

New Space – Hype or Revolution?

„Is Space slowly developing as Aviation did some 100 Years ago“?

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Former Managing Director German Space Agency; Head of Systems Engineering European Space Agency

Emeritus Chair for Space Systems Engineering, TU Delft; Member Supervisory Board OHB SE, Germany

Chair Systems Engineering Qualification Progr. Airbus DS; Distinguished Visiting Scientist NASA JPL, Pasadena, California

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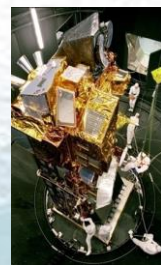
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Professional Background

- **Studies:** Tech. Physics, Bus. Admin., Systems Management, Germany & USA
- **Airbus, Space Division Munich, Project Engineer 3rd Stage ELDO Launcher**
- **Boeing, Systems Engineer Post Apollo Projects, Project Manager Space Tug**
- **ESA/ESTEC, first Project Manager Spacelab, Founder Sys. Eng. & Progr. Dept**
- **TU Delft, Chair Space Systems Engineering, Founding Director „SpaceTech“,**
- **German Space Agency, Managing Director Programmes, Member ESA Council, Chair ESA Programme Board Meteorology & Earth Observation**



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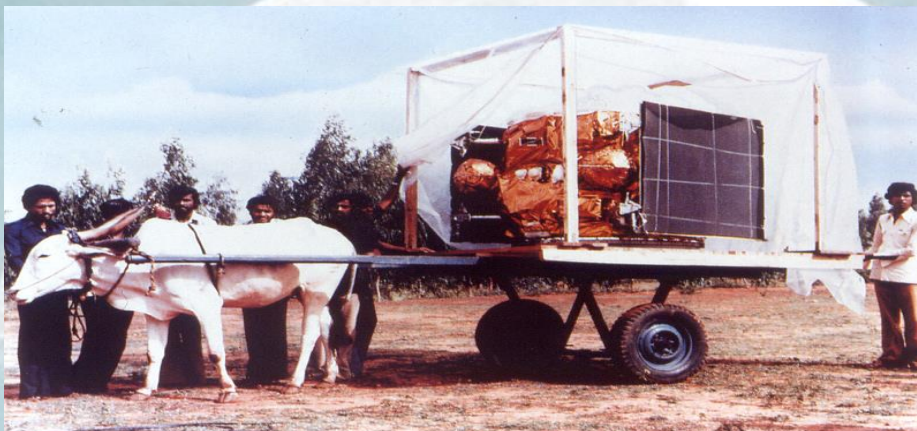
Current & more recent Activities

- President Space Associates GmbH 
- Member Governing Boards   (until 2015)
- Member Sci/Tech Advisory Groups  
- University Associations    
- Professional Societies     
- Distinguished Visiting Scientist, NASA-JPL 
- Publications, Books, Editorial Boards, Honors 

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Space has come a long way!



+/- 8740 Satellites
launched since
Sputnik 60 years
ago (Ref FCC 1118)

Approx. 2000 Sats
operational today,
of which +/- 350
launched in 2017 &
2018

**How many in
2028? 2038?**

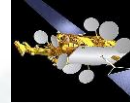
In 2016 the global space economy represented 329 billion US \$; 76 % are commercial efforts!
Projections are that the space sector will grow to \$2.7 trillion next three decades, or 500 B\$ p.y. by 2030

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Three Topics for Today

Satellites in Earth Orbits
→ Engines of our Economy



Rockets → we have to get „up there“



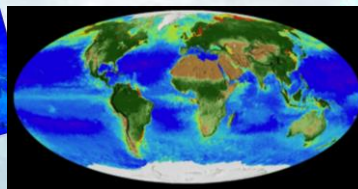
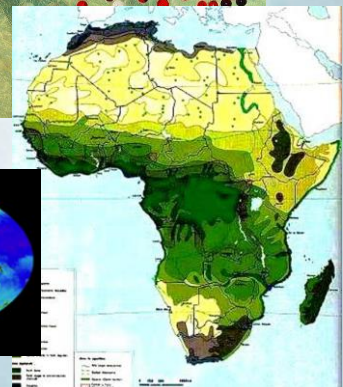
What does all this mean?
→ Hype, Revolution, Evolution?



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Water Management, Food Security, Climate Change, and more UN Sustainability Goals depend upon Space Observations



“Paris and Bonn” agreements would not have been possible without “Space Information”

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What is the **Future** of Earth Observation?

→ From “Space to Place”

→ From selling data to selling answers

→ From Monitoring to Prediction

→ From Data to Fusion, AI and “Big Data Analytics”

→ From Ground- to “in-space” computing/learning

→ From Big to Small Satellites!?

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Earth Observation (EO) Services

	Operational	Planned	High Resolution (<1m)	High revisit time (<1day)	Sensor Description	System or Constellation Size	Satellite Mass (kg)
Large Sats	Airbus D&S		•		Optical and radar	4	1,000
	DigitalGlobe		•	•	Optical	5	2,800
	DMCii		•		Optical	6	450
	ImageSat		•		Optical	3	
	MDA				Radar		
	UrtheCast		•	•	Optical	24	1,400
Small Satellites (<200 kg)	Aquila Space		•		Optical	30	6
	Planet Labs		•		Optical	5	150
	DigitalGlobe/TAONIA		•		Optical	60	50
	XpressSAR		•		Optical	6	TBD
	GeoOptics		•		Radar	4	TBD
	Hera		•		Radio occultation	25	100
	Iceye		•		Optical	48	24
	OmniEarth		•		Radar	50	<100
	PlanetIQ		•		Optical	15	110
	Planet Labs		•		Radio occultation	12	22
	SatelloLogic		•		Optical	100	3
	Spire Global		•		Optical	30	35
	Terra Bella		•		Radio occultation	50	3
			•		Optical and video	24	120

How many of these companies were around 10 years ago?

A recent **Goldrush** of new Players & Business Models proves the Potential

New Services, addressing Meteorology, Agriculture, Security, Urbanisation, Traffic, etc. etc.

... which of these will succeed?

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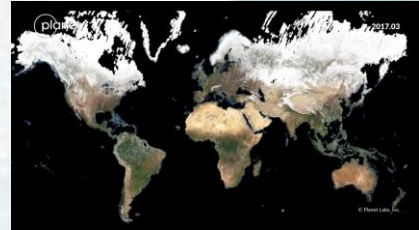
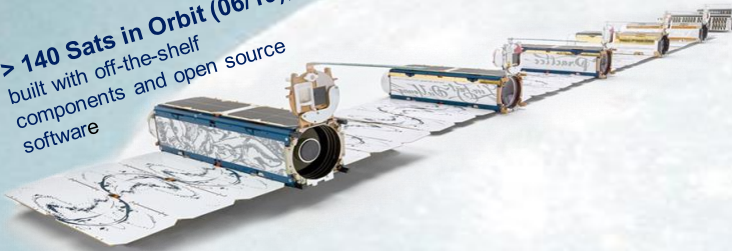
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Example Planet Labs – „The entire Earth, every Day”



> 140 Sats in Orbit (06/19),
built with off-the-shelf
components and open source
software

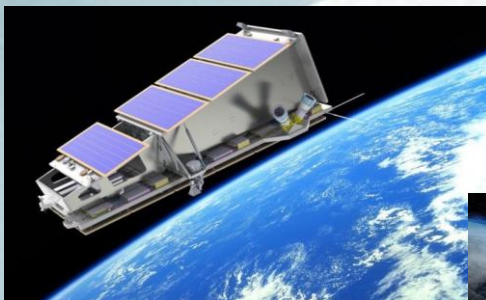


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... and some small Radar Sat Developments with <1m Resolution



Capella 36 Cubesats with
0.5 m Radar Resolution
and hourly updates by
2021

NovaSar by SSTL
for UrtheCast



Hawkeye 360, 18 Radarsats
for 1 m resolution



Iceye of Finland > 18
small Radar Cubesats



For reference: US Congressional Budget Office estimated in 2007 a constellation
of 21 radar sats to cost up to \$94 billion — or more than \$4 billion each

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Monitoring of our Planet has become Big Business

Examples:

- Google Earth - mapping, localization, tourism, advertising and more
- Tom Tom, Navionics, car manufacturers – „navigating“ billions of people
- Smart Agriculture, harvest predictions, pesticides tailoring, soil moisture
- Geo-localisation of precious resources, e.g. water, minerals, fish
- Weather, Climate, Oceans, Security and Disaster mitigation

→ Knowledge explosion from Earth observing satellites has become a big dynamic engine of our digital society

→ Small sats, helped by billion \$ investments into IT, data analytics, A.I., miniaturization and additive manufacturing, are moving into mainstream

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Big Issues on the Horizon for Space-based Telecommunication Commercial Services

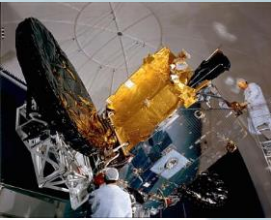
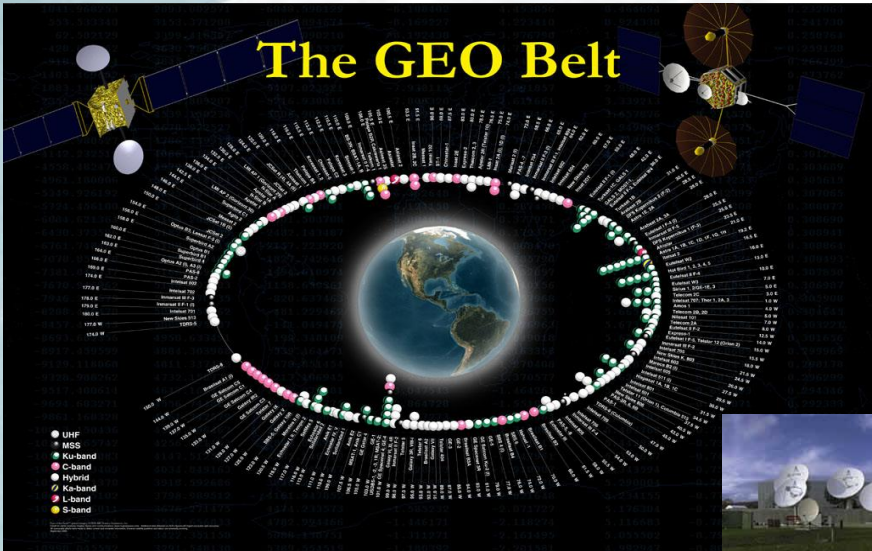


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Current Telecom Satellites cover the Globe

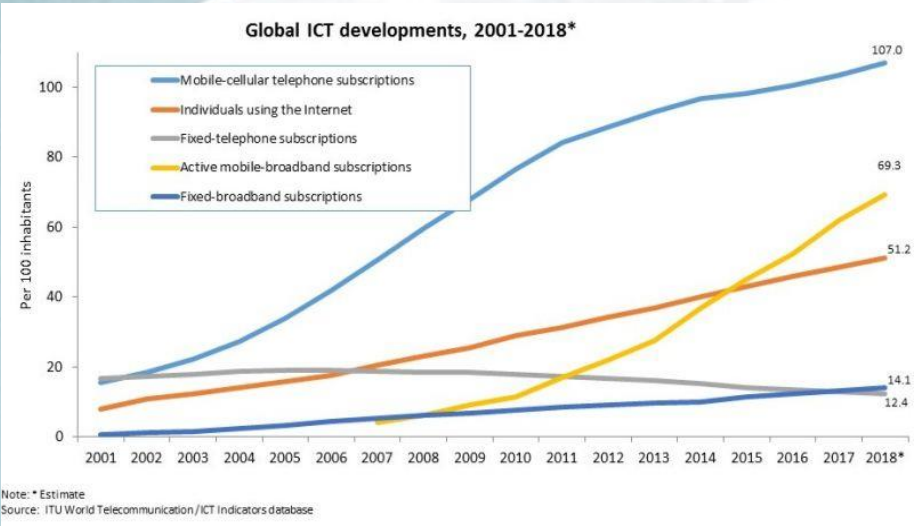
Largest commercial Space Business to date, GEO Business weakening



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Global Communication Demands growing , especially for IoT

More than half the World will be Online by the End of 2018, Ref. UN ITU, 1218



51% global population 2018 vs 48% in 2017

Developed countries 80.9% vs 51.3% in 2005

Developing Nations 45.3% vs 7.7% in 2005

96% population lives within range of cellular network

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IoT & “Big Data” has stimulated a Wave of Telecom Constellations with huge Ambitions “Constellation” projects and proposals to date (not complete):

- OneWeb: 600 to < 1980 (?) (2019++)
- Space X Starlink: up to 12,000 Sats, VLEO 550 km (2019++, <10B\$)
- Amazon “Kuiper”: 3,236 - 3 layers around 600km
- Telesat Canada: 117 (292- 512) by 2022/23
- LeoSat Lux: 78 -108; O3b (SES): 24+;
- Kepler Canada; 140 in Vband
- Boeing: 1,396 to 2,956 ?(with Apple?) withdrawn?
- Theia Holdings:??; China Hongyun/CASIC: 300+ Sats 2020-25
- Astrocast, CH, 80 cubesats 2020
- SKIF Russia 12 polar sats & Marathon Sat System, EFIR 288 Sats, SAS Pearl 200 sats; Athena Facebook: ???
- Etc etc

This could mean
12,000++ new
satellites in the
coming decade

Remember: in 60 years
since Sputnik, only some
4,700 satellites were
launched

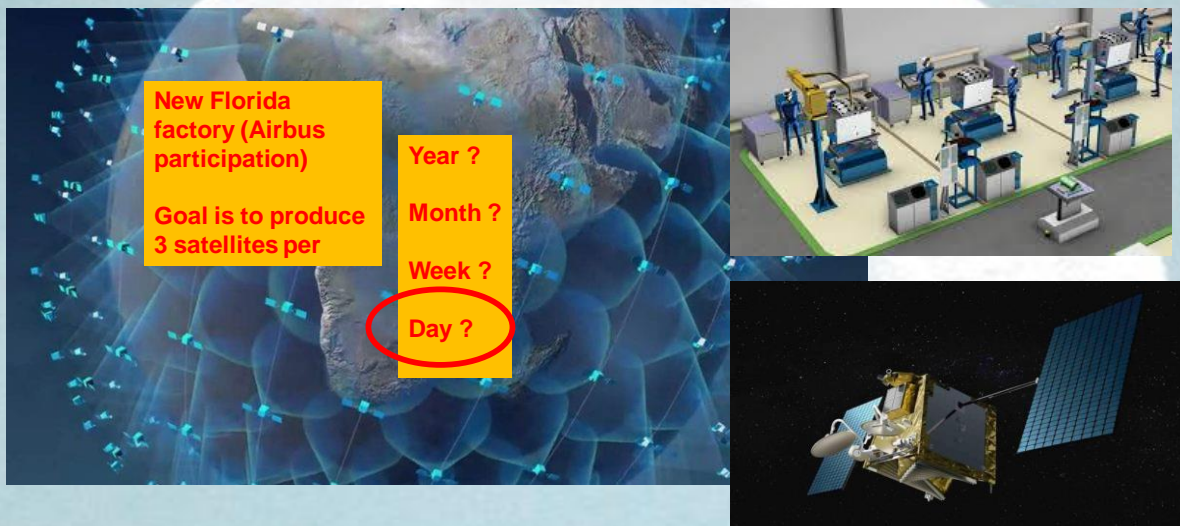
→ Dream, Hype, Reality? How many can survive?

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Example: One Web < 900 Satellites, Growth to 3000+

@ some 150-200kg each, 6 GB throughput, 1200 km orbit & < 1 M\$ per Sat, 6 in orbit 02/19



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Example Starlink Constellation 4,425 (to 12,000) Sats (Musk Jan 2015)

Low latency, GB speed, direct to home in LEO orbits, 2 Demo Sats + 60 Sats launched 2018/19



Some 180 more in 2019; economic viability at appr. 1,000 Sats; expected by 2020



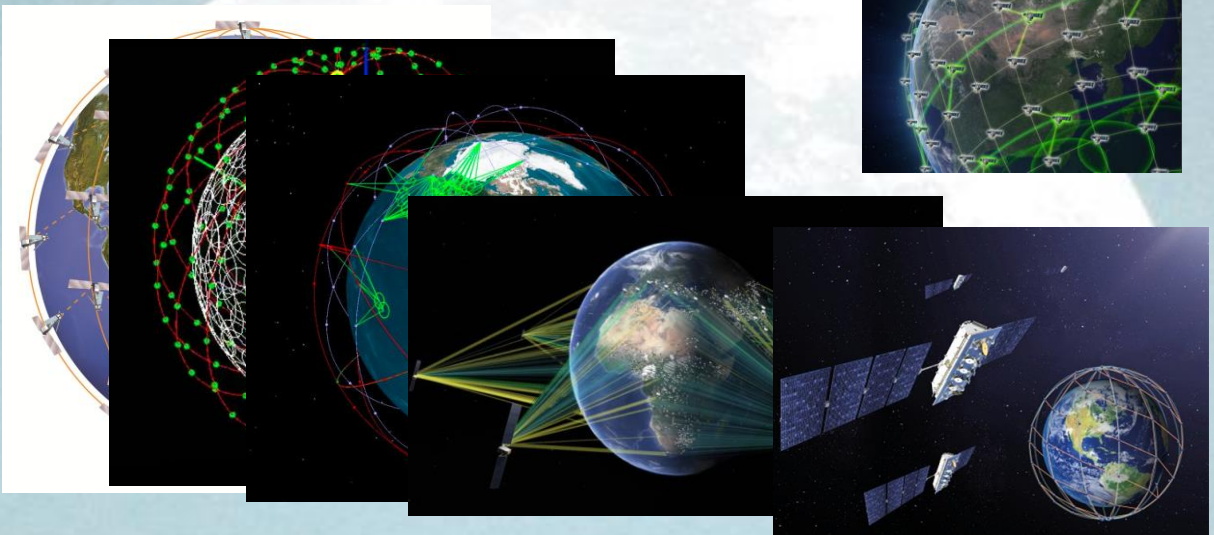
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Several more Constellations in planning/build-up Phases (new and upgrades)

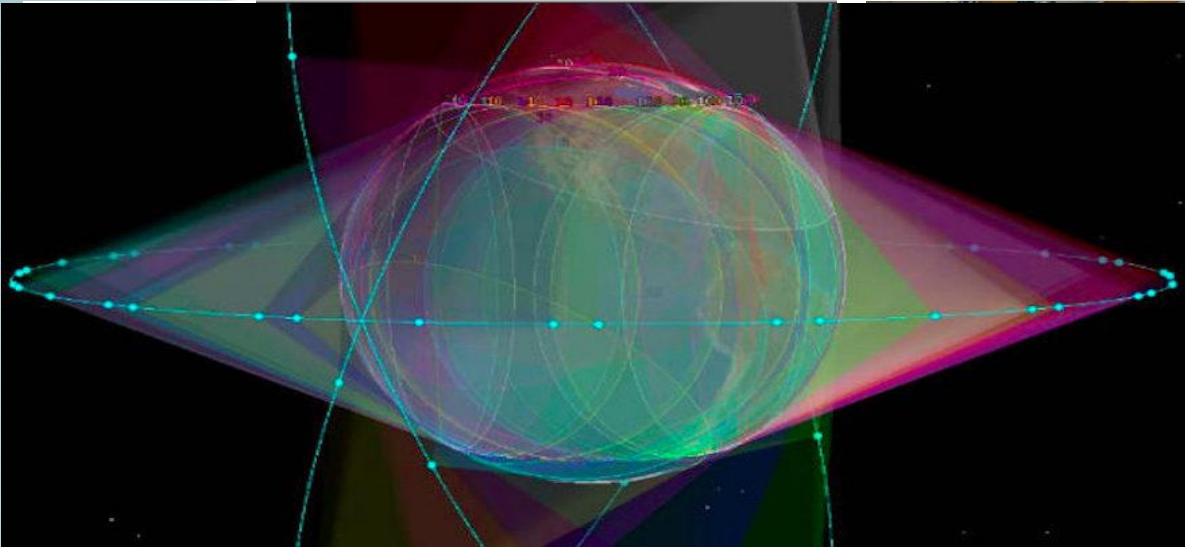
e. g. Iridium Next, Telesat, Teledesic, O3b, LEO Sat, Blackjack Darpa, or Russian Sphere IoT constellation (2026), mix of 640 satellites for com, nav, remote sensing



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The Space Communication Architecture is changing massively
GEO, MEO and LEO Services will grow together for the future
Space Telcom Infrastructure



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Three Topics for Today

Satellites in Earth Orbits
→ Engines of our Economy



Rockets → we have to get „up there“



What does all this mean?
→ Hype, Revolution, Evolution?



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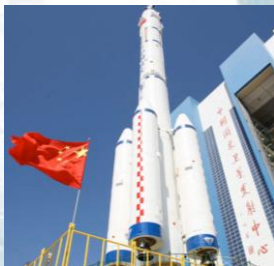
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We have an impressive worldwide Launcher Stable



Vehicle - Nationality - Launch Site - Status	Kg to LEO	Vehicle - Nationality - Launch Site - Status	Kg to LEO
A Atlas 5 - USA - Cape Canaveral & Vandenberg Spaceports - Operational	13000	A Delta 2 - USA - Vandenberg Spaceport - Operational	8100
B Delta 4 (Heavy-IF shown) - USA - Cape Canaveral & Vandenberg Spaceports - Operational	28700	B Thunderbolt (Bratolauca) - USA - Cape Canaveral & other spaceports - In Development	8000
C Falcon 9 - USA - Cape Canaveral, Vandenberg, Boca Chica Spaceports - Operational	13150	C Dragon - Ukraine - Dniprovarsk & Bakuor Spaceports - Operational	4500
D Falcon Heavy - USA - Cape Canaveral, Vandenberg, Boca Chica Spaceports - In Development	83000	D Haneul 1 - South Korea - Haneul Spaceport - Operational	100
E Vulcan - USA - Cape Canaveral, Vandenberg - In Development	31751	E Ullua 3 - North Korea - Sohae Spaceport - Operational	100
F Angara 5 - Russia - Plesetsk, Bakuor & Vostochny Spaceports - In Development	22228	F Cosmos - Russia - Plesetsk Spaceport - Operational	1800
G Ariane 5 - Europe - Kourou Spaceport - In Development	1800	G Vega - Europe - Kourou Spaceport - Operational	1600
H Long March-5 - China - Wenchang Spaceport - In Development	25000	H Rocket 7 (Strela) - Russia - Bakuor & Plesetsk Spaceports - Operational	1950
I Zenit - Ukrainian/Russia - Sea Launch & Bakuor Spaceports - Operational	19140	I Long March-6 - China - Taiyuan - Operational	1080
J Atlas 5 - USA - Cape Canaveral & Vandenberg Spaceports - Operational	18510	J Athena 2 - USA - Cape Canaveral & Kodiak Spaceports - Operational (2B model planned)	1899
K H-3 - Japan - Tanegashima Spaceport - In Development	18000	K Taivus-1 - USA - Mid-Atlantic & Vandenberg Spaceports - Operational	1320
L Long March-3B - China - Xichang Spaceport - Operational	15000	L Bragh - Iran - Imam Khomeini Spaceport - In Development	160
M Blue Origin Orbital Launch System - USA - Cape Canaveral Spaceport - Proposed	TBD	M Shavit - Israel - Palmachim Spaceport - Operational	800
N H-2B - Japan - Tanegashima Spaceport - Operational	19000	N Minotaur 4 & 5 - USA - Mid-Atlantic, Vandenberg & Kodiak Spaceports - Operational	1735
O Ariane 5 - Europe - Kourou Spaceport - Operational	20000	O Epsilon - Japan - Utsunomiya - Operational	1200
P Proton - Russia - Bakuor Spaceport - Operational	18780	P Firefly Alpha - USA - TBD spaceports - In Development	450
Q Athena 3 - USA - Cape Canaveral, Kodiak & Vandenberg Spaceports - Proposed	8000	Q Bolt - Iran - Van Space Center - Operational	50
R GSLV MK-2 - India - Sriharikota Spaceport - Operational	5000	R Long March-11 - China - Jiuquan - Operational	700
S Soyuz - Russia - Bakuor & Kourou Spaceports - Operational	7800	S Athena-1c - USA - Cape Canaveral & Kodiak Spaceports - Operational	794
T Soyuz-1 - Russia - Bakuor, Plesetsk & Vostochny Spaceports - Operational	7800	T Minotaur 4 - USA - Cape Canaveral & Kodiak Spaceports - Operational	280
U PSLV - India - Sriharikota Spaceport - Operational	7800	U Athena-1c - USA - Cape Canaveral & Kodiak Spaceports - Operational	660



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But three Billionaires shake up the Launcher Market



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Space X – a major Actor of commercial Space and Exploration



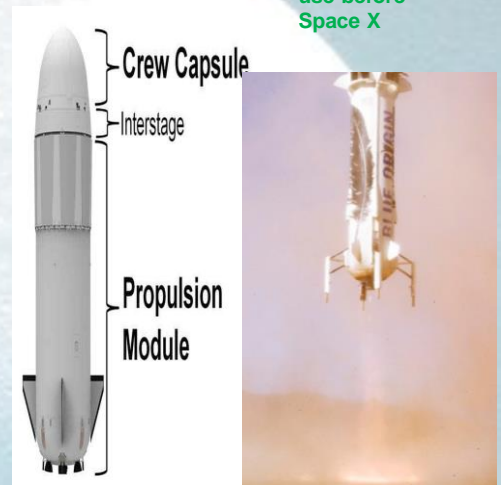
Re-use, on the way to a 100-fold cost reduction?

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Jeff Beso's Blue Origin with gigantic Ambitions

Blue Origin has demonstrated landing and re-use before Space X



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Two more Billionaires on the Block - with Aircraft based Rockets

Richard Branson
“Launcher One”



Paul Allen
“Stratolaunch”



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... and the “ultimate” USAF XS-P reusable Rocket Plane with expendable rocket on top - from Boeing Phantomworks; 1st flight 2020?



“PHANTOM EXPRESS”

Objectives:

- Fly 10 times in a 10-day period to demonstrate efficient, aircraft-like access to space
 - Reduce launch cost to some 5 M\$ per flight for payloads of up to 1400 kg
- 10 - 20x cheaper than current rockets

Source Space Com News 0517

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Multi-Satellite Launch Offerings sprawling Example Soyuz and Indian PSLV in 2017



**PSLV-C37
successfully
launched 104
satellites in a
single flight**



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...and some 100++ “small” expendable Launcher Project Initiatives Examples: Rocket Lab New Zealand; Vector Mojave; F; D; ES; Japan; China; +Balloon based concepts



→ How many can
survive?

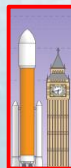
→ Consolidation
expected!

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The Commercial Launcher Future

- The market demand for launch services is skyrocketing!
- International competition growing massively; many new small and large launchers in development, launch prices tumble
- Moreover 3 new huge US launchers - capable of Moon and Mars journeys in development by NASA, Space X and Blue Origin
Russia, India, China have similar plans!

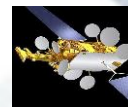


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Three Topics for Today

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Rockets → we have to get „up there“



What does all this mean?
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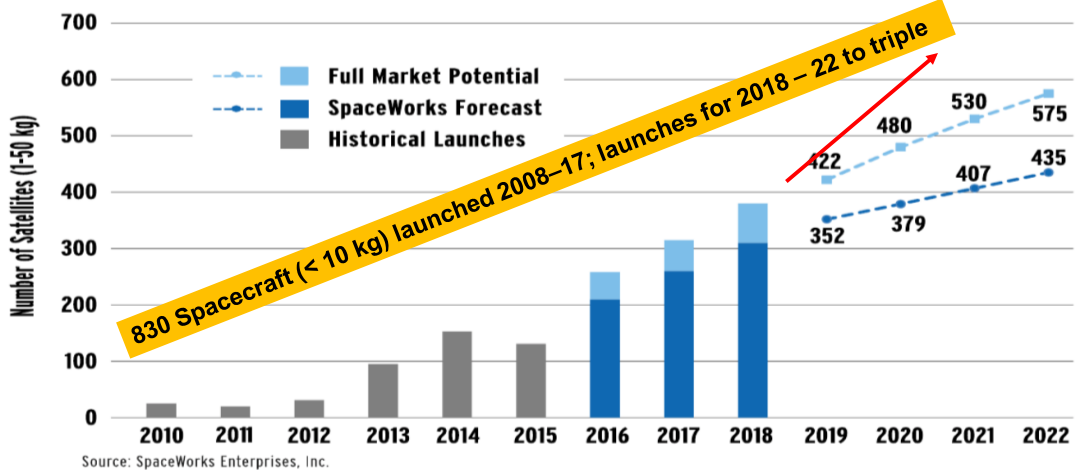
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Small Satellite Launches have skyrocketed

From 20 to 300 per year in just 5 years Ref.: Space Works

Projections based on announced and future plans of developers and programs indicate as many as 3,000 nano/microsatellites will require a launch from 2016 through 2022.

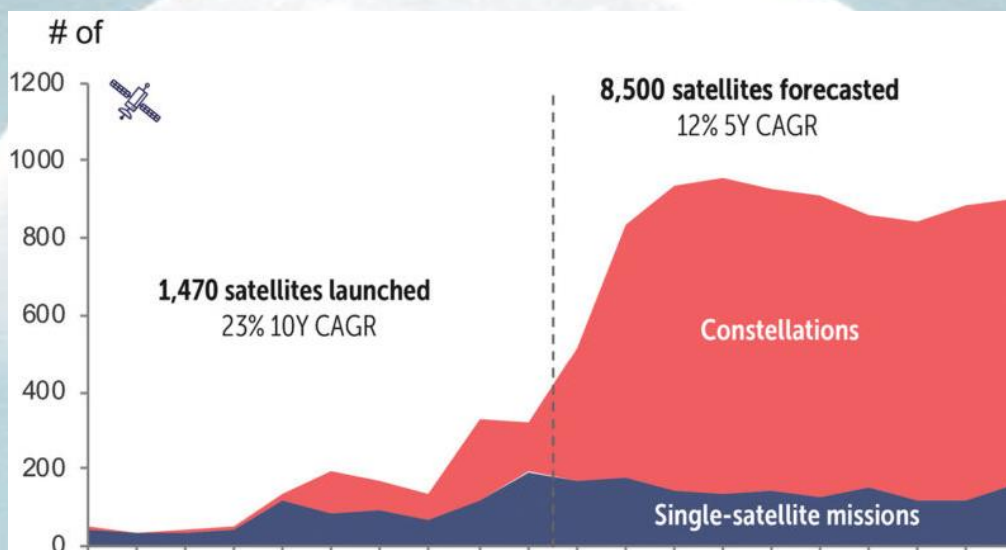


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Small Satellites Forecast (Eurosace August 2019)

(Some 8500 satellites @ < 500kg to launch 2019 – 2028)

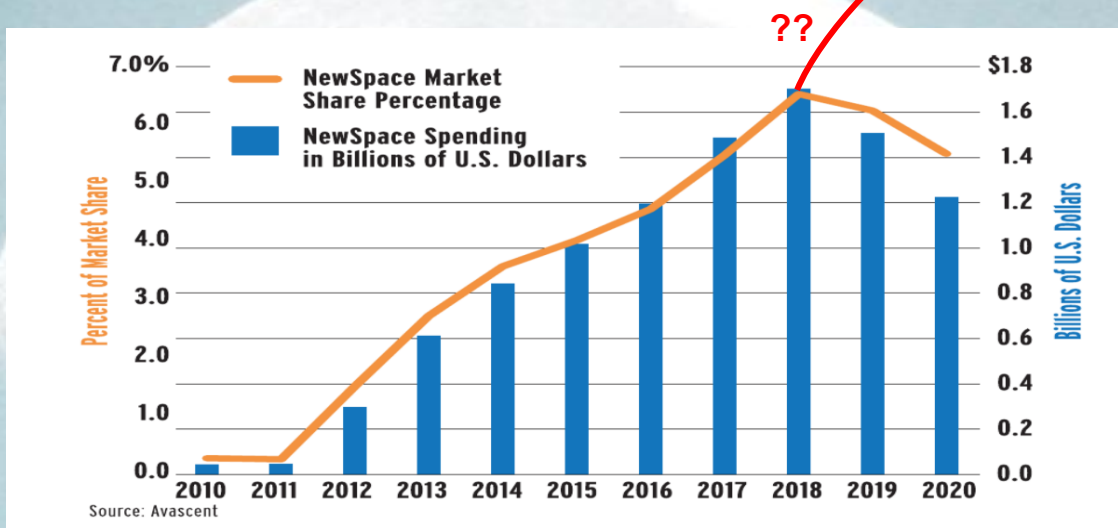


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“New Space” Funding

Growth in 6 Years from Zero to > 1 B \$ p.y. 1st Quarter 2018 = 1B\$



This amounts to some 1,5% of global space budgets or 2.5% of USA \$, but huge growth

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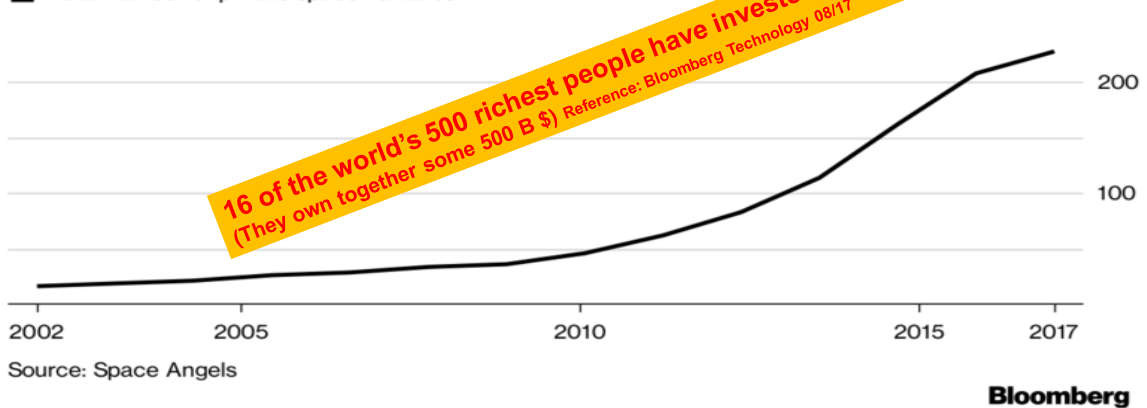
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Space Startups have skyrocketed since 2002 (Billionaires have a new Hobby)

Space Startups

The number of commercial space companies has rocketed since 2002

■ Total number of private space ventures



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So what is the “New Space Future” in 4 Lines?

- Commercial services for the management of our Planet, Telecom & Navigation growing massively
- Internet from space drives several new constellation initiatives; some could become **goldmines** or **failures**
- Trend to smaller and small satellites with enormous growth rates
- Launch service offerings multiplying - at lower cost



PS: even Moon and Mars initiatives involve commercial “new space” initiatives
 PPS: most of this is happening in the US – Europe’s posture is not equivalent ☹
 PPS: established space companies are challenged!!!



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In Conclusion:

We will continue to observe a Hype, along with some Revolutions and rapid Evolutions
 ... and Space may just be developing as Aviation did some 100 Years ago“?

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