ECONOMIC PLANETARY SCIENCE IN THE 21ST CENTURY

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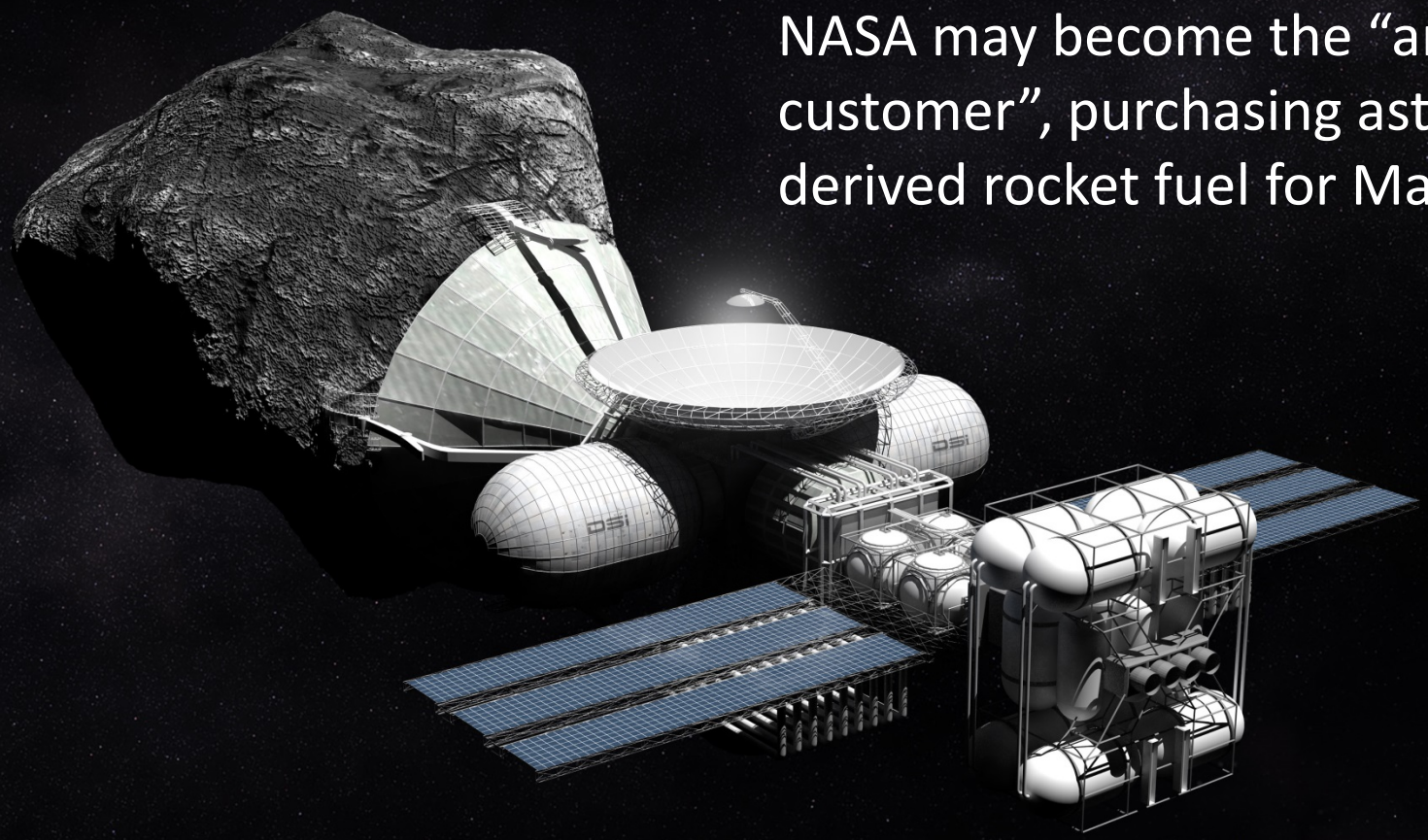
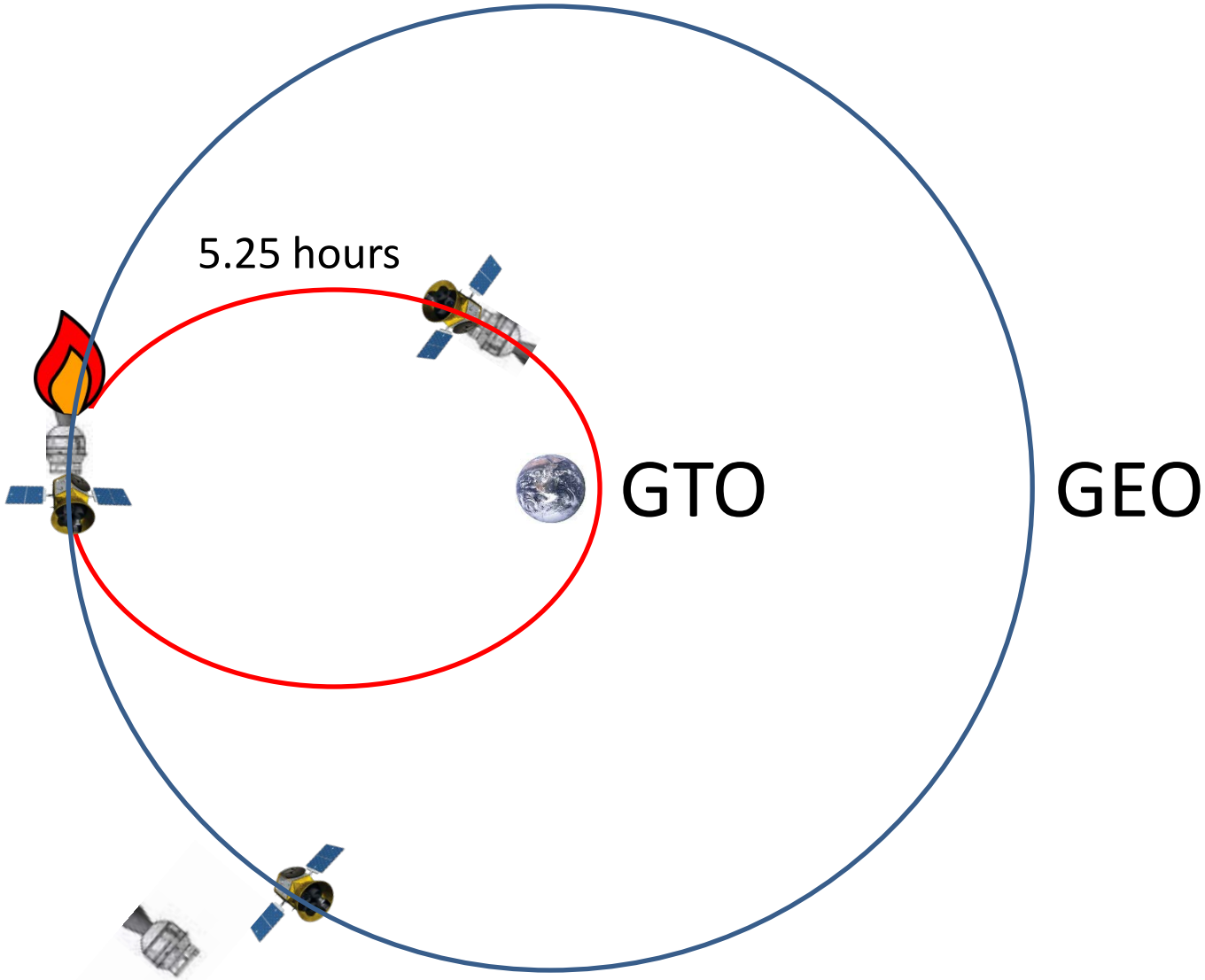
NASA, Luxembourg, and private investors are funding technology for asteroid mining.

NASA may become the “anchor customer”, purchasing asteroid-derived rocket fuel for Mars missions



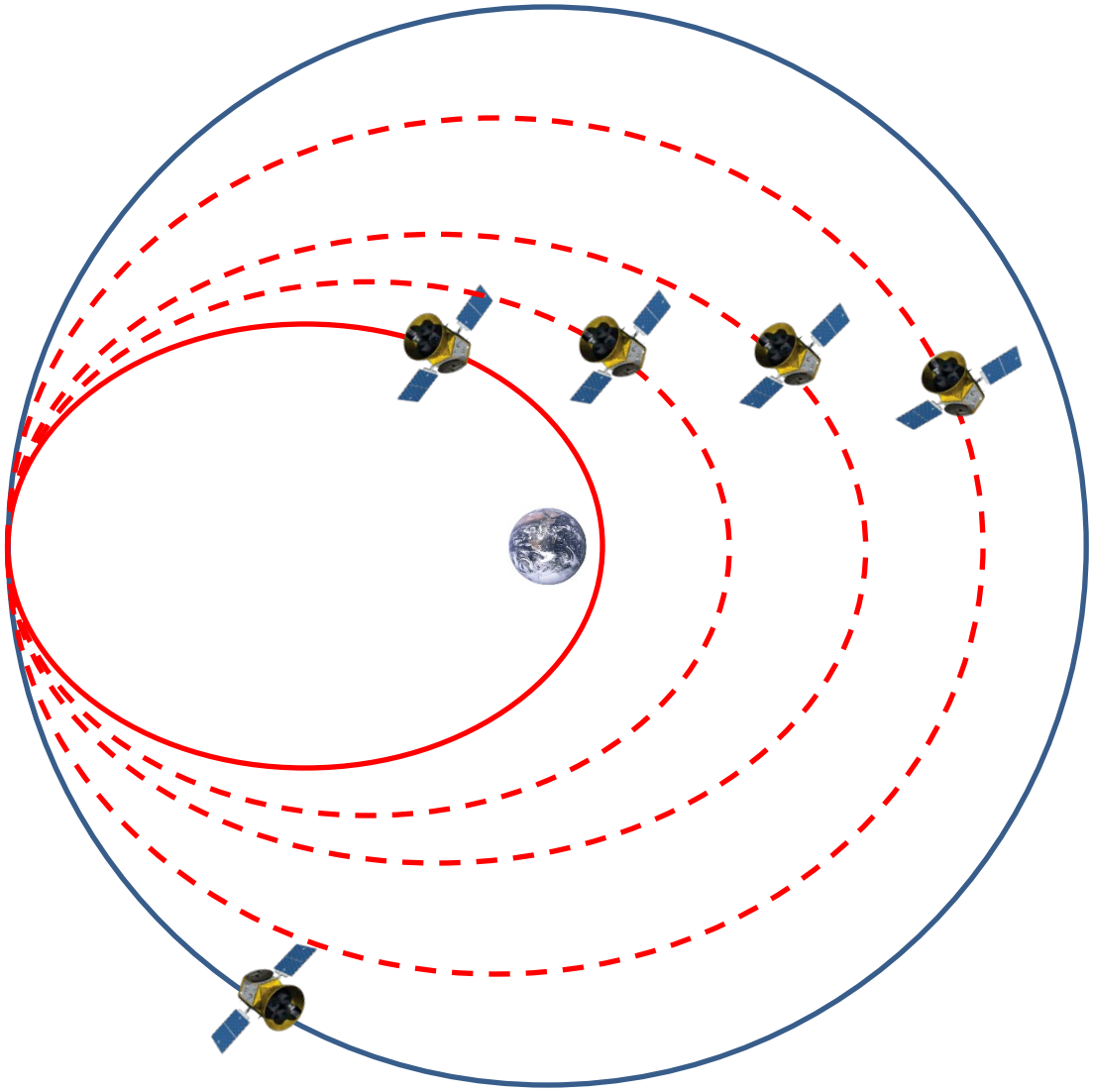
Boosting telecommunications satellites with asteroid-derived rocket fuel is a viable commercial business

Original Method to Boost Comsats



Upper Stage Image credits: Richard Kruse (Historic Spacecraft)

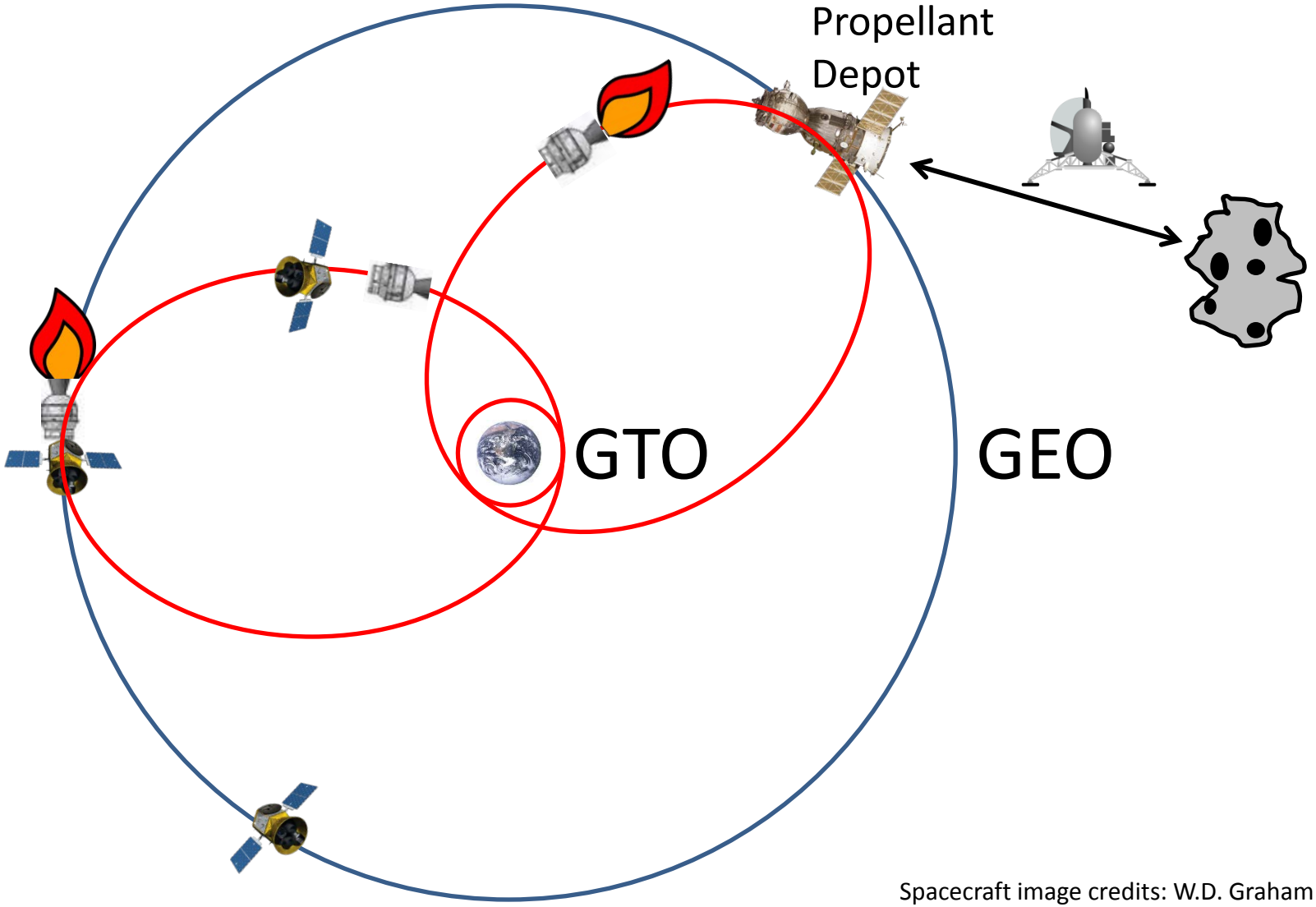
Improved Method to Boost Comsats



6 - 12 Months!

Loss of Revenues in >$100M

Business Case for Asteroid Mining



Spacecraft image credits: W.D. Graham (Wikimedia), Richard Kruse (Historic Spacecraft)

Deep Space Industries / UCF Asteroid Simulant

Spider Miner For Large Asteroids

Captures, Processes and Recovers in Situ

Chart credit: Kris Zacny, Honeybee Robotics

Honey Bee Robotic Asteroid Capture for ISRU Resource Return

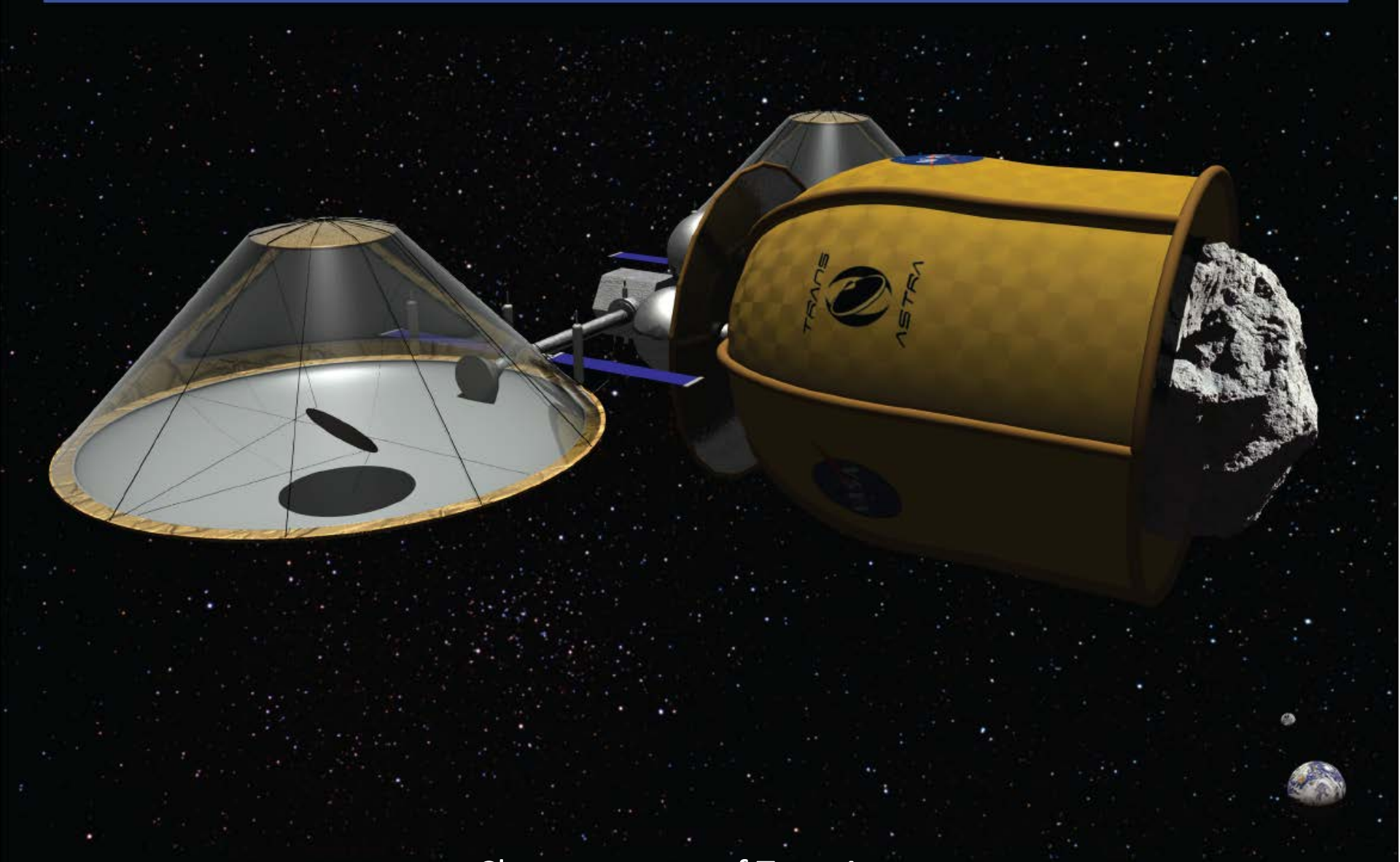


Chart courtesy of TransAstra

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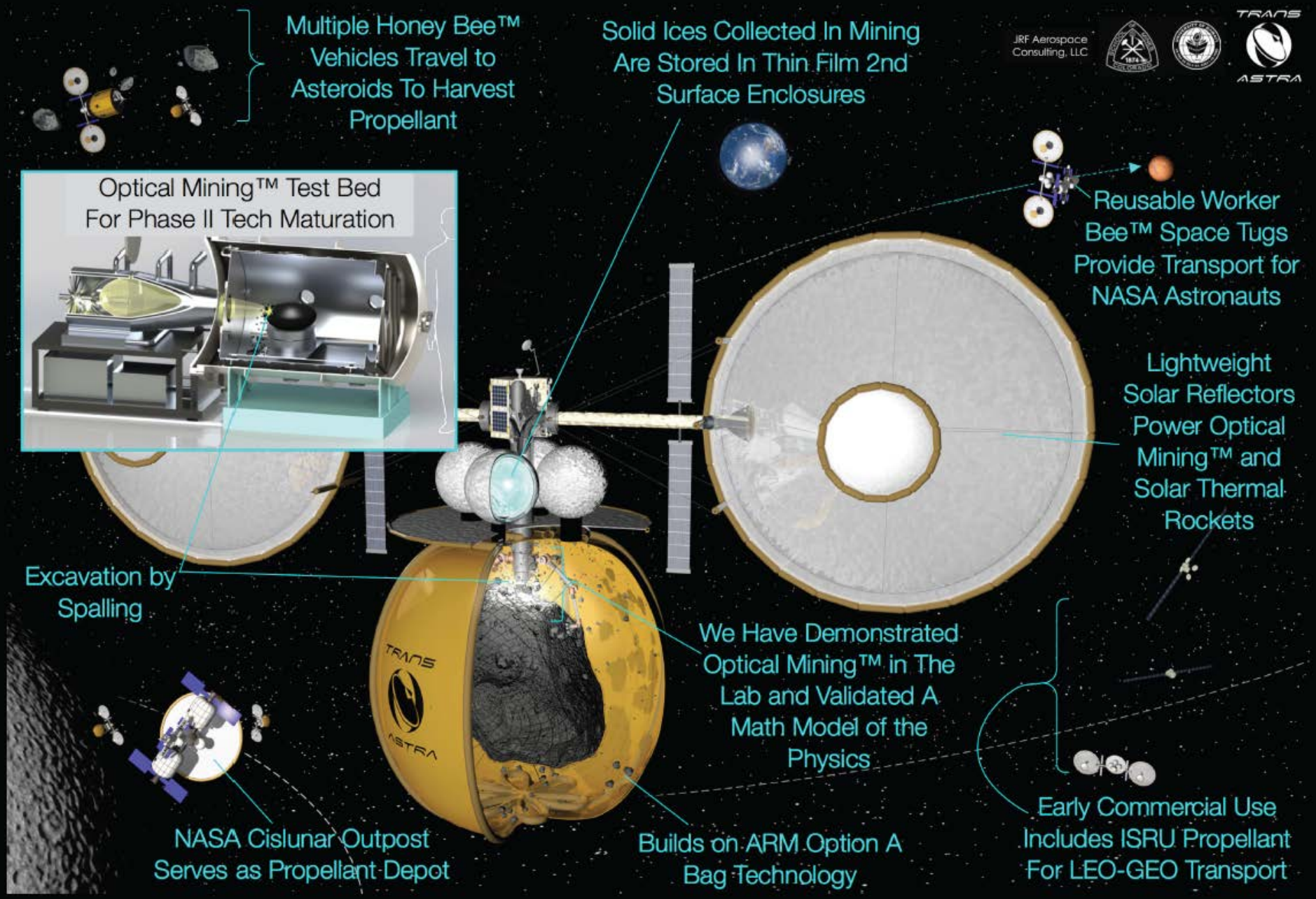
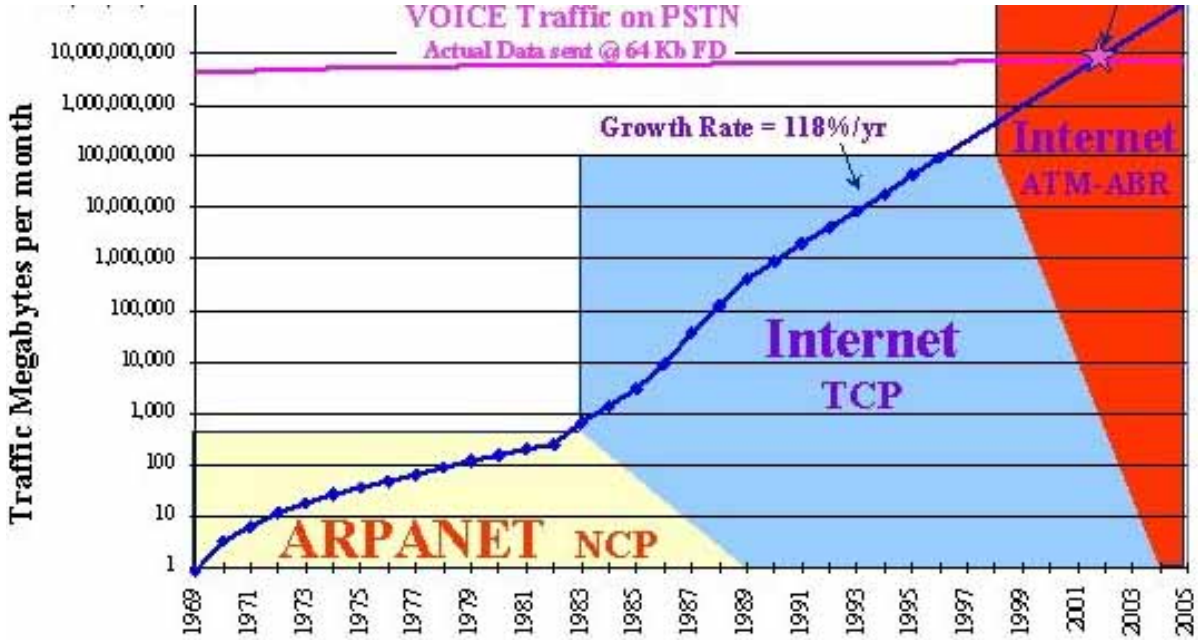


Exponential Growth of the Internet



Source: The Roads and Crossroads of Internet History by Gregory R. Gromov

Source: Wikimedia

Source: Wikimedia

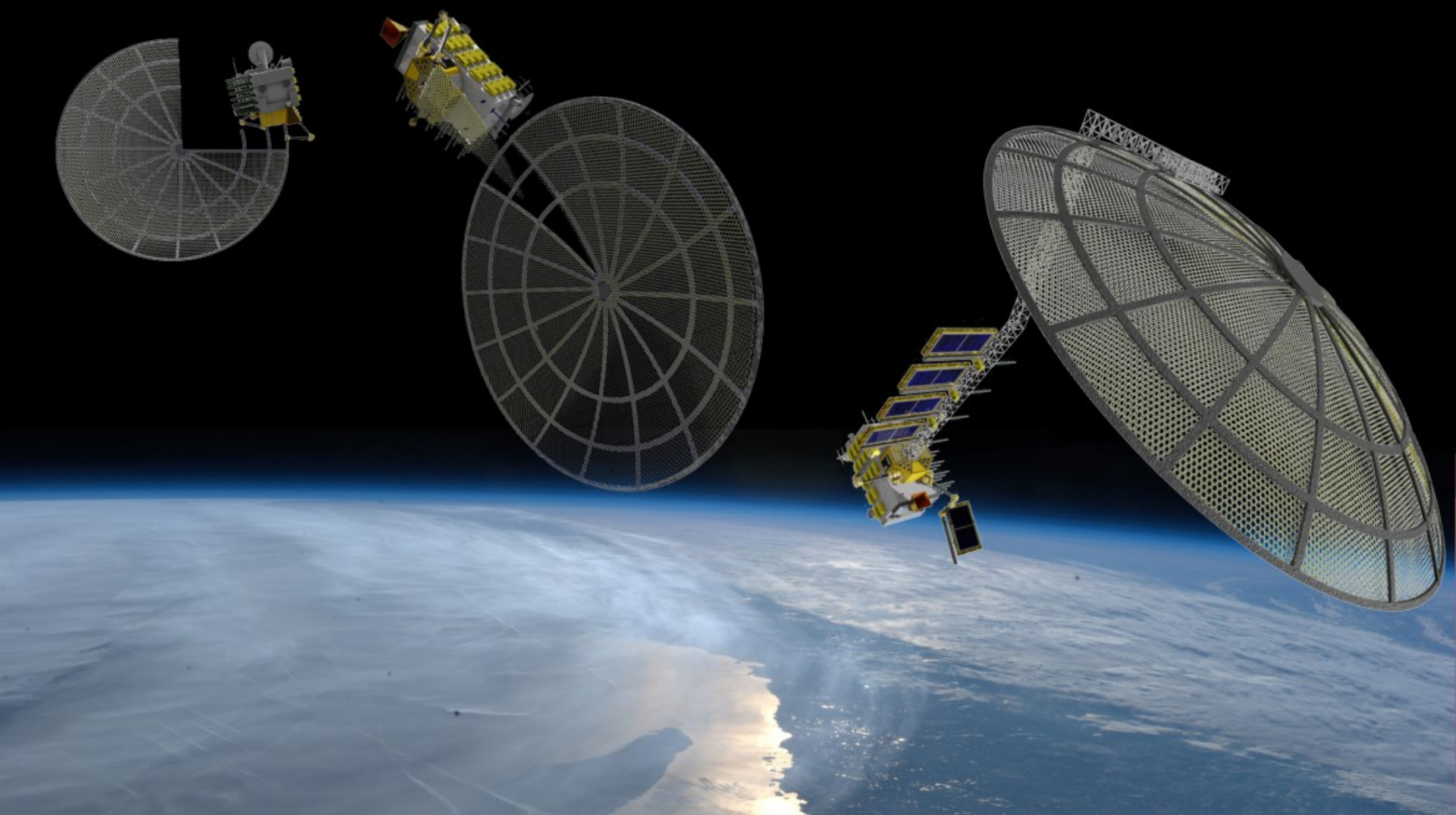
- 50 to 100 billion physical objects will be using the internet by 2020
- User interfaces grow exponentially 50% per year

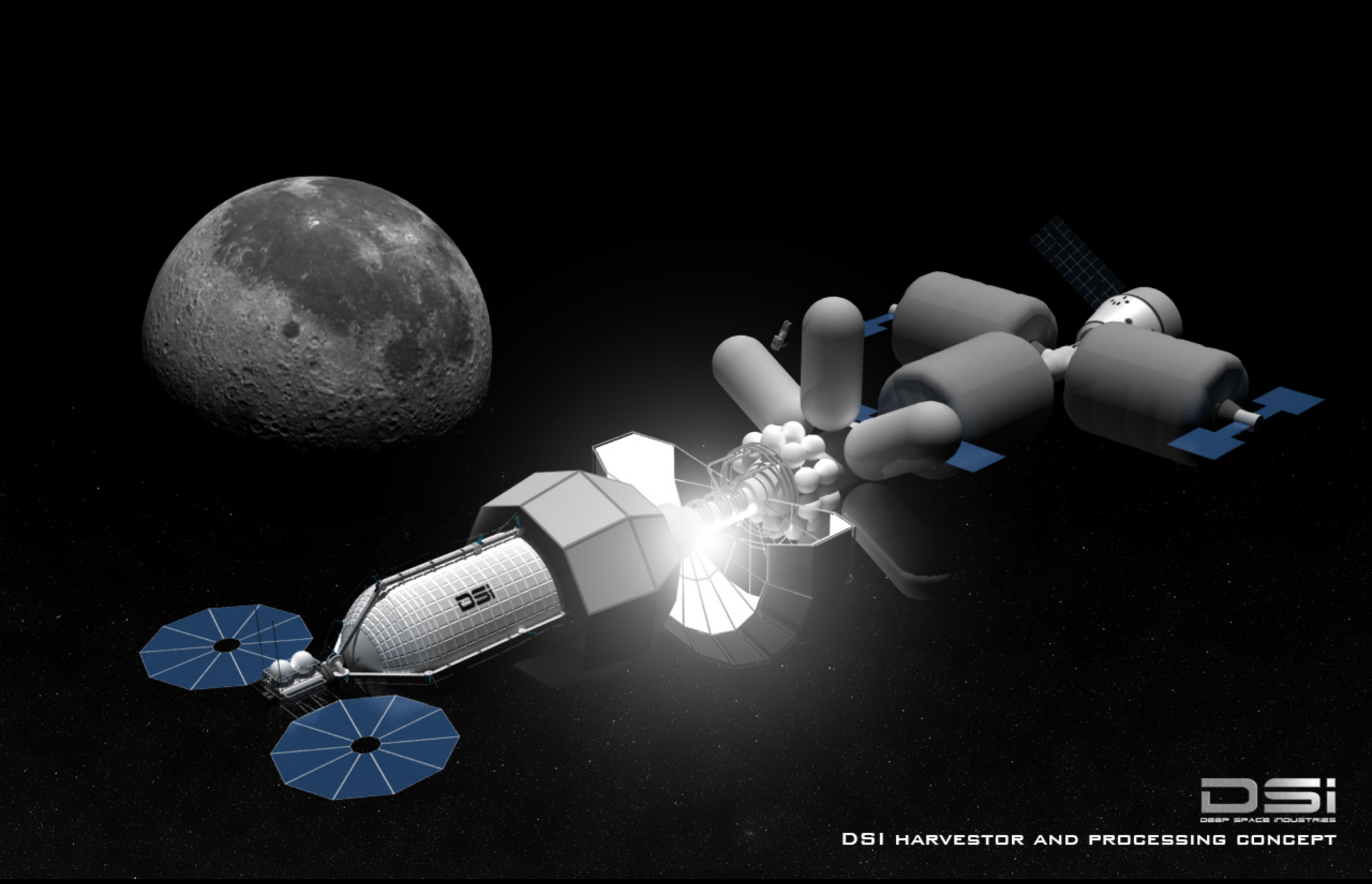
Meeting Demand for Data

- Royal Society: we are nearing the “capacity crunch” of Shannon’s Law
- A 2015 report by the Semiconductor Industry Association and the Semiconductor Research Corporation: “Unfortunately, neither existing technologies nor current deployment models will be able to support the skyrocketing demand for communication, especially in the wireless sector”
- LEO and MEO constellations (OneWeb, SpaceX, etc.) can extend Internet growth only a couple decades
- Building giant antennas in space can sustain Internet growth through end-of-century
- In-space construction opens additional business opportunities

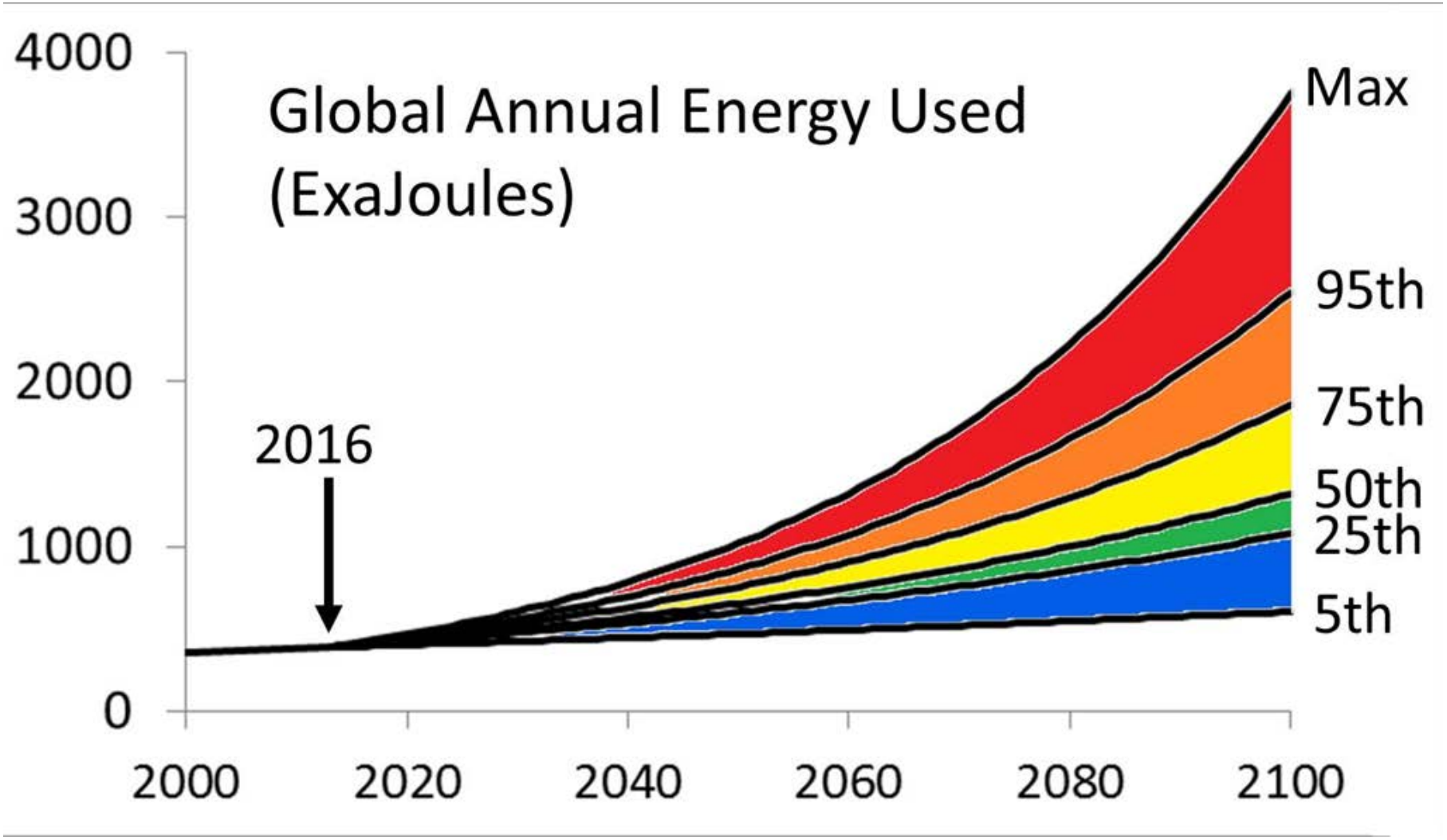
Archinaut: 3D Printing Giant Antennas in Space

Made In Space, Northrop Grumman, and Oceaneering, funded by NASA




DSI
DEEP SPACE INDUSTRIES
DSI HARVESTOR AND PROCESSING CONCEPT

Energy Needs to 2100

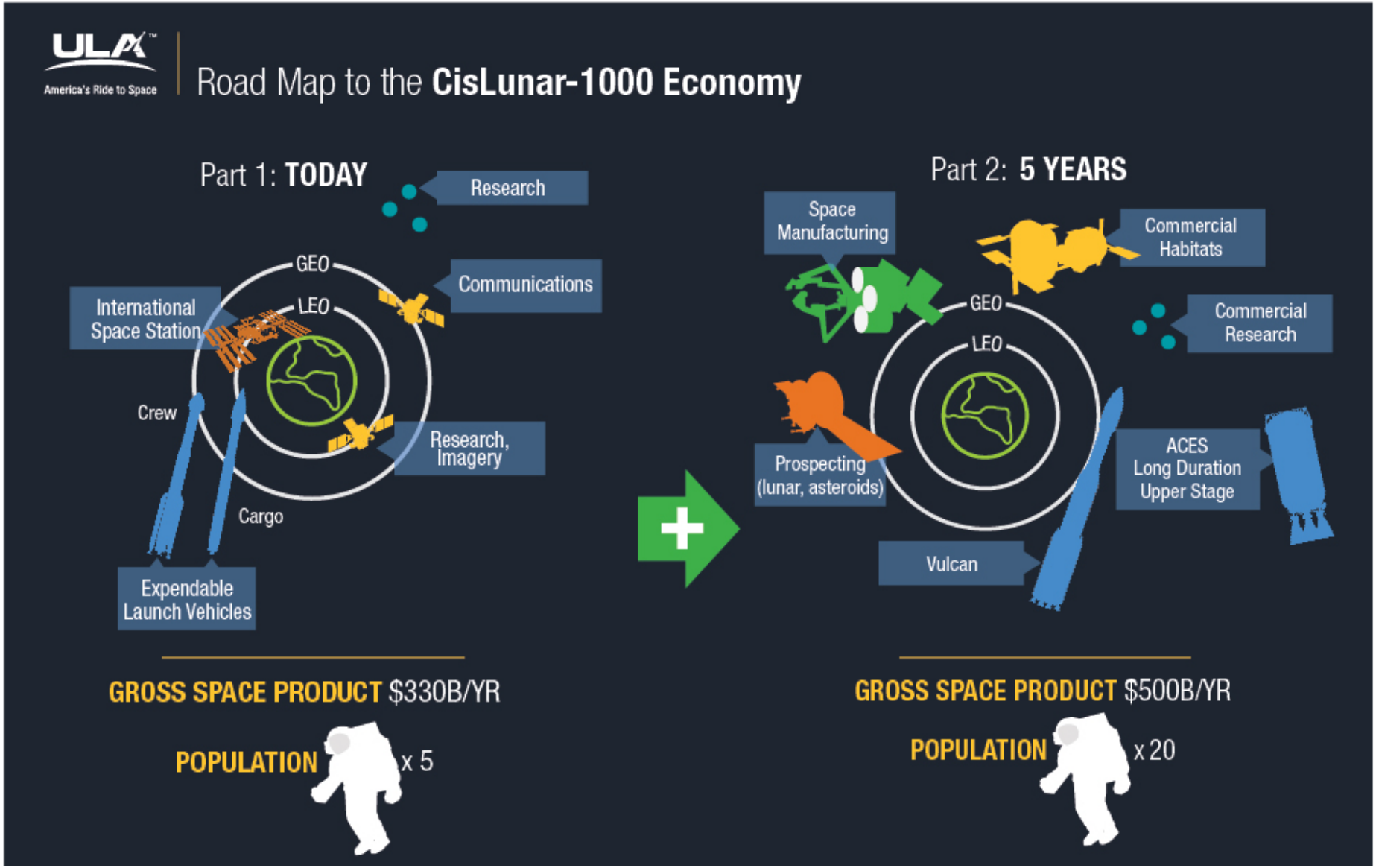


The Big Picture

- Human civilization has grown so large that it pushes against planet-scale physical limits
- This causes environmental harm
- But even more growth is needed for developing economies to end poverty and promote peace
- Moving industry off-planet becomes increasingly vital to our planet's health
- Technology is making this increasingly possible

Cislunar 1000 Vision

(Chart courtesy of United Launch Alliance)



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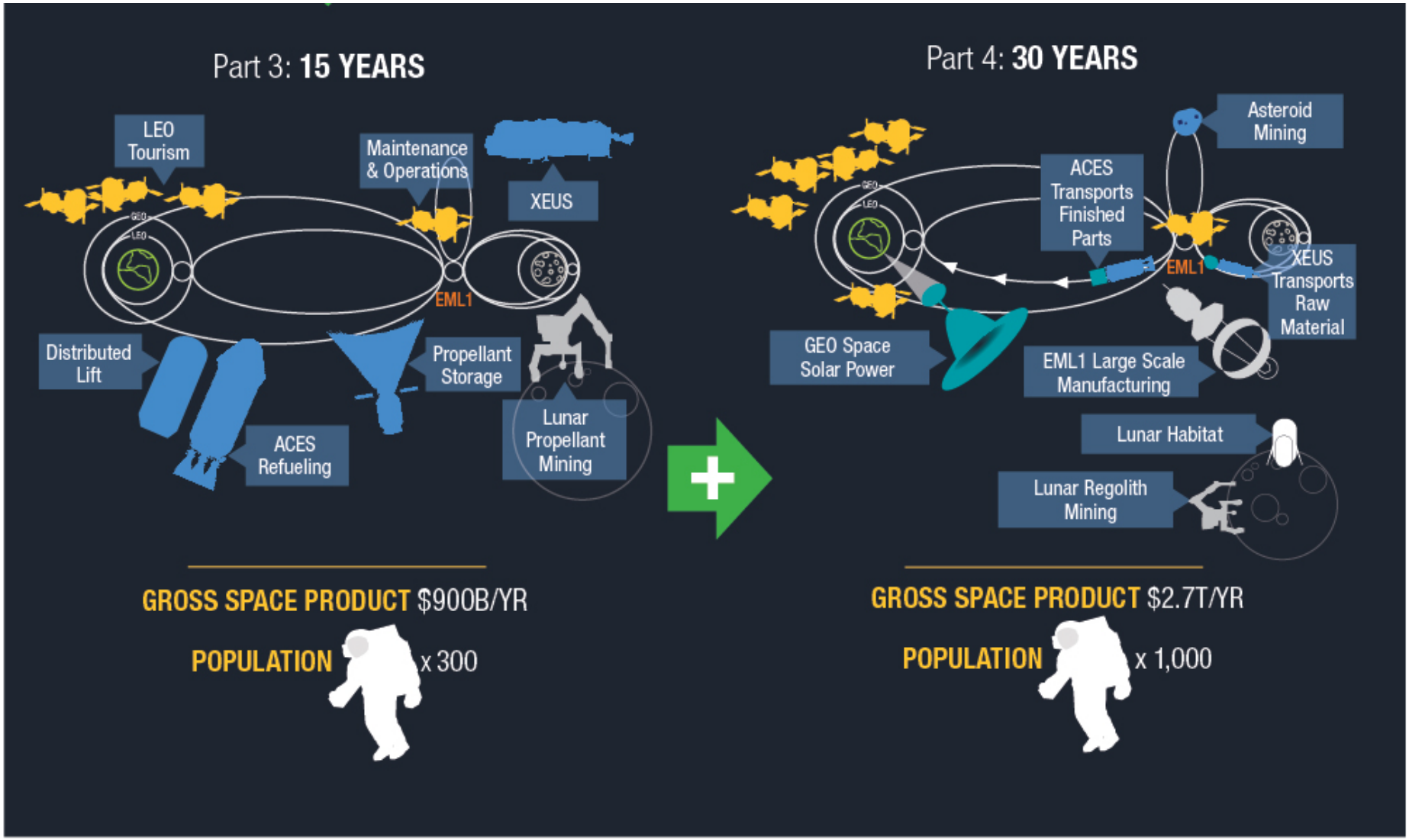


The 21st Century is When This Will Happen

This will lead to a new profession and a new academic discipline:

"Economic Planetary Science"

Development of Economic Geology

- Stanford Professor of Economic Geology, C.F. Tolman (1939) Sigma Xi Quarterly:
- Period of Uncontrolled Speculation
  - Until 1830, the start of State Geological Surveys
- Period of General Observation
  - The Epoch of State Surveys: 1830 - 1860
  - The Epoch of United States Exploratory Surveys: 1865-1880
  - The Epoch of United States Geological Survey's dominance, 1880 - 1914
- Period of Detailed Observation
  - 1914 to present

Tolman's Observations

- "Descriptive paleontology, especially of microfauna, has grown by leaps and bounds since laboratories were established by the oil companies for the purpose of studying the fauna as an aid to the working out of the stratigraphy of the oil fields. There are probably over one hundred well equipped micro paleontologic laboratories in this country "

Tolman's Observations

- "The stratigraphy and the compilation of the geological column in the oil fields has been worked out in greater detail than would have been possible for investigators without the facilities given the geologist by the operating companies."

Tolman’s Observations

- “Ralph Reed's book, *The Geology of California*, is a compilation chiefly of the detailed work of the oil geologists and paleontologists because most of the detailed work in California geology has been done by them. This work was financed by the Texas Oil Company and was published by the American Association of Petroleum Geologists.”

Tolman's Observations

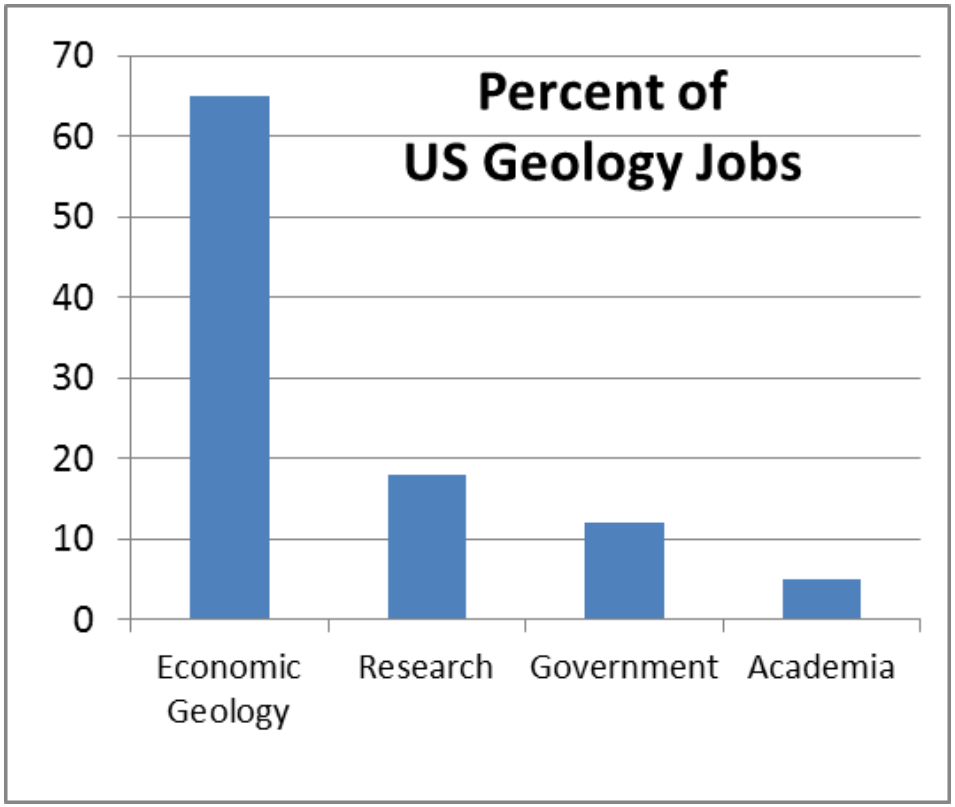
- "Since the Great War the greatest advances in ore deposits is due to the development of special detailed method of underground mapping in mines…The fundamental data thus collected now furnishes material that can be analyzed by the structural geologist."

Tolman's Observations

- "Finally, ground water hydrology…one of the important specialized fields of economic geology. As an example…the Hawaiian Islands…This detailed mapping of the ground water geologist has furnished us pictures of the structure of the Hawaiian volcanoes which could not be obtained by any other method of investigation."

US Geology Jobs

- US Bureau of Labor Statistics
- 65% in economic geology such as mining
- 18% in research
  - many funded by economic interests
- 12% in government
  - mostly managing economic activities
- 5% in academia
  - with most of their students going into economic geology



Correlation of Science & Economics

- 2012 study of the publishing record of scientists in 147 countries
- Scientific productivity strongly correlates with 2 things:
  - 1. How <u>developed</u> the country is (intensive)
  - 2. How <u>large</u> the economy is (extensive)

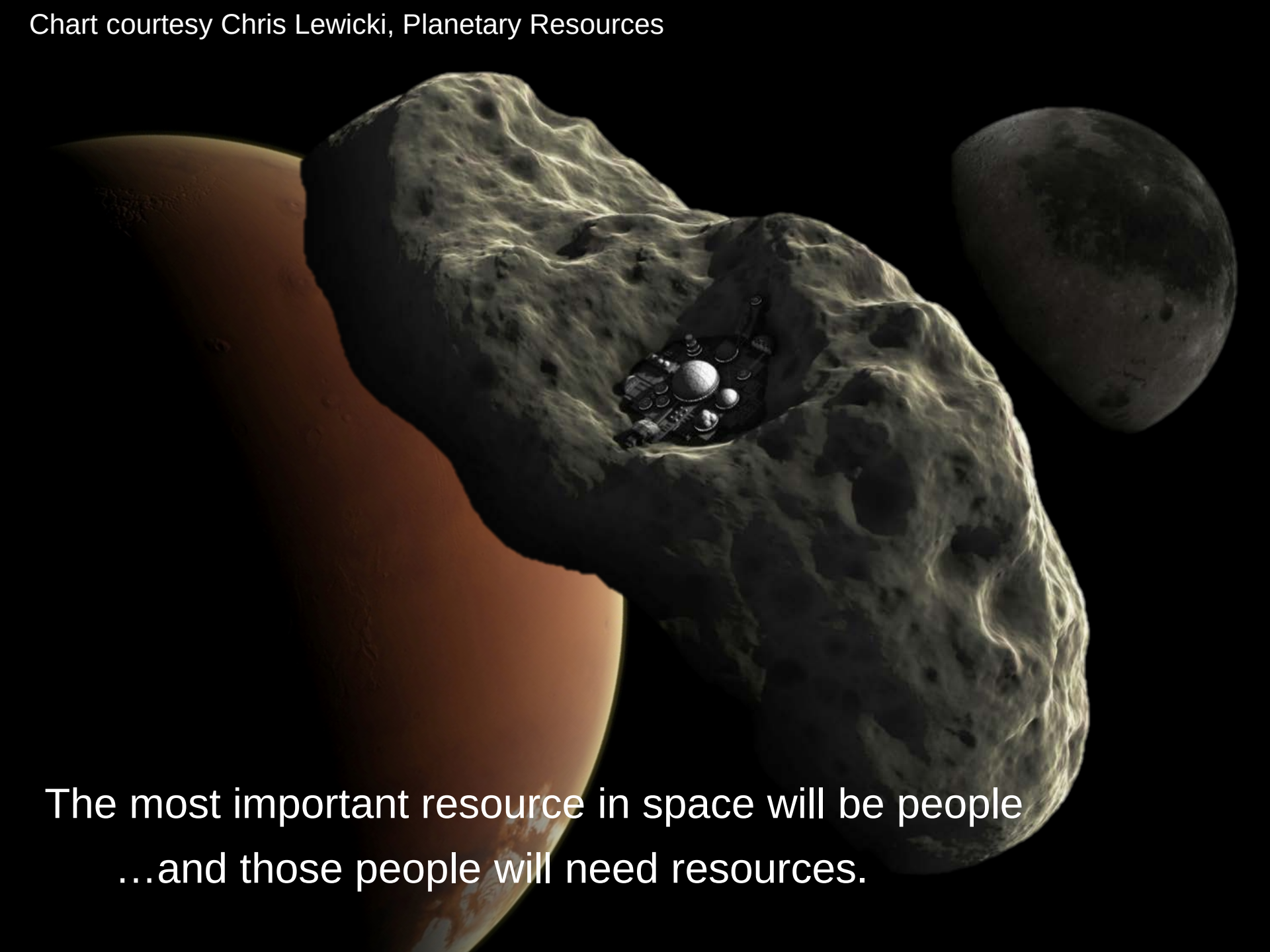
Will Space Mining Hurt Space Science?

- Ruin sites of high scientific value?
  - Lunar Polar Ice Deposits
- Example: Apollo landing sites
- **<u>More policy will be needed</u>**
- Mining companies desire the clarity it brings
  - Reduces uncertainty for potential investors
- On balance, space development will <u>dramatically</u> <u>help</u> space science

Demand for Human Spaceflight

- Robotics are increasingly capable for sortie science missions without humans
- Robots cannot (yet) repair and develop other robots
- Human astronauts will be vital for in-space industry
- In-space industry will then make human spaceflight affordable and permanent
- Robots will <u>not</u> replace humans in spaceflight

Chart courtesy Chris Lewicki, Planetary Resources



The most important resource in space will be people

…and those people will need resources.

The Golden Age of Planetary Science

- Our civilization is outgrowing our planet.
- Planetary science is becoming vital to the health of our civilization and of our planet.
- The Golden Age of Planetary Science is about to begin.