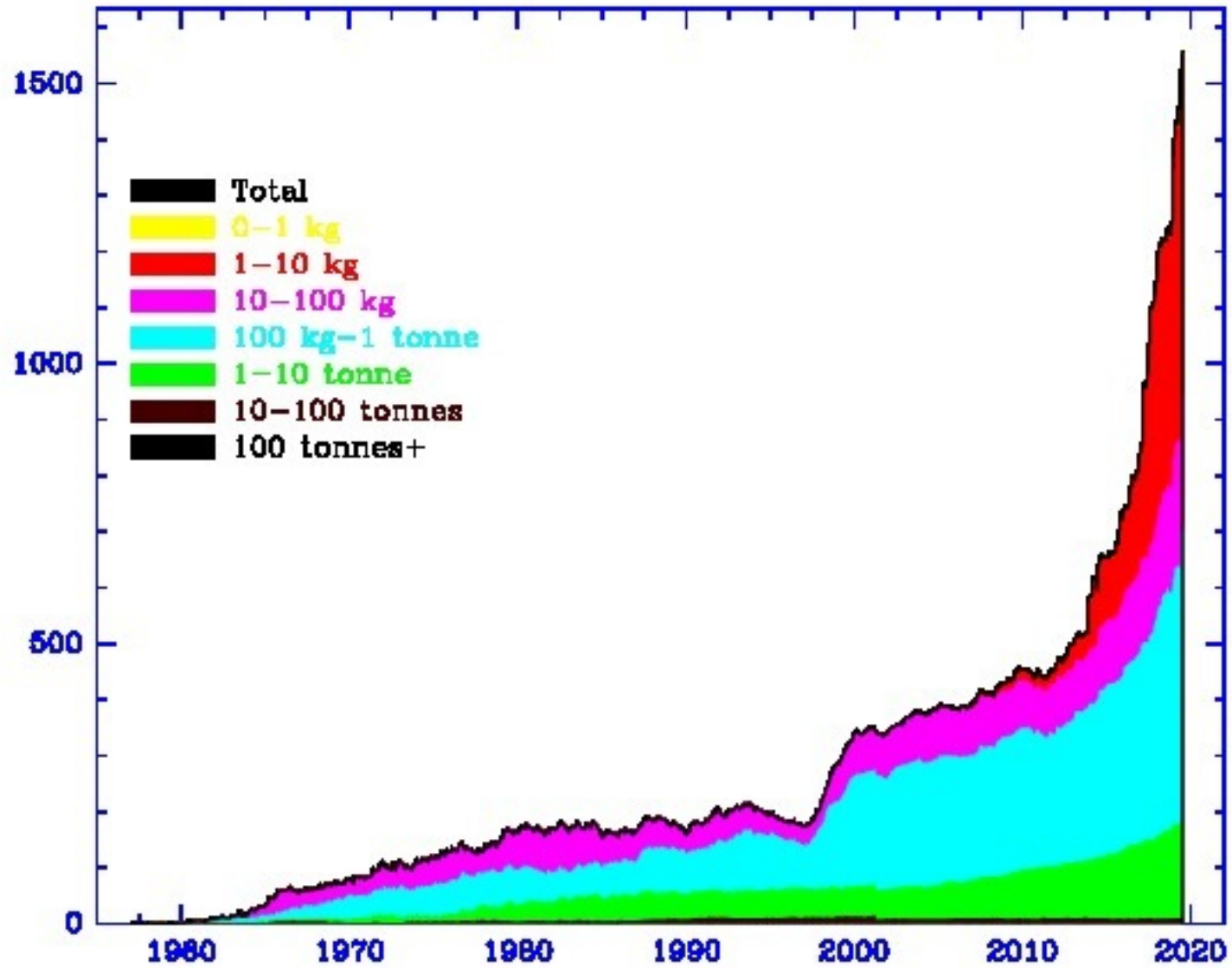


LEO Active sats

- Total
- 100 tonnes+
- 10-100 tonnes
- 1-10 tonne
- 100 kg-1 tonne
- 10-100 kg
- 1-10 kg
- 0-1 kg

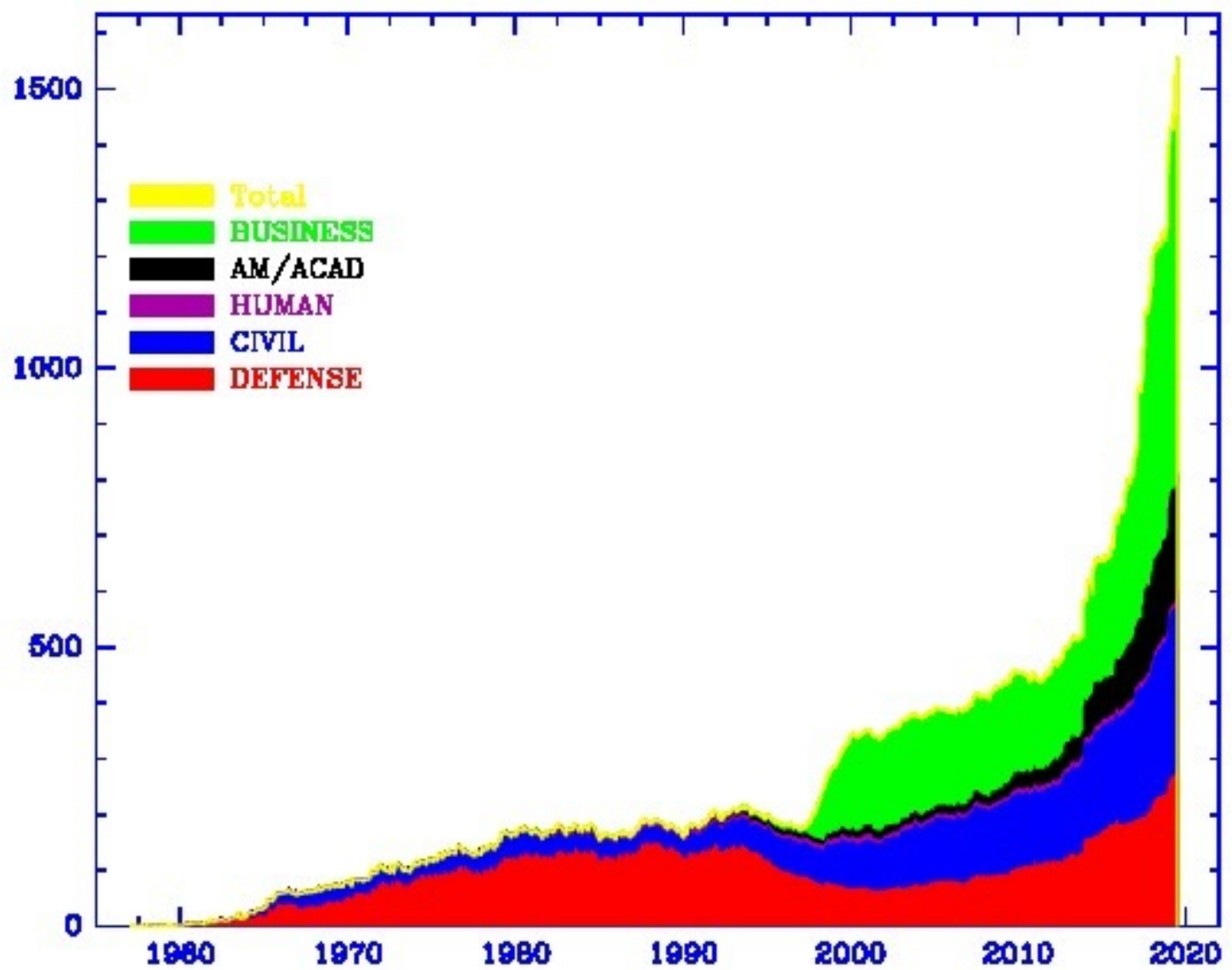


LEO/SSO Active satellites

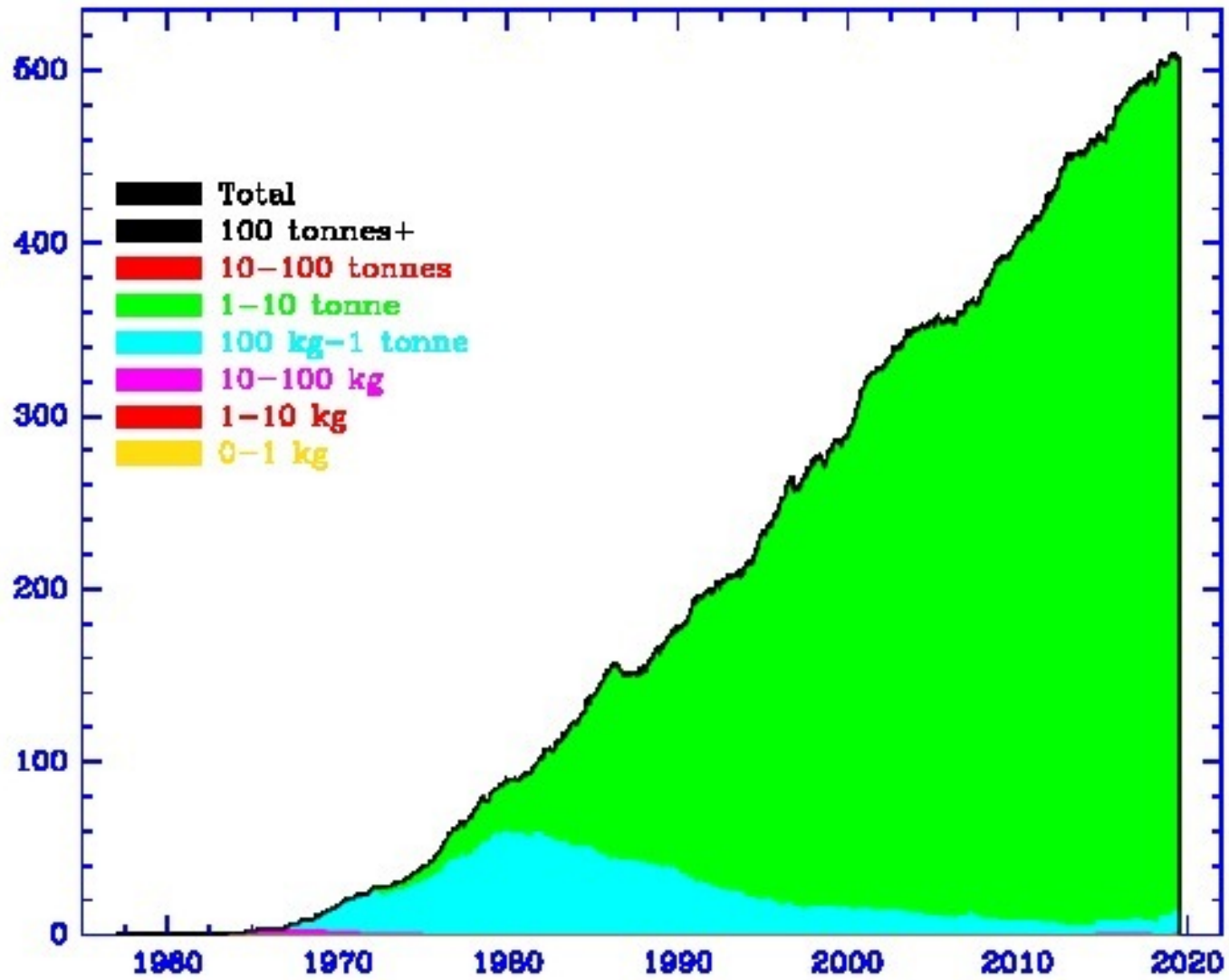


LEO+SSO

LEO Active satellites



GEO Active satellites



Summary:

The satellite population has evolved over the 6 decades of the space age

In the 21st century:

- many nations have assets in orbit
- by number, satellites are comparably divided between civilian, defense, commercial and non-profit.
- by mass, the non-profit (amateur and university) sats are negligible and human spaceflight vehicles are a major component
- The cubesat revolution has changed the median mass of satellites in LEO
- Global overviews of the satellite population give insight into technical and political trends in the use of space

Data: <https://planet4589.org>

A good resource for a policy overview that complements this technical overview: the Space Security Index

<http://spacesecurityindex.org/2018/10/space-security-2018/>