



Impacts of the Entrepreneurial Space Sector on Planetary Science

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Senior Applied Planetary
Scientist, First Mode



One of my weirder days at work at Planetary Resources: Explaining meteorite formation to Luxembourg's Deputy Prime Minister

My Background

2014 PhD, Planetary Geochemistry, CU-Boulder

2014-2016 NASA MESSENGER Postdoc, Carnegie DTM

2016-2018 Director, Data Products, Planetary Resources, Inc.

2018-present Senior Applied Planetary Scientist, First Mode

2020-present Chair, LEAG Commercial Advisory Board

But before all that.. I was an LPI intern!



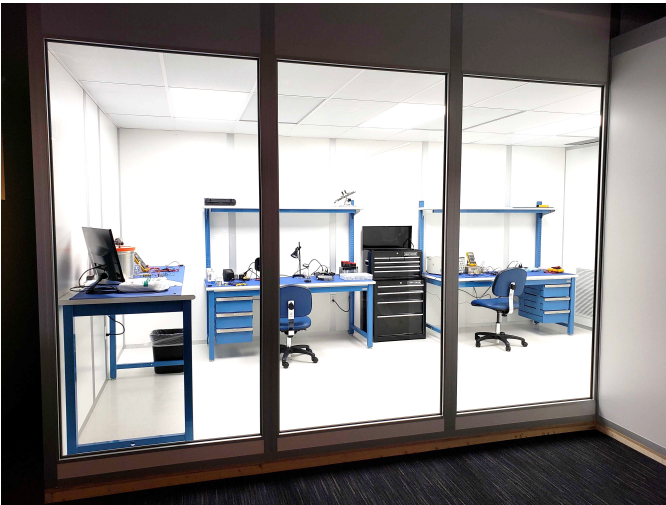


First Mode

building the barely possible

Company

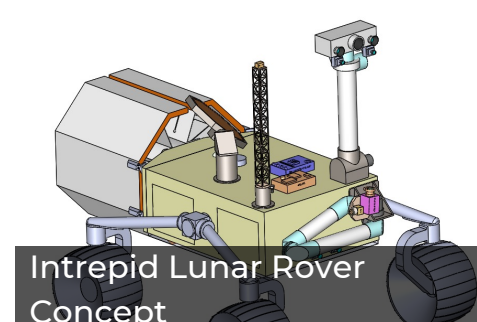
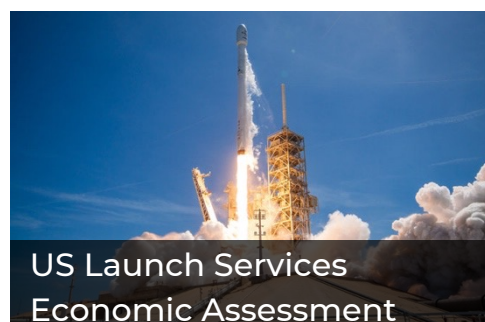
- Created in February 2018 by 11 co-founders
- Providing engineering consulting services
- Customers in industry, government, and academia
- 90+ employees & growing

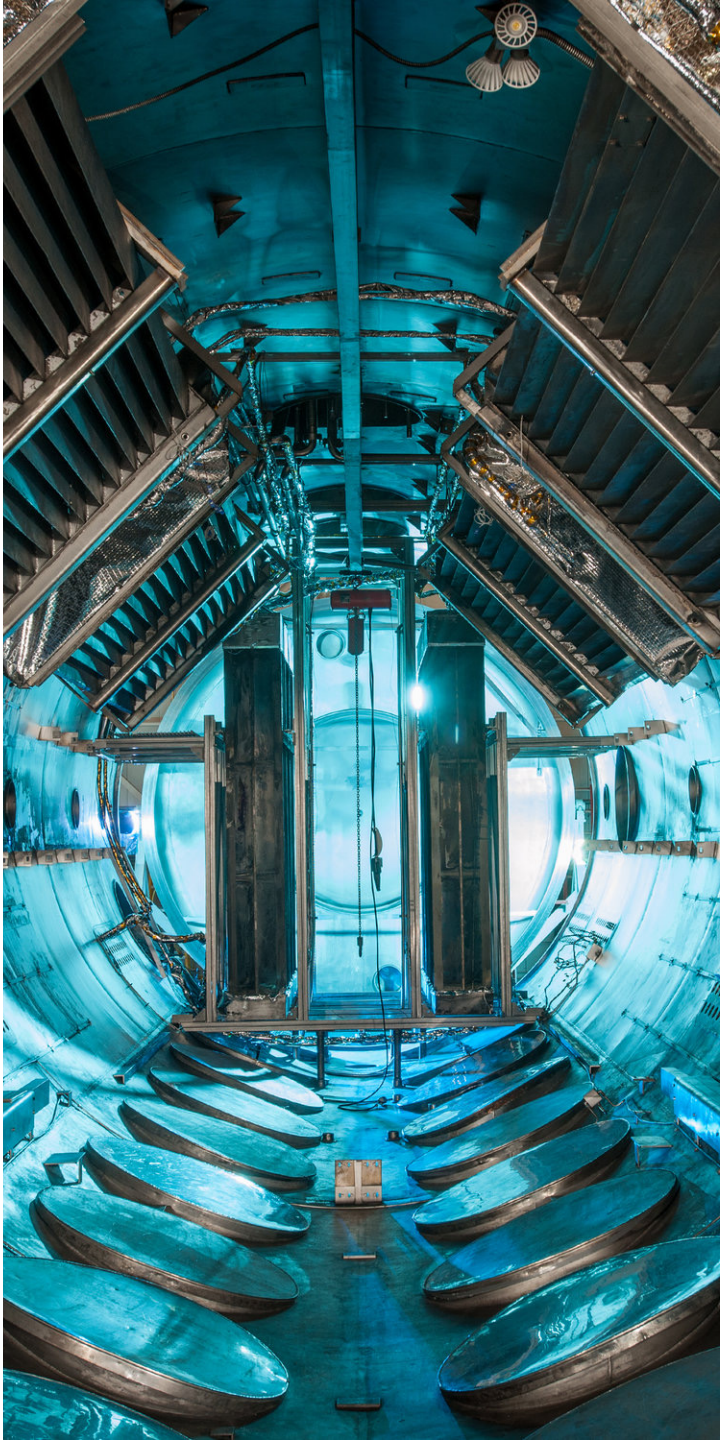


Facilities

- 7,500 sq ft office in downtown Seattle
- 10,000 sq ft hardware test & integration facility in SoDo, Seattle
- ISO 7 clean room for hardware development
- Growing office in Perth, Australia

First Mode Projects





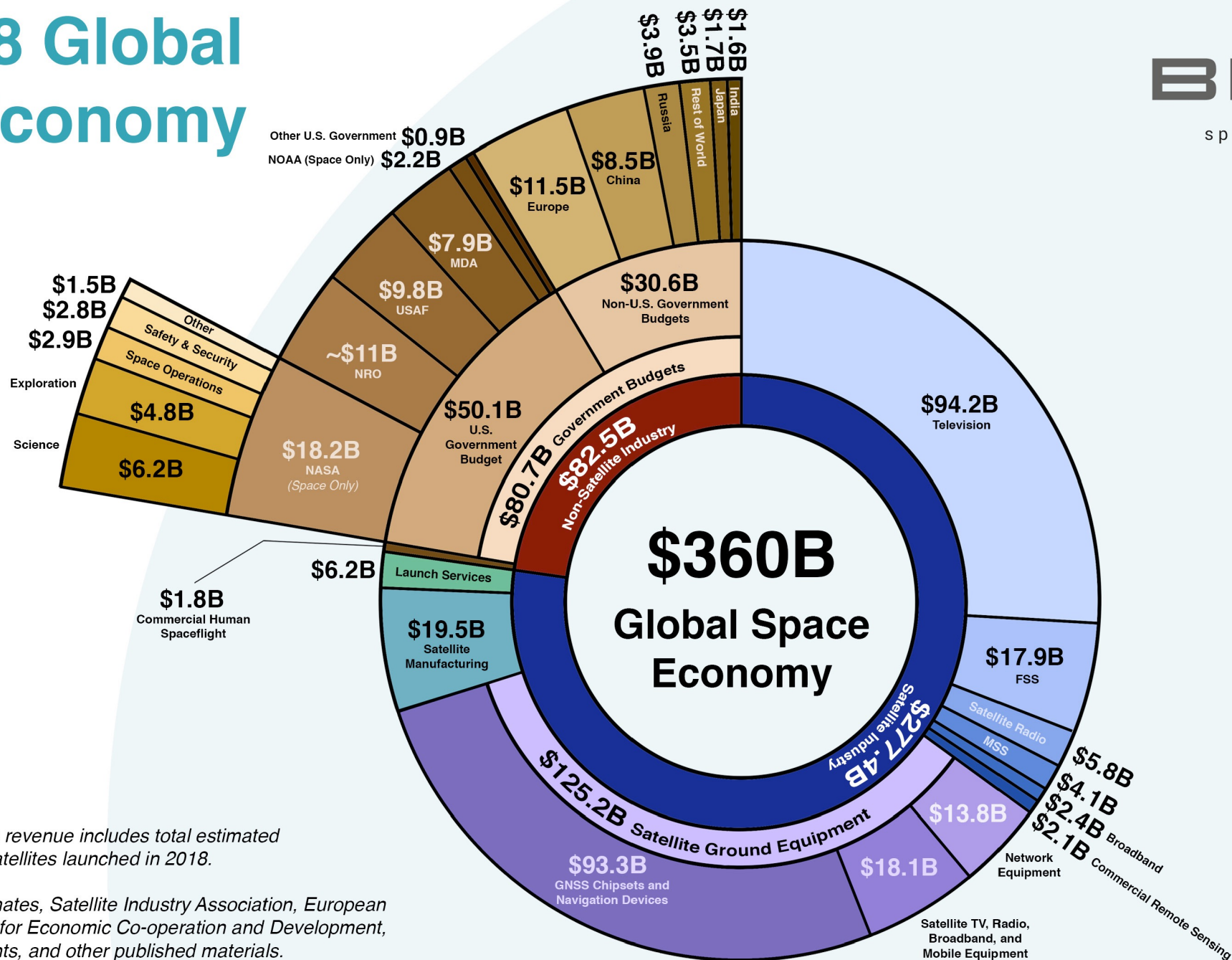
Outline

- Entrepreneurial Space Sector
- Small Satellites
- NASA's Response
- Conflict Ahead
- New Career Options
- Q&A



Entrepreneurial Space Sector

The 2018 Global Space Economy



Note: Satellite manufacturing revenue includes total estimated manufacturing revenue for satellites launched in 2018.

Sources: Bryce internal estimates, Satellite Industry Association, European GNSS Agency, Organisation for Economic Co-operation and Development, government budget documents, and other published materials.

“NewSpace” vs. “OldSpace”



Perceived Differences

	"OldSpace"	"NewSpace"
Examples	Lockheed Martin, Boeing	SpaceX, Blue Origin
Pace	Slow, often delayed	Fast
Cost	Overpriced	Cost-effective
Risk Posture	Cautious	Aggressive
Money Source	Government Contracts	Venture Capital, Individual Investment
Alignment with Government	Fully Aligned	Independent

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Entrepreneurial Space

“Private companies that act independent of governmental space policies and funding, target equity funding, and promote affordable access to space and novel space applications.”

A Map of the Entrepreneurial Space Industry

**EARTH
ORBIT:
UPSTREAM**

Build
Space Hardware - Manufacturers
Propulsion
Modules
Other Components & Engineering

Launch
Launchers & Launch Services
Flight & Delivery
Space Tugs

Data
Remote Sensing
Connectivity
Drones & UAV

Downlink
Communications
Ground Terminals
Security & Storage

Analysis
Satellite Data Analysis
Drones & UAV Data Analysis

Product
Data Platforms
Location & Mapping

**EARTH
ORBIT:
DOWNSTREAM**

**BEYOND
EARTH**

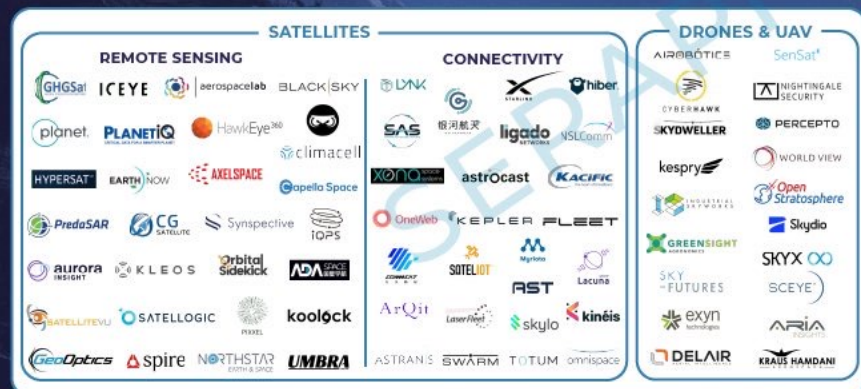
Space Exploration & Resources
Space Infrastructure
Space Research

Credit: Seraphim Capital

UPSTREAM



DOWNSTREAM



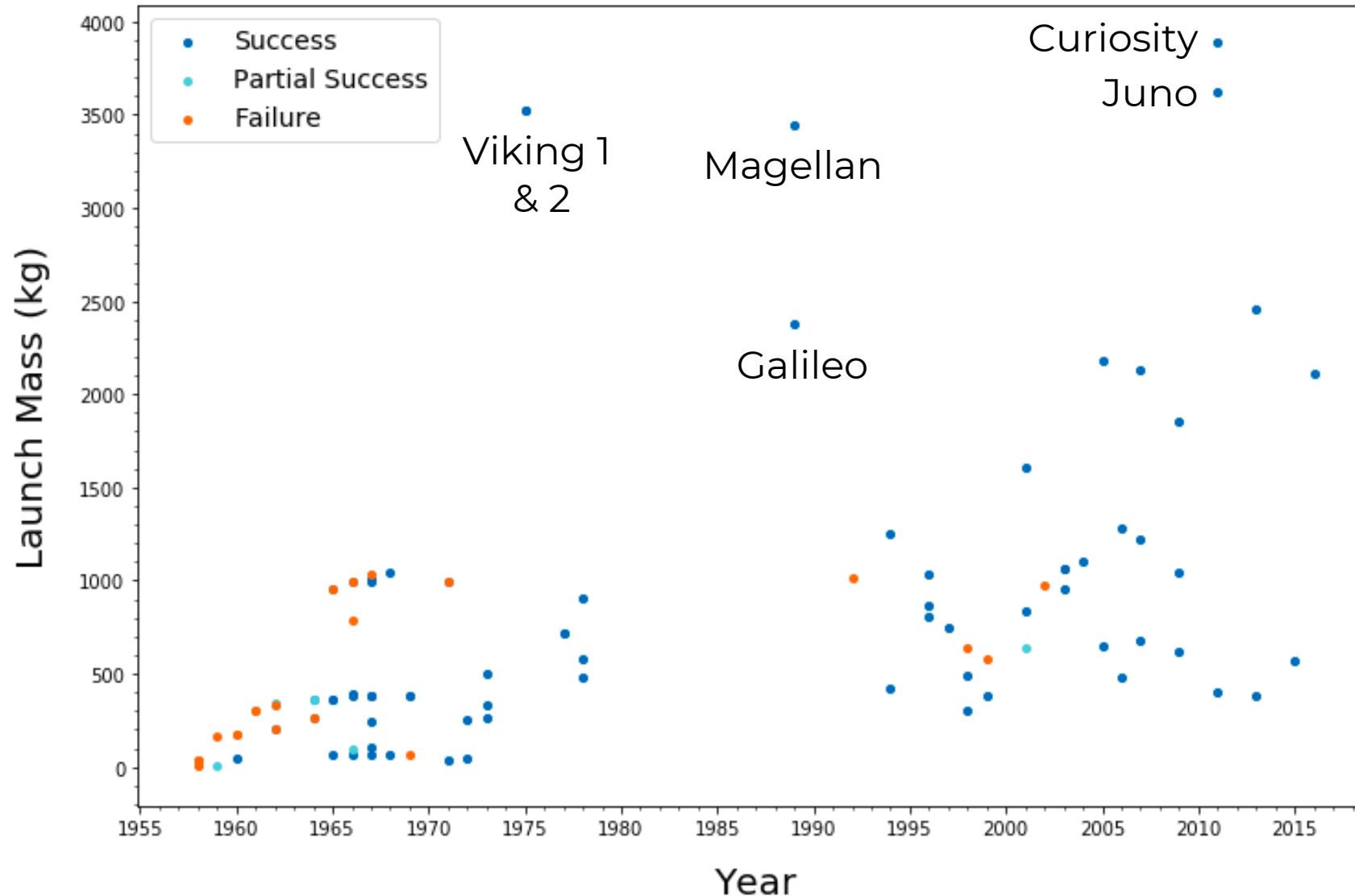
BEYOND EARTH





Small Satellites

NASA Deep Space Missions (1958-2016)



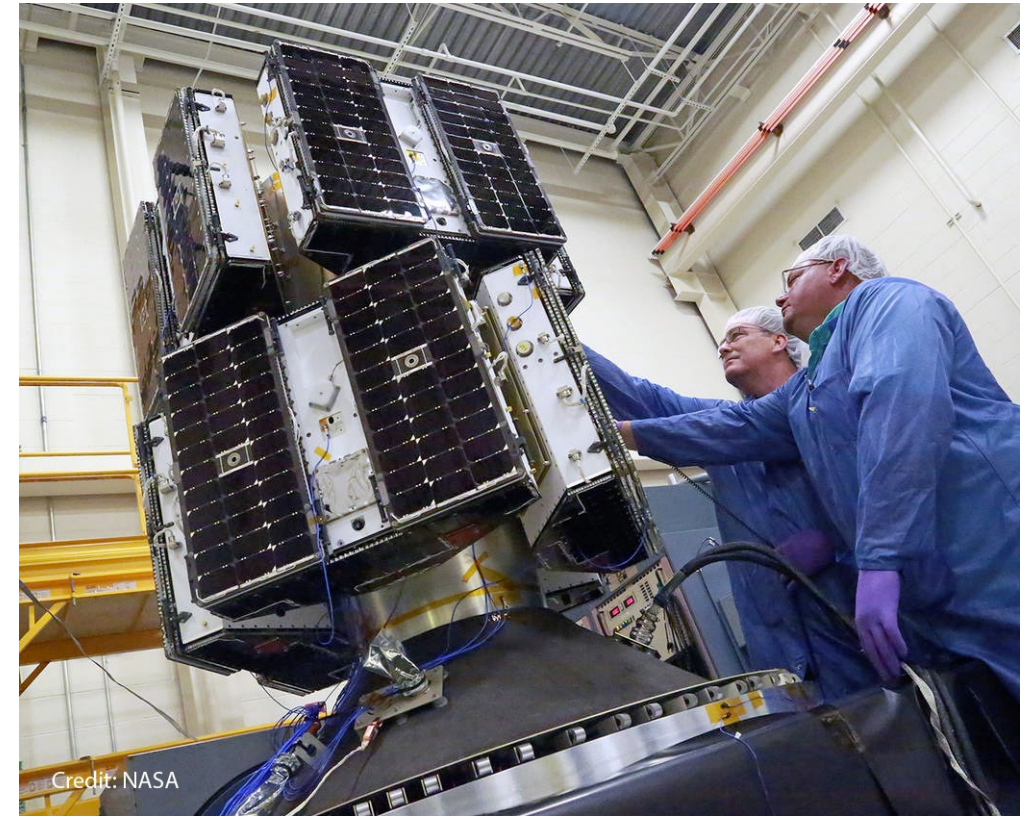
Note:

1. Mass of heaviest spacecraft
2. 11-year gap between 1978 and 1989
3. 1990s Faster, Better, Cheaper era

Data from Siddiqi (2018)

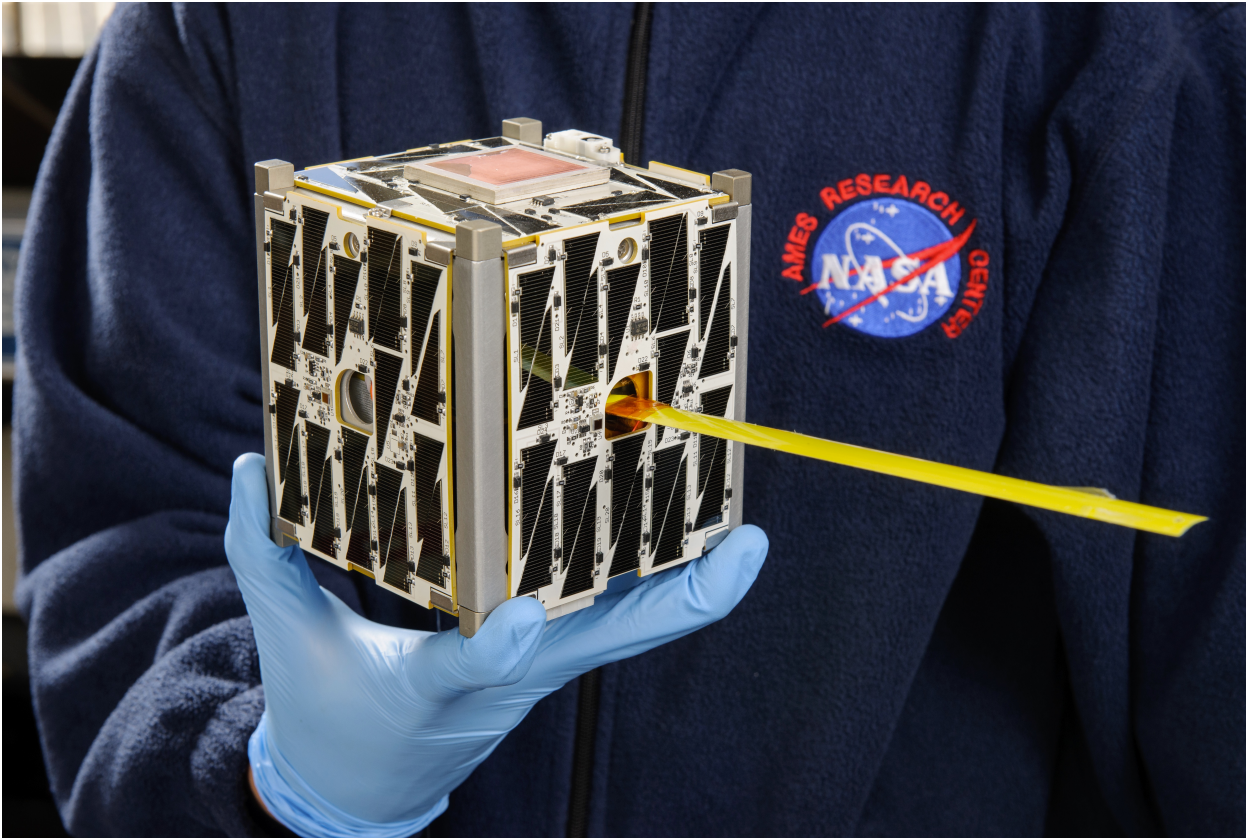
Small Satellites (SmallSats)

- Spacecraft with a dry (unfueled) mass of <180 kg
- Can fly multiple spacecraft in formation (“constellation”)
- Typically launched as secondary payloads

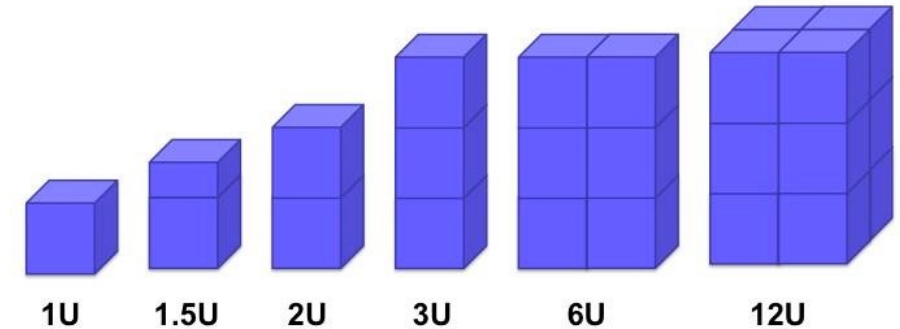


2 of the 8 CYGNSS smallsats (NASA)

CubeSats



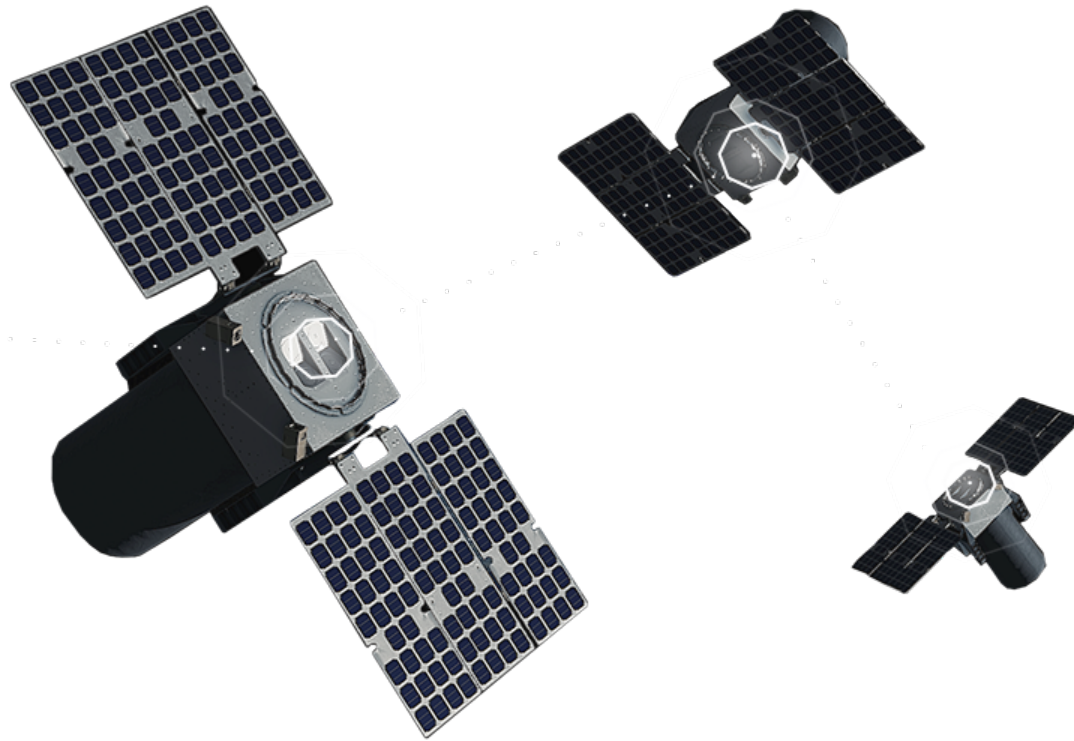
PhoneSat, a 1U CubeSat



- Created in 1999 at Cal Poly and Stanford
- By 2014, most CubeSats launched by space companies instead of universities
- >1,000 launched to date (of ~9,000 total satellites launched since the late 1950s)

Blue Canyon Technologies

Boulder, CO



- Provider of:
 - Standardized spacecraft buses
 - Attitude determination & control components
 - Integration & test services
 - Operations services
- **Implications for planetary science:**
 - The standardization of spacecraft components makes hardware cheaper
 - Standardization also means there is less design. Less design = less labor = lower mission costs



Spaceflight Industries *Seattle, WA*

- Provides rideshare logistics & integration services for secondary payloads
- Now also offers imagery & geospatial intelligence services with acquisition of BlackSky satellites
- **Implications for planetary science:**
 - More launch opportunities
 - Someone else handles logistics & integration



Planet

San Francisco, CA

- ~200 smallsats in orbit around Earth delivering daily imagery
- 1 fleet of CubeSats developed in-house
- 2 acquisitions of other satellite networks
- **Implication for planetary science:**
 - What science questions can we answer with distributed lower-quality data instead of high-quality data from one location?
 - What science questions can we answer with daily/weekly lower-quality data instead of yearly/decadal high-quality data?

Benefits of SmallSat Market Growth to Planetary Science

Technology standardization

Rapid technology development ("test early, test often")

Lower costs → More science





NASA's Response

Why NASA Cares About SmallSats

They're relatively cheap...

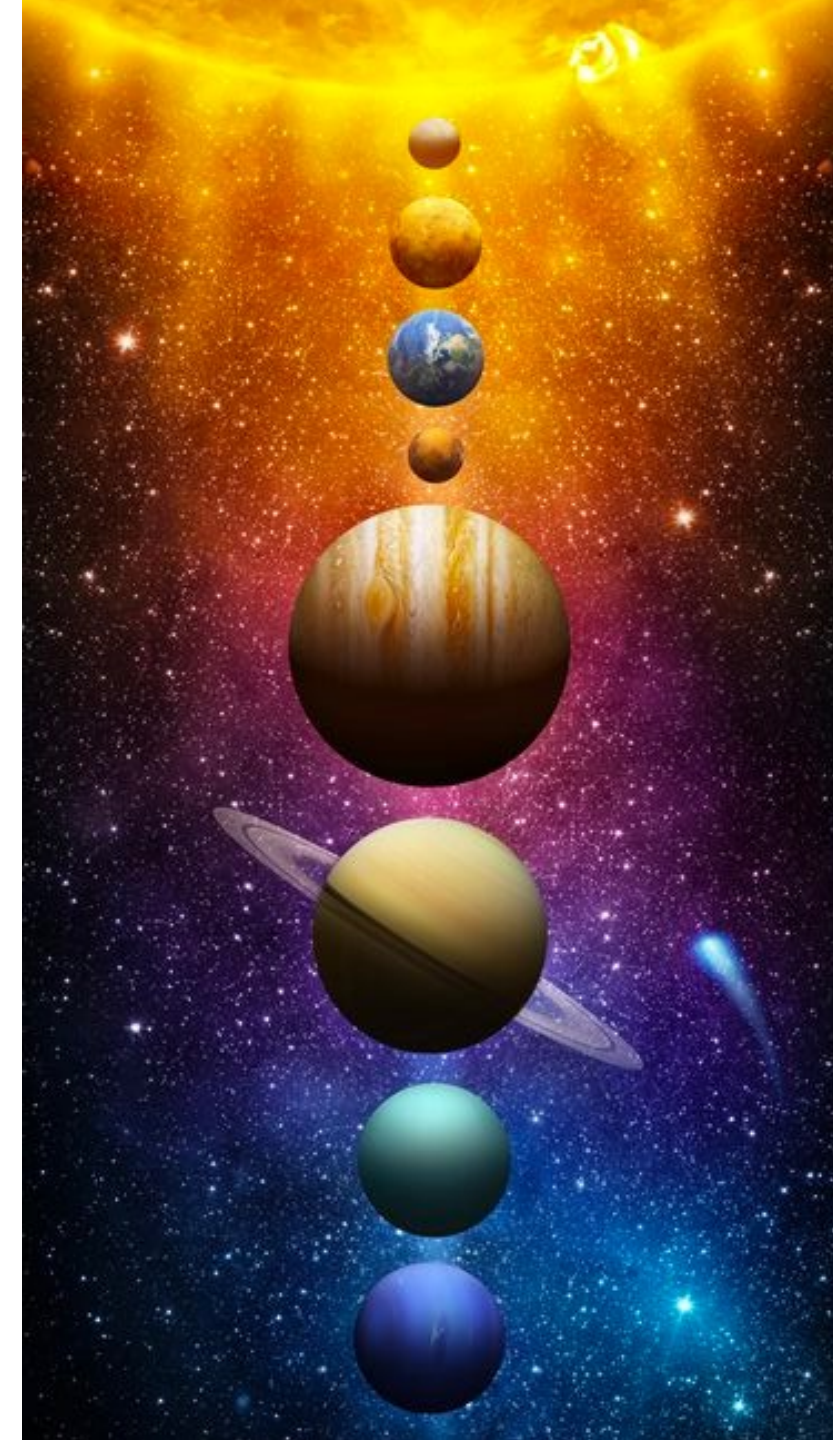
- **New Frontiers:** \$850M
- **Discovery:** \$500M
- **SIMPLEX:** \$55M

...enabling more flight opportunities....

- **New Frontiers:** ideally 1 every 5 years
- **Discovery:** ideally 1 every 2 years
- **SIMPLEX:** secondary payloads as permitted

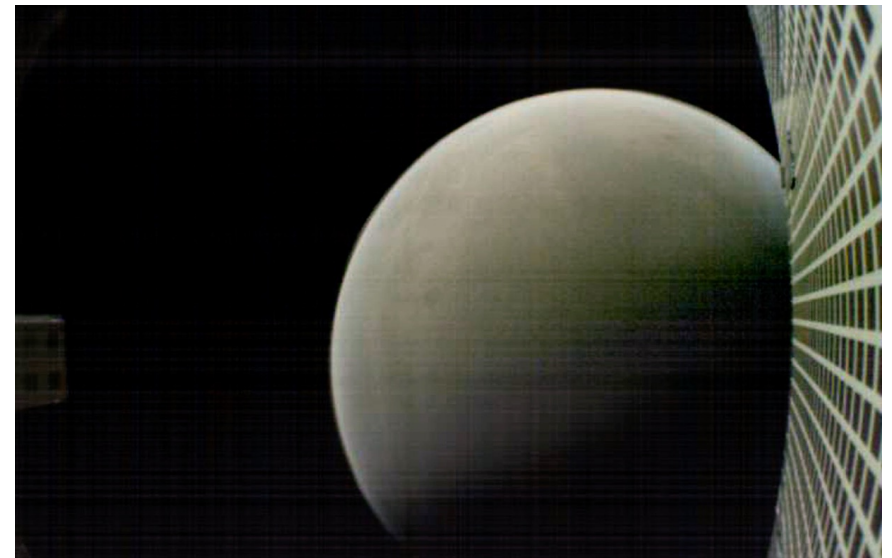
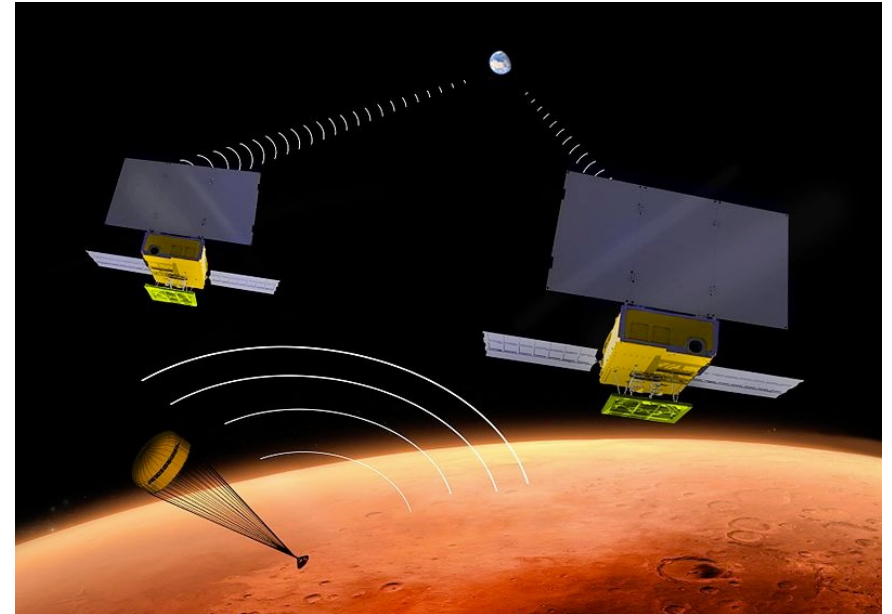
...and lowering the cost barrier to entry.

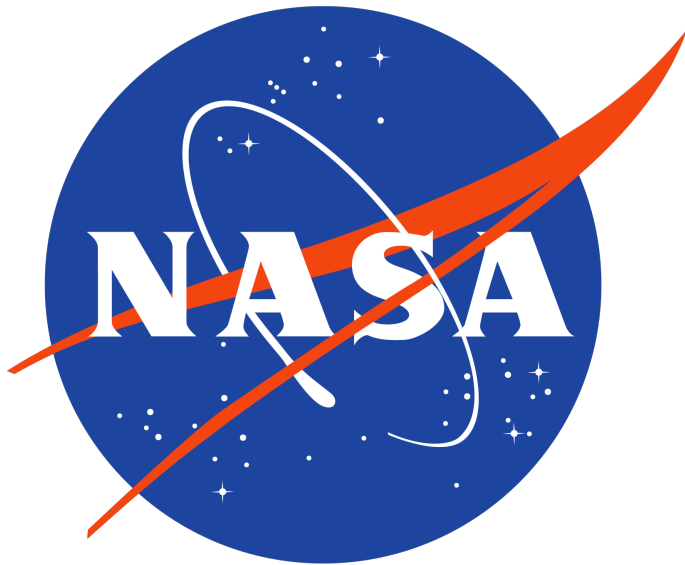
- **More chances** for **more scientists** to gain mission experience
- Easier for **new space agencies** to send a spacecraft



NASA Tech Demo at Mars: MarCO

- Mars Cube One (WALL-E and EVE)
- Built by JPL
- First test of a CubeSat in deep space
- Launched in 2018 with NASA's InSight lander
- Performed a comm relay to confirm successful InSight entry, descent, and landing in near-real time





NASA SmallSat SMD Programs

Small Innovative Missions for Planetary Exploration (SIMPLEx)

- 3 planetary missions selected last summer for development
- Spacecraft masses <180 kg
- **Science:** lunar mapping, asteroid binary, Mars' atmosphere

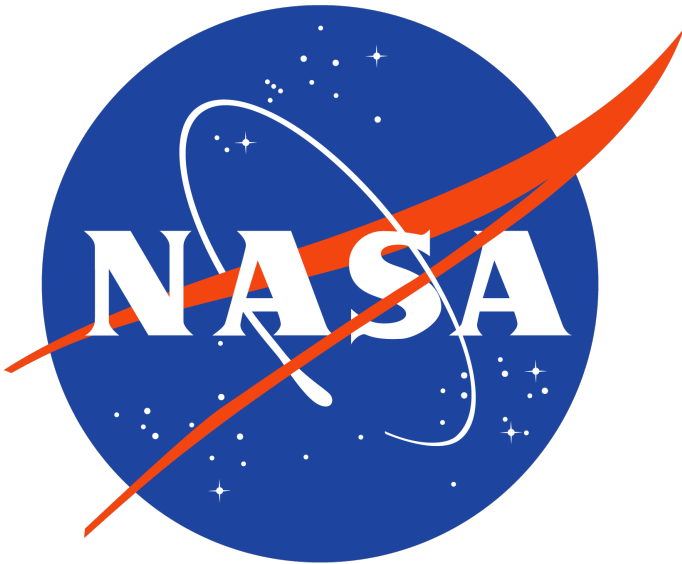
Astrophysics SmallSat Missions

- 9 astrophysics mission concepts selected for study in 2018
- 4 down-selected for further study in January 2021
- Spacecraft masses range from 12 to 180 kg
- **Science:** exoplanet obs., gravitational waves, x-ray spectroscopy

Heliophysics Flight Opportunities for Research & Technology

- Call for smallsat (including cubesat), suborbital, ISS rideshare, balloon, and sounding rocket missions

NASA Programs Leveraging Commercial Capabilities



Balloons & Suborbital Flights

- NASA pays for payloads that can be launched on balloons and suborbital launches
- **Industry partners:** Blue Origin, World View, more

SBIRs & STTRs

- Small businesses propose to develop technology of interest to NASA
- Opportunities to partner with experts at universities or national labs
- **Industry partners:** any US small business

Commercial Lunar Payload Services (CLPS)

- Companies compete for a fixed price contract to deliver payloads to the Moon
- **Industry partners:** Astrobotic, Intuitive Machines, more

NASA Commercial Data Buys (ROSES 2020)

A.42 COMMERCIAL SMALLSAT DATA EVALUATION TEAM

NOTICE: NASA anticipates soliciting this program element in the spring of 2020. The final text will be released as an amendment to ROSES-2020 with a submission deadline no fewer than 90 days after the release of the amendment.

1. Scope of the Program

The Commercial Smallsat Data Acquisition Program (CSDAP) identifies, evaluates and acquires data from commercial sources that support NASA's Earth science research and application activities (<https://science.nasa.gov/earth-science>). Commercially acquired data may provide a cost-effective means to augment and/or complement the suite of Earth Observations acquired by NASA and other US government agencies and those acquired by international partners and agencies. Emphasis is placed on data acquired by small-satellite constellations, affording the means of complementing NASA acquired data with higher resolutions, increased temporal frequency or other novel capabilities in support of existing Earth science research and application activities.



Conflict Ahead

SpaceX submits paperwork for 30,000 more Starlink satellites

by [Caleb Henry](#) — October 15, 2019



“If SpaceX launches 30,000 Starlink satellites in addition to the 12,000 it already planned, the company will by itself be responsible for about a **fivefold increase in the number of spacecraft launched by humanity.**”



Lessons from Mining

Mining's justifiably bad reputation

- Displacing locals
- Negatively impacting locals' quality of life
- Environmental pollution & destruction

Social license to operate

"The ongoing acceptance and approval of a mining development by local community members and other stakeholders that can affect its profitability."

Conflicts Related to Space Science & Exploration



Starlink



Mauna Kea Telescopes



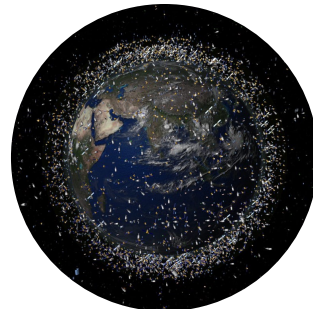
Boca Chica



Apollo Heritage Sites



Resource Extraction

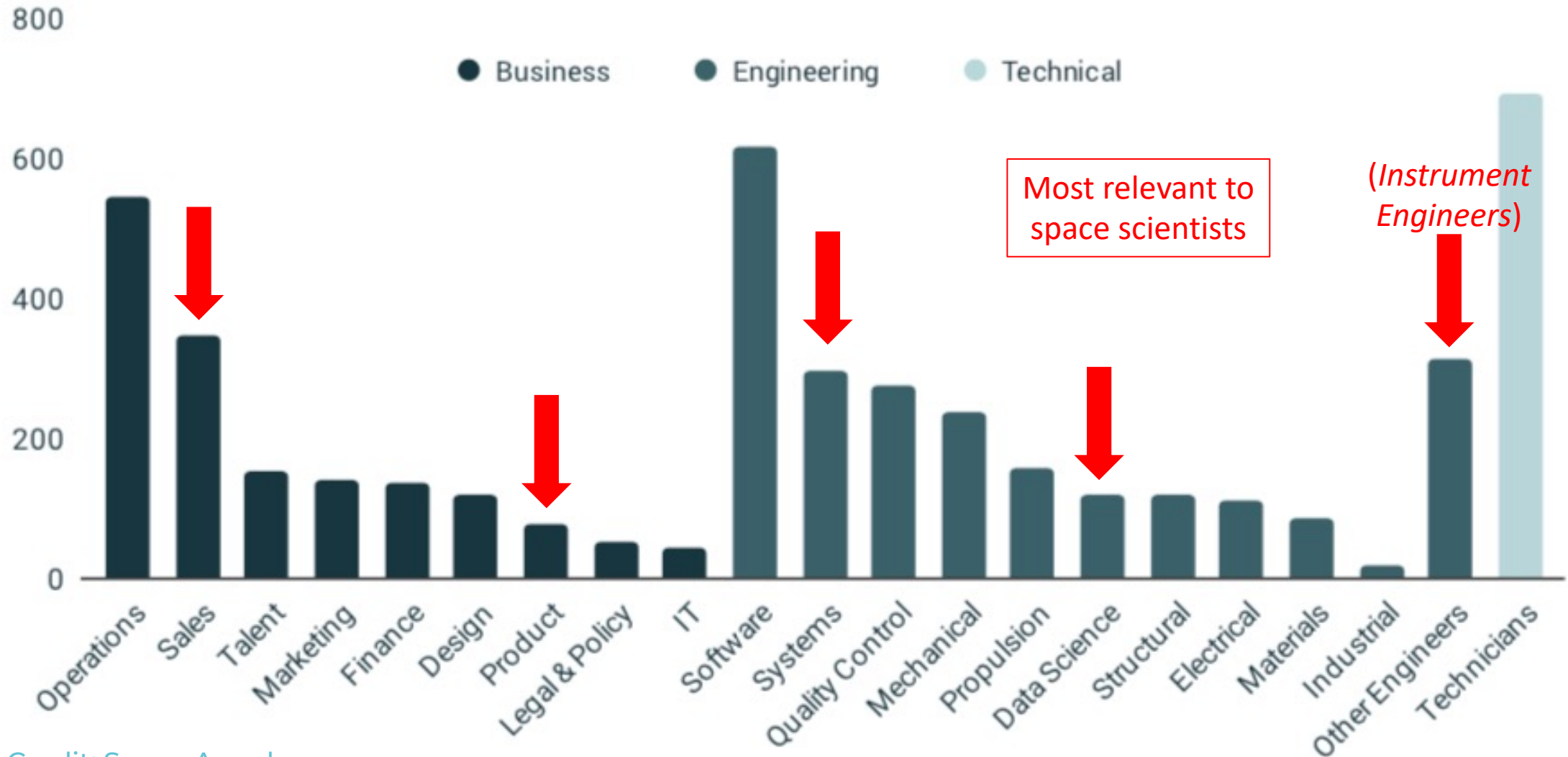


Space Debris



New Career Options

What Jobs Are Out There?



Entrepreneurial Space Job Database

jobs.spacetalent.org

Concluding Thoughts

- SmallSats & entrepreneurial space companies will play an **increasingly prominent role** in space exploration
- **NASA is actively leveraging** these capabilities
- We must be **vigilant to avoid the missteps** of the terrestrial mining industry
- **You must advocate** for your science in this transitional era of space exploration to maximize the good and minimize the bad



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