NewSpace:

The Emerging Commercial Space Industry

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LEARNING OUTCOMES

At the end of this lecture you should be able to:

1) Describe the areas in which entrepreneurial companies are developing new markets
2) Name a few companies that are examples of the commercial space revolution
3) Discuss how governments can facilitate the birth of this new industry
4) Describe a range of disruptive technologies in the space sector.

WHY IS THIS LECTURE IMPORTANT?

- We are at a turning point in the history of space exploration and development – the cusp of a revolution, new industries are being born that use space in many non-traditional ways
- The established military industrial space sector is no longer the only game in town
- Increased competition and new capabilities will change the marketplace forever
- Everyone interested in working in the space sector will be effected

OUTLINE

1. Regimes for NewSpace Opportunities
   - Suborbital
   - Orbital
   - Deep Space
2. Example NewSpace Companies
3. The Role of Government
4. The Role of Private Industry
5. Disruptive Technologies

WHAT IS NEWSPACE?

HobbySpace.com:
"Alt.space, NewSpace, entrepreneurial space, and other labels have been used to describe approaches to space development that different significantly from that taken by NASA and the mainstream aerospace industry."

From Wikipedia:
"NewSpace, alt.space, and entrepreneurial space are umbrella terms for a movement and philosophy often affiliated with, but not synonymous with, an emergent private spaceflight industry. Specifically, the terms are used to refer to a community of relatively new aerospace companies working to develop low-cost access to space or spaceflight technologies and advocates of low-cost spaceflight technology and policy."

SUBORBITAL

Description:

- Spacecraft reaches space 100 km (62 miles) or higher but does not have the forward velocity to go into orbit (e.g. 7.7km/s at 300 km)

Tourist Industry:

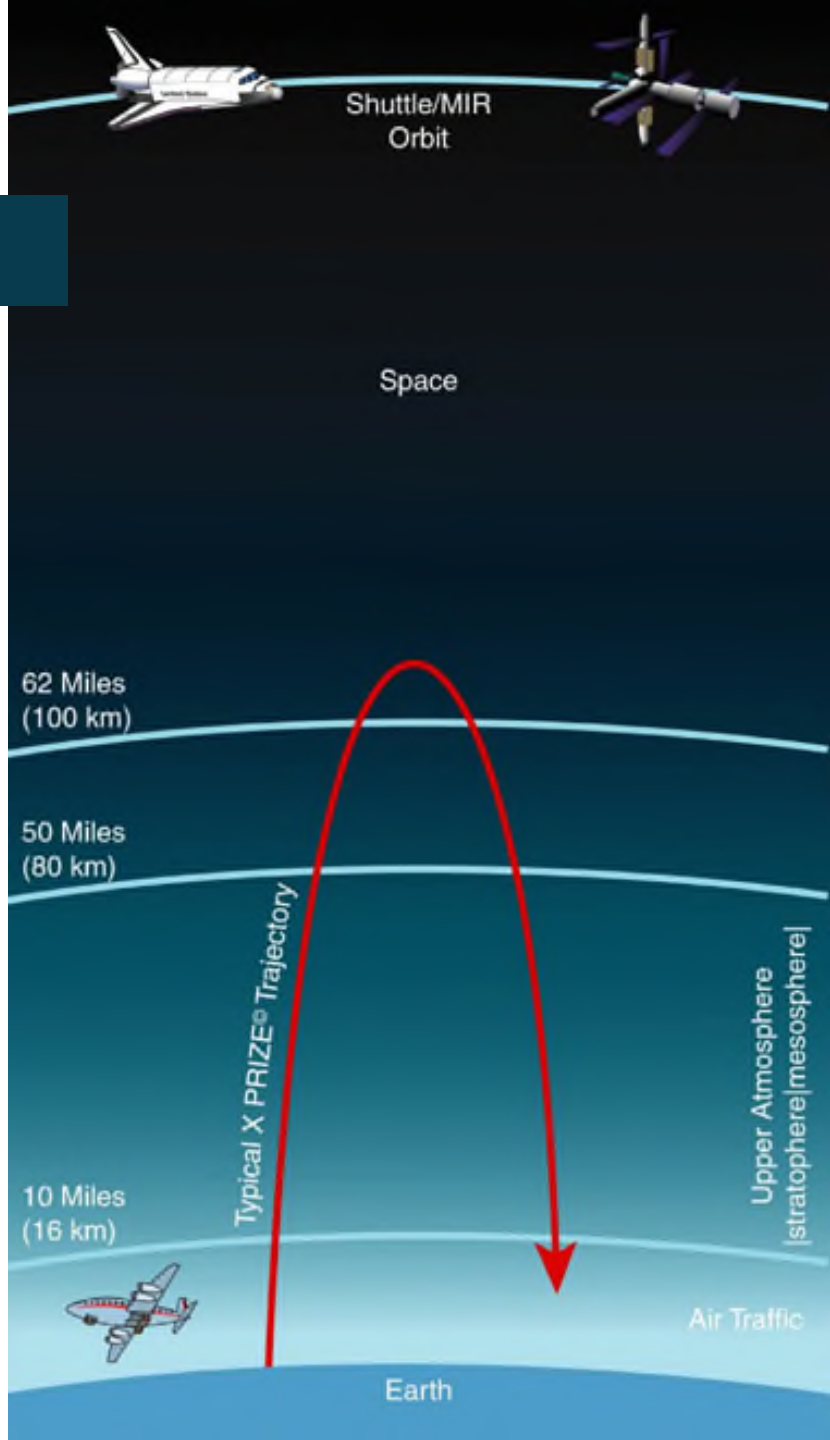
- Companies selling tickets for the suborbital experience from $250K (Virgin Galactic) to $95K/$100K (XCOR) per seat

Research:

- Microgravity (around 4 minutes)
- Upper atmospheric measurements
- Technology demonstrations
- Life Science experiments

Point-to-Point Travel:

- Travel from one location on Earth to another through space
- Challenging technical problems
- Long-term goal not a current focus



ORBITAL

Description:

- Low Earth Orbit (LEO) 180 – 3000km
- High Earth Orbit (HEO) – Geocentric 35,786km

Tourist Industry:

- Spend long periods of time in microgravity at ISS or on private space stations
- Space Adventures: 7 private citizens to ISS (8 missions – $20M – $40M per trip)

Research/Applications:

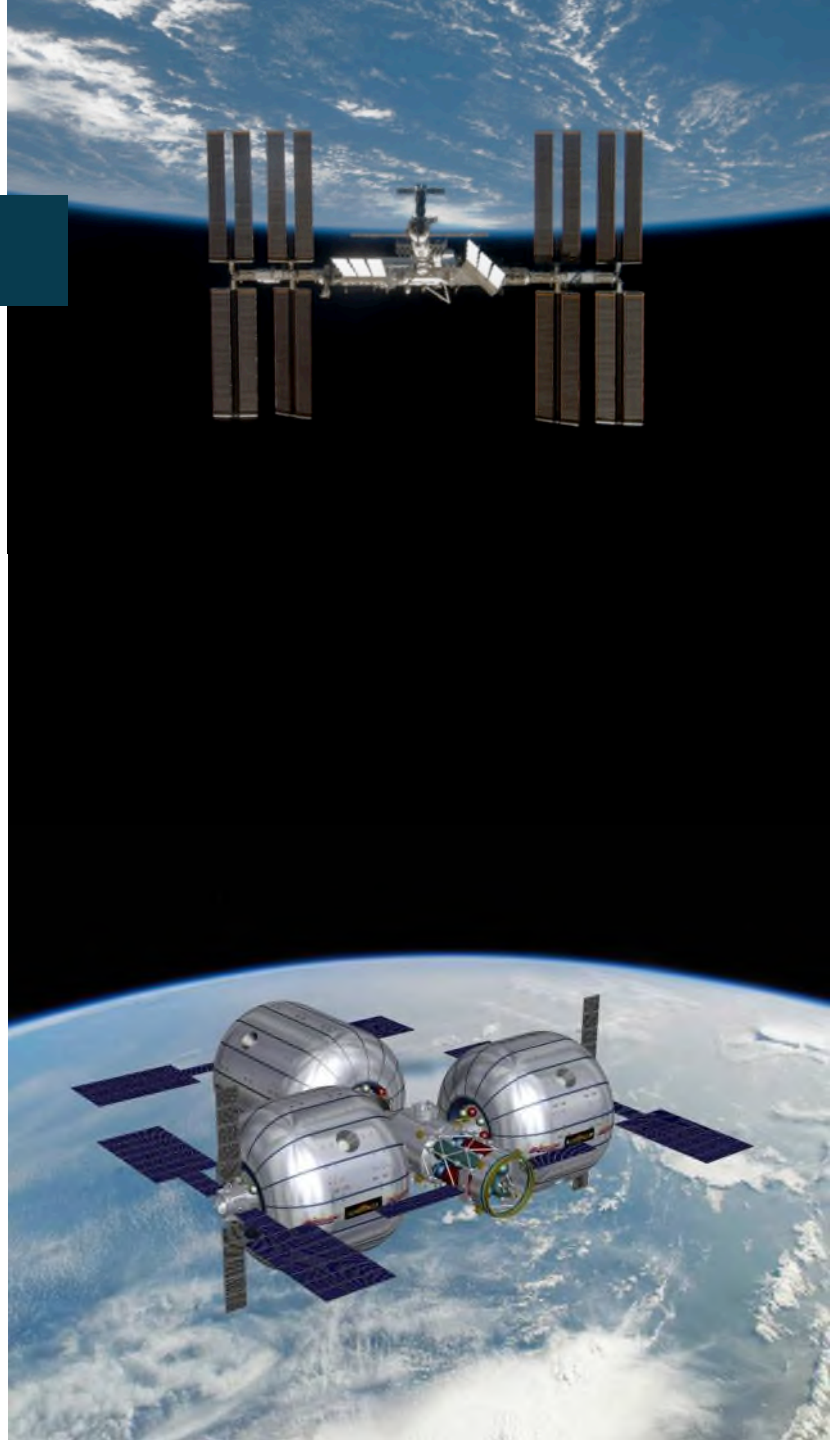
- Microgravity (around 4 minutes)
- Developing new materials and processes to create new markets and improve life

Mining and In Situ Resource Utilization:

- Examples: Propellants, metal & materials processing, and building materials
- Earth Imaging

Servicing a space-based economy:

- Examples: 3D printing in space, space manufacturing



DEEP SPACE

Description:
- Lagrange points, Moon, Asteroids, Mars and beyond

Tourist Industry:
- Ultimate in exotic experiences
- The Inspiration Mars Foundation

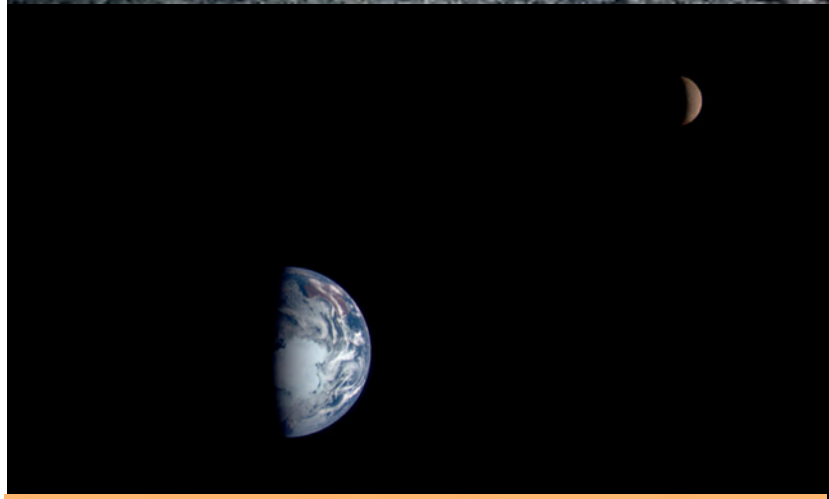
Research:
- Enabling Humans to be productive and happy in space; in-space economy
- Conduct experiments continuously in the orbital environment (microgravity and life sciences)
- Launch small sats from ISS

Satellite Servicing:
- Service satellites, put them in proper orbits, refuel, fix and upgrade systems

Earth Imaging:
- Natural resources, site development, crop monitoring, asset management ….

Broadband:
- Global internet connectivity

Settlement:
- Moving human civilization to Moon and Mars



Examples of NewSpace Companies

SUBORBITAL, ORBITAL

Virgin GALACTIC

HQ: Las Cruces, New Mexico

Founded: 2004 Richard Branson (Virgin Group)

Focus: Space Tourism & Research; Low-cost small satellite launch

Cost: $250K per seat, $10M per satellite

Major Partnerships: Spaceport America in New Mexico

ORBITAL

NANORACKS

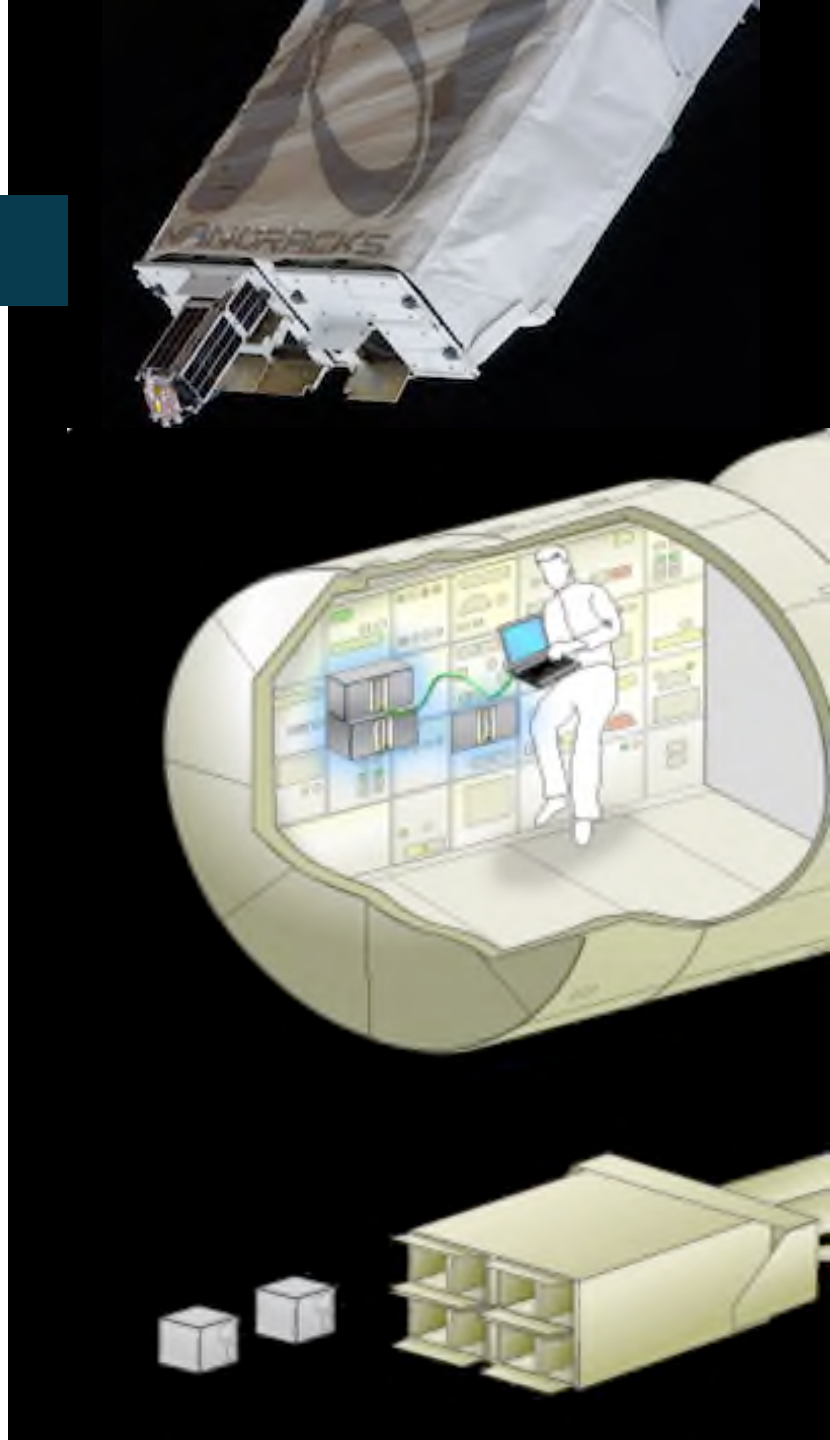
HQ: Houston, TX

Founded: 2009 CEO Jeff Manber (MirCorp)

Focus: On-orbit research and smallsat launch

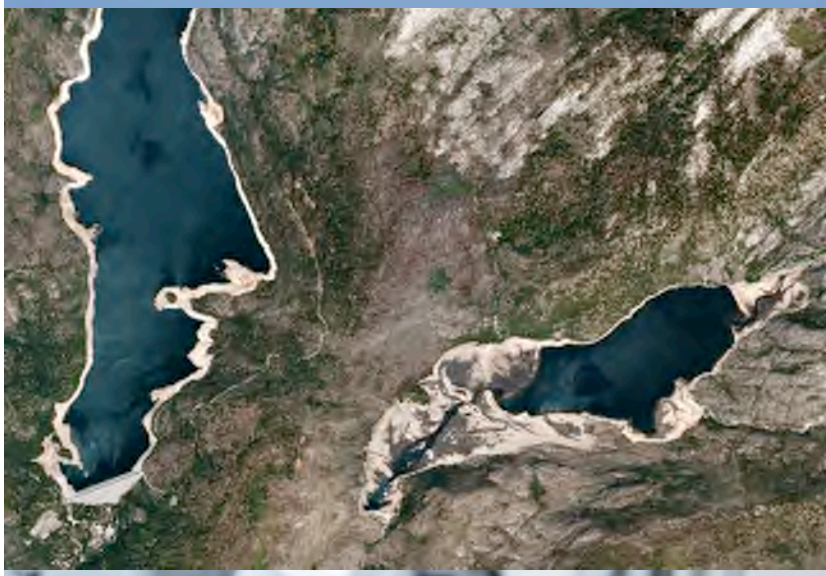
Cost: $30K-$60K for a 1U cubesat

Major Partnerships: XCOR for suborbital, Astrium for USS External Platform Program and Entropy Engineering (2010 NASA SBIR)



Examples of NewSpace Companies

ORBITAL



HQ: San Francisco, California

Founded: 2010 Will Marshall, Robbie Schingler, Chris Boshuizen

Focus: Applications, Earth Sensing

Capacity: Launched 73 smallsats, resolution: 10 square feet

Major Partnerships: Raised $183M in 5 years

ORBITAL

BIGELOW

HQ: North Las Vegas, NV

Founded: 1998 by Robert Bigelow

Focus: Orbital habitation

Capacity: BA330 has 330m^3 of internal space

Cost: \$25M for 110m^3 for 60 days

Major Partnerships: Raised \$183M in 5 years

Examples of NewSpace Companies

ORBITAL, DEEP SPACE

SPACEX

HQ: Hawthorne, California

Founded: 2002 Elon Musk

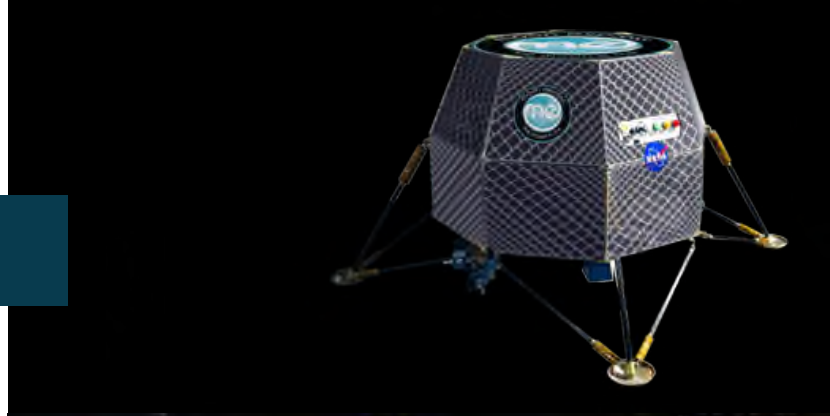
Focus: Transport to Low Earth Orbit (ISS), Geostationary Transfer Orbit (GTO), planetary missions

Cost: Falcon Heavy $84M for 6.4t to GTO

Major Partnerships: NASA Commercial Crew

Examples of NewSpace Companies

DEEP SPACE



HQ: NASA Research Park, Mountain View, CA

Founded: 2010 Bob Richards, Andy Aldrin

Focus: Lunar payloads, resource exploration, Google Lunar X Prize.

Cost: Initial cost ~$3M/kg

Major Partnerships: NASA innovative Lunar Demonstration Data (ILDD) program ($30M); Dynetics

Examples of NewSpace Companies

DEEP SPACE

DEEP SPACE INDUSTRIES

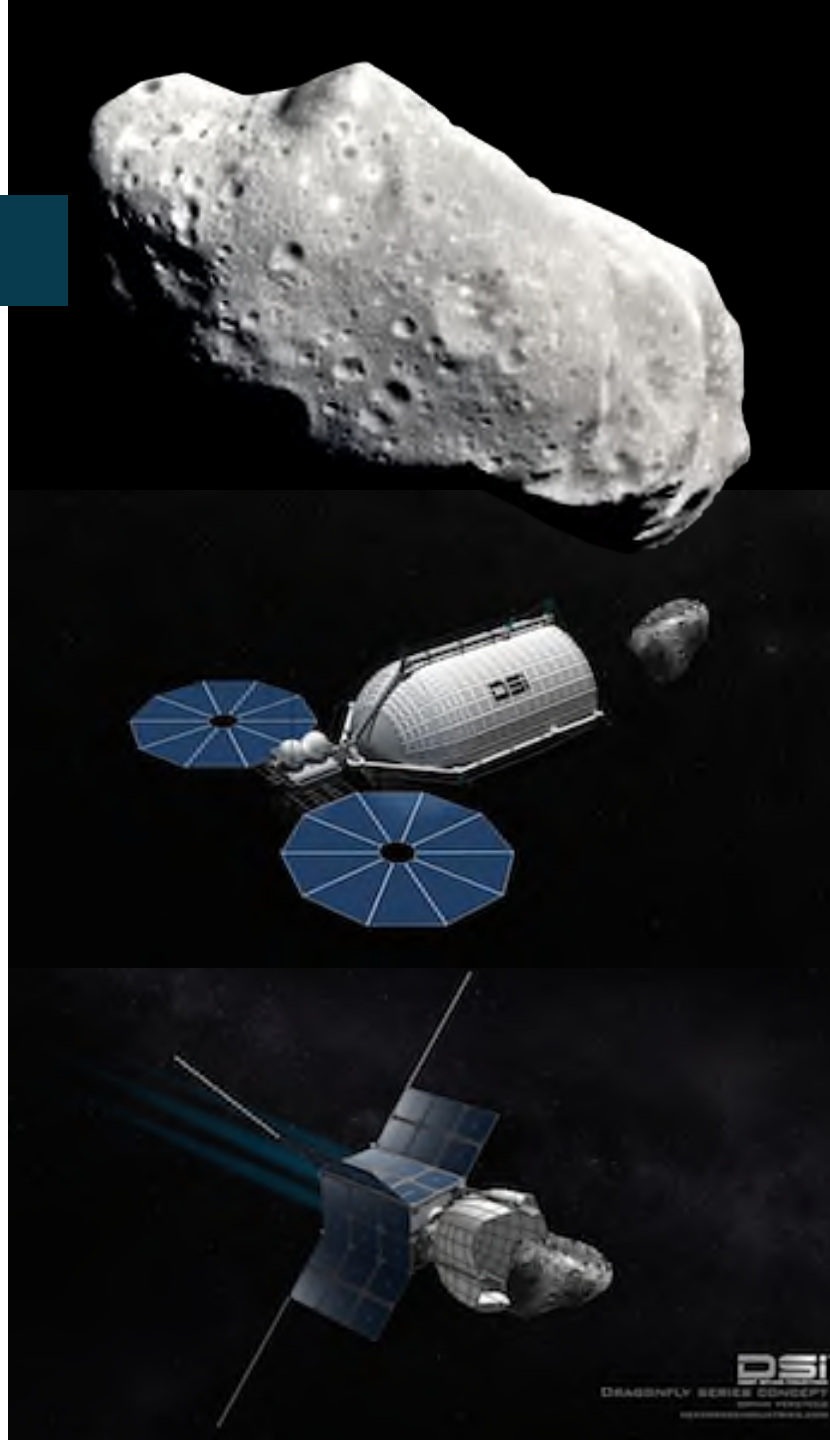
HQ: Mountain View, CA

Founded: 2013, Rick N. Tumlinson, Daniel Faber, David Gump et al.

Focus: Asteroid Mining: Water & Rare Metals

Implementation: Four stages: Prospect, Harvest, Process, Manufacture in space.

Major Partnerships: NASA Asteroid Initiative, ISISpace, Solid Prototype



The Government's Role in Commercializing Space

Key question:

"What role should the government play in the commercialization of space?"

NATIONAL ADVISORY COUNCIL FOR AERONAUTICS (NACA)

- Established in 1915 by Congress
- Developed key technologies to **enabled air travel** to become effective, economical and safe
- Studied the problems of flight to **identify and resolve risks** that kept air travel from being **safe and commercially viable**
- Government **worked closely with industry** to fund studies that retired technological risks and **enabled private enterprise** to successfully create a new industry

CHANGES AT NASA

Program Characteristic	Early Space Age Approach	Commercial-Oriented Approach
Owner	NASA	Industry
Contract Fee-Type	Cost Plus	Fixed Price
Contract Management	Prime Contractor	Public-Private Partnership
Customer(s)	NASA	Government and Non-government
Funding for Capability Demonstration	NASA procures capability	NASA provides investment via milestone payments
NASA's Role in Capability Development	NASA defines "what" and "how"	NASA defines "what" Industry defines "how"
Requirements Definition	NASA defines detailed requirements	NASA defines top-level capabilities needed
Cost Structure	NASA incurs total cost	NASA and Industry share cost

US NATIONAL POLICY ON COMMERCIAL SPACE

"Develop a robust and **competitive U.S. commercial space sector**"

&

"**Energize competitive domestic industries** to participate in global markets"

– NASA Act (as amended June 28, 2010)

US NATIONAL POLICY ON COMMERCIAL SPACE

NASA is to achieve this by:

- Purchasing and using **commercial space capabilities** and services to the maximum practical extent
- Actively exploring the use of **inventive, nontraditional arrangements** for acquiring commercial space goods and services
- **Refraining from** conducting U.S. Government space **activities that preclude, discourage, or compete with U.S. commercial space activities**
- Pursuing potential opportunities for **transferring routine, operational space functions to the commercial space sector** where beneficial and cost-effective.

June 28, 2010

FAA Office of Commercial Space Transportation

Founded 1984, to:

- **Regulate** the commercial space transportation industry, **only to the extent necessary**
- **Encourage, facilitate, and promote commercial space** launches by the private sector
- **Recommend appropriate changes** in Federal statutes, treaties, regulations, policies, plans, and procedures:
- Facilitate the strengthening and **expansion of the U.S. space transportation infrastructure**

WHY COMMERCIAL?

- **Why Commercial?**
  - Commercial companies must be competitive and governments have other priorities (safety, jobs, etc.)
  - Example: comparison of SpaceX to NASA Development Costs
    - NASA initial estimates using its normal cost estimating software for Falcon 9 were 10 times more expensive than SpaceX actuals
    - Even when NASA made adjustments its estimates were still 4 times more
- **Conflicting goals**
  - US Congress focused on jobs in their districts

NASA PROGRAMS TO STIMULATE COMMERICAL SPACE

- **Commercial Orbital Transportation Services (COTs) 2006**
  - NASA investment $800M produced 2 new launchers 2 new ISS cargo carriers
- **Commercial Crew Development (CCDev) 2009 – 2011**
  - Stimulate development of privately operated crew vehicles
- **Commercial Crew Integrated Capability (CCiCap) 2012 – 2014**
  - Advance multiple integrated crew transportation systems
  - Develop a Commercial Transportation System capability to LEO
- **Commercial Resupply Services**
  - 12 missions for SpaceX and 8 missions for Orbital Sciences ($3.5B)
- **Collaborations for Commercial Space Capabilities – SAAs**
  - Advance private sector development of emerging products and services commercially available to government and non-government customers
- **Flight Opportunities Program 2010 – Suborbital**
  - Commercial Reusable Suborbital Research Program (CRuSR) – supports commercial suborbital spaceflight by providing a steady, guaranteed market for research payloads
  - Facilitated Access to Space Technology (FAST) – funding microgravity research

ALTERNATIVES TO GOVERNMENT FUNDING

Google Lunar X-Prize (GLXP) 2007 - 2016

- Eighteen teams currently in competition for $30M in prizes
- Land a robot on the Moon then travel more than 500m and transmits high definition images and video to Earth

NASA Innovative Lunar Demonstration Data

- Indefinite delivery/indefinite quantity (IDIQ) contracts totaling up to $30.1M

Crowdfunding

- Kickstarter: Lunar Space Elevator (Liftport Group), CubeSat Ambipolar Thruster (CAT) (UMich), Arkyd Telescope $1.5M (Planetary Resources) etc.
  - Spire

NEWSPACE INVESTMENTS (NSG 50)

$200M-$2B

SpaceX
Virgin Galactic*
Blue Origin*
Vulcan Aerospace*
O3B
OneWeb
Planet Labs
Cloudera

$20M-$200M

Skybox
Spaceflight Industries
MapBox
Spire
Moon Express
SpaceIL
Kymeta

$2M-$20M

Dauria Aerospace
Planetary Resources
OmniEarth
Satelogic
Astroscale
Nanoracks
XCOR
Rocket Lab
Firefly
Reaction Engines
Accion Systems
Orbital Insight
ClearStory Data
SpaceKnow

Crunchbase Data 2015

(*) SVSC estimates

Source: Sean Casey (SVSC)

From 2015-2015 $12B in private investment Source: Silicon Valley Space Center

Disruptive Technologies

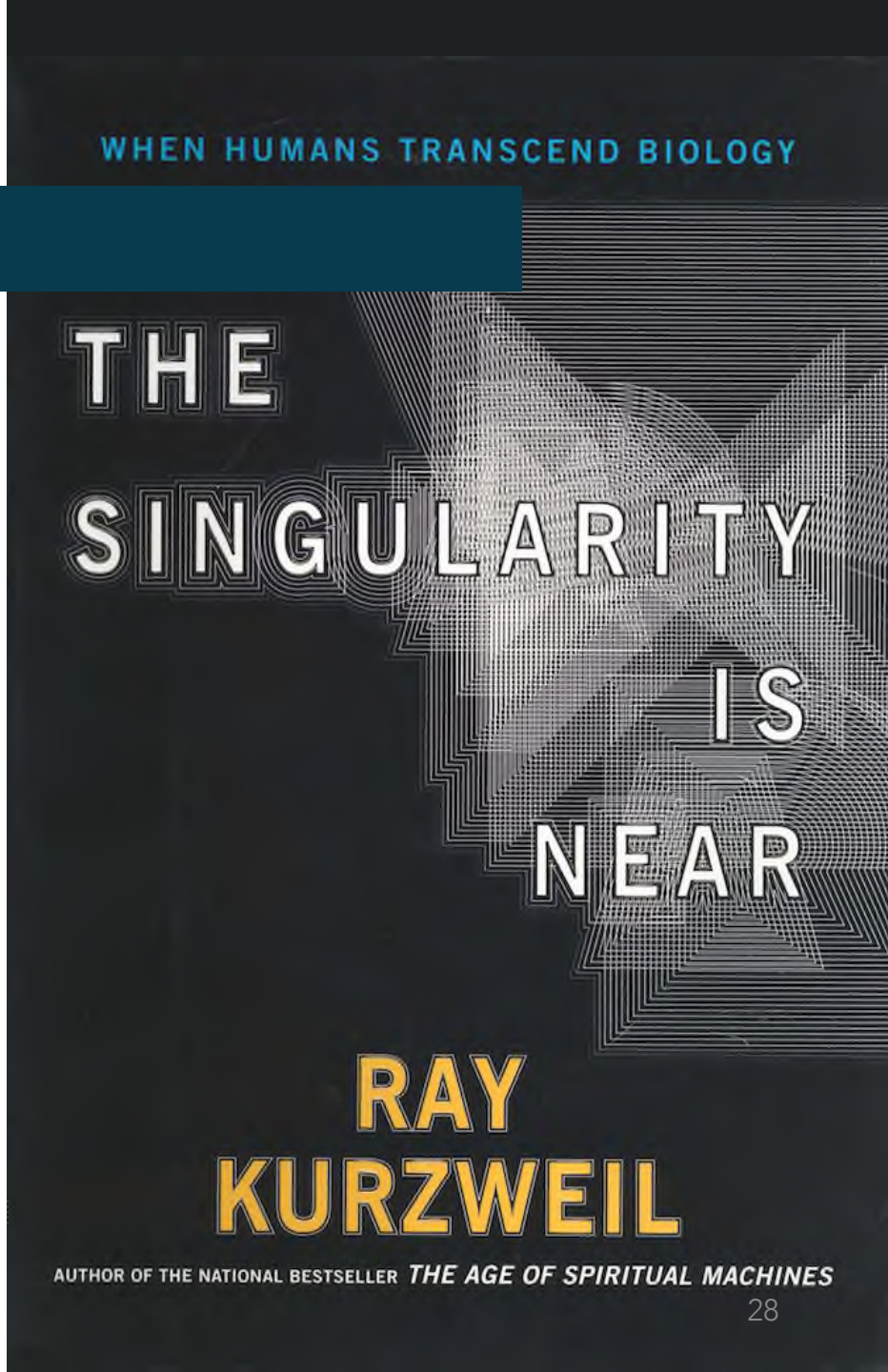
MOORE'S LAW

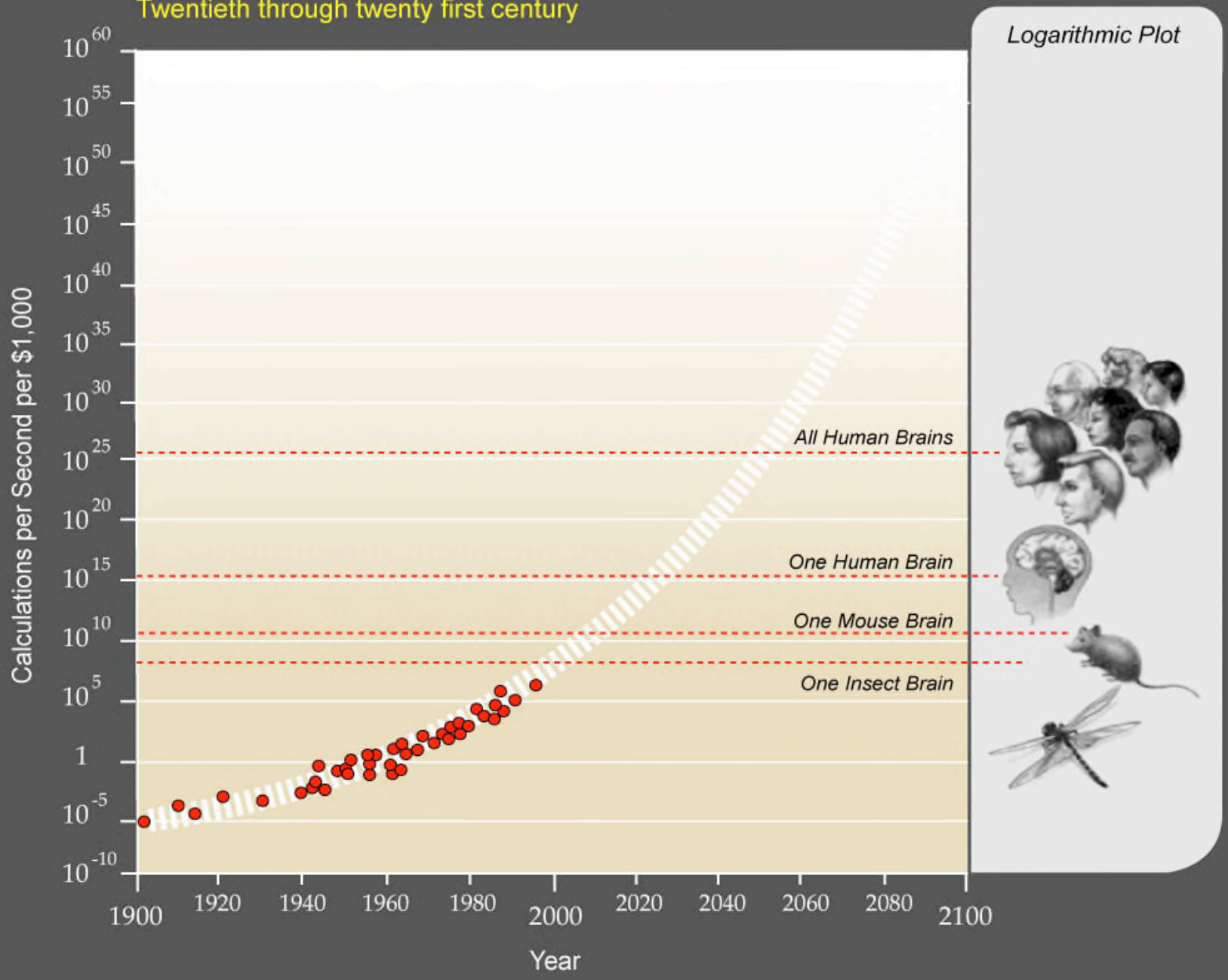
"Moore's law" is the observation that, over the history of computing hardware, the number of transistors in a dense integrated circuit has doubled approximately every two years.

EXPONENTIAL GROWTH

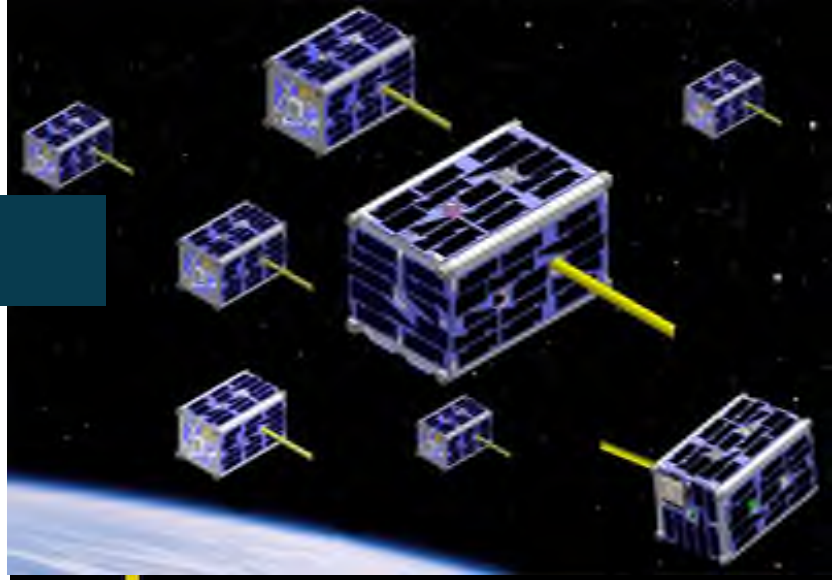
Computers are becoming exponentially more powerful – in accordance with Moore's Law.

The advances in computing are allowing science and technology to follow suit.




Exponential Growth of Computing
Twentieth through twenty first century
Logarithmic Plot
Calculations per Second per $1,000
10^{60}
10^{55}
10^{50}
10^{45}
10^{40}
10^{35}
10^{30}
10^{25}
10^{20}
10^{15}
10^{10}
10^{5}
1
10^{-5}
10^{-10}
All Human Brains
One Human Brain
One Mouse Brain
One Insect Brain
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Year

SMALLSATS



Mass: 1kg-500kg

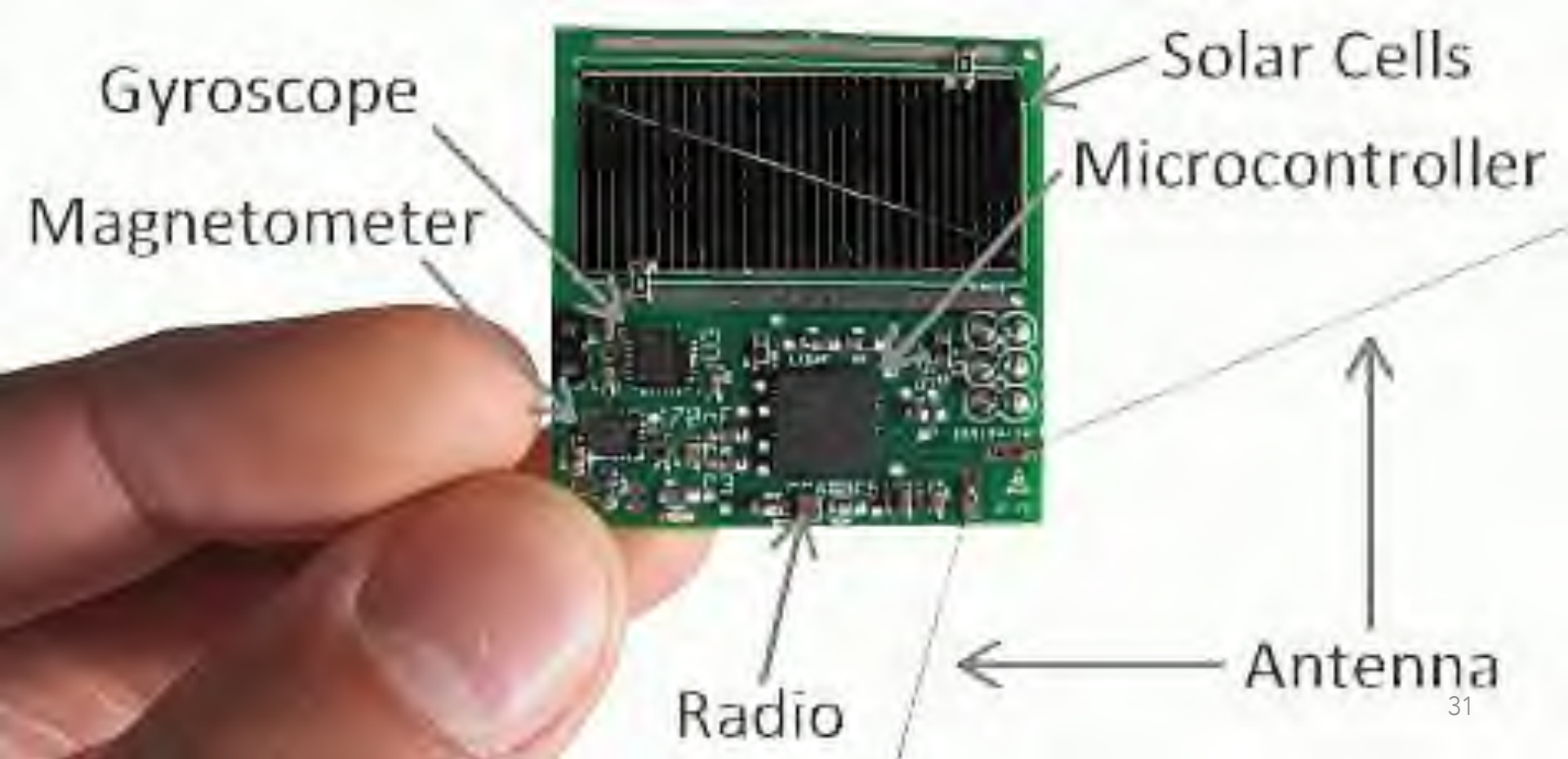
Cheap and quick

Lower cost of entry to the space market

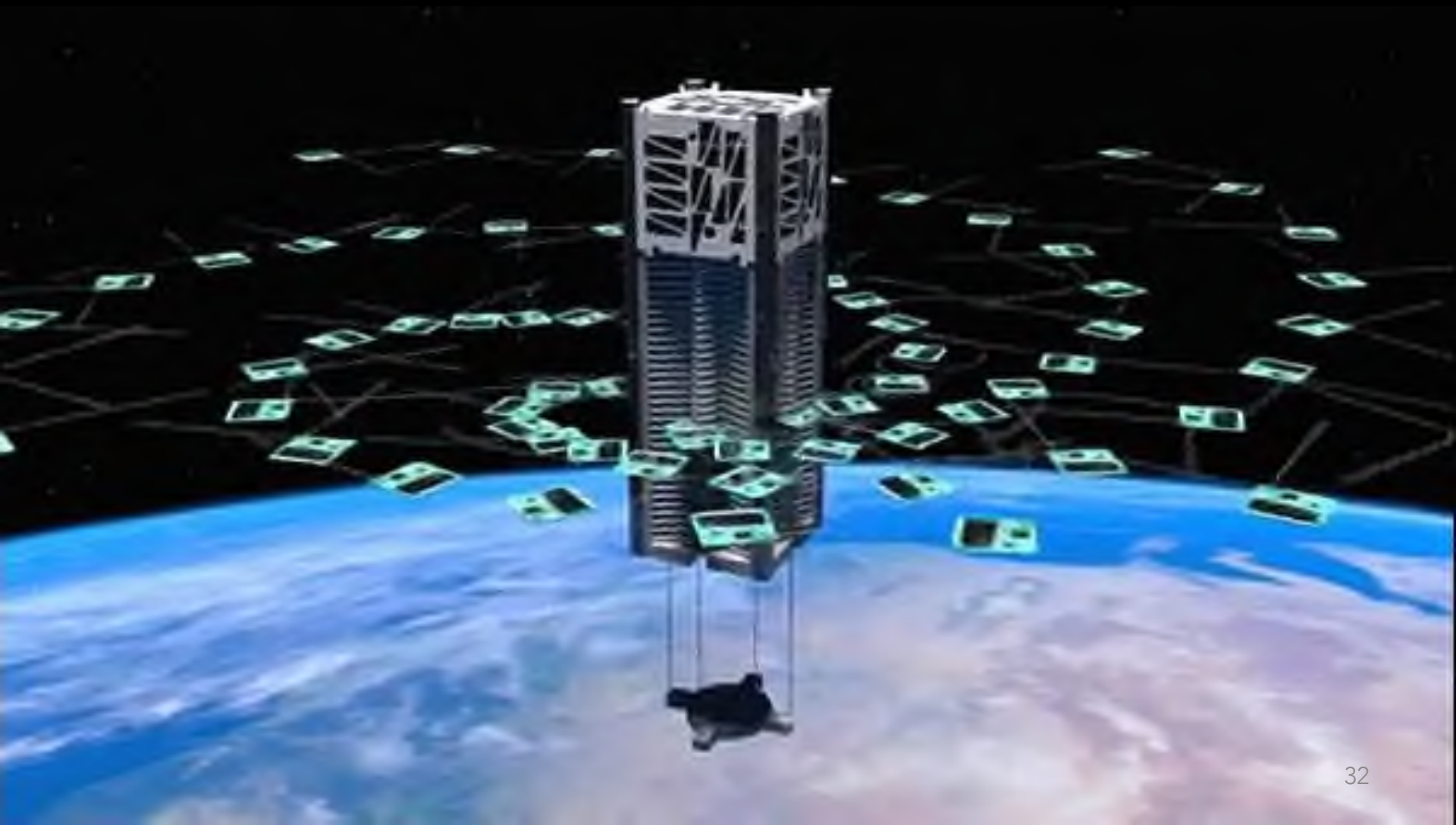
Constellations of small satellites may replace single larger satellites

Smallsats are technologically less advanced then conventional satellites. However, they provide a very useful test bed low-cost missions and for technology demonstrations.

DOES THIS LOOK LIKE A SATELLITE?



HOW ABOUT NOW?

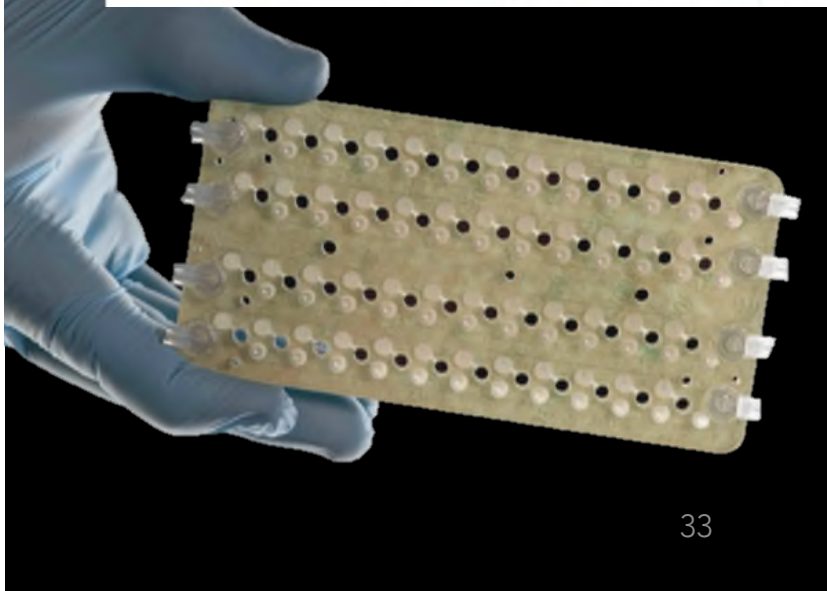


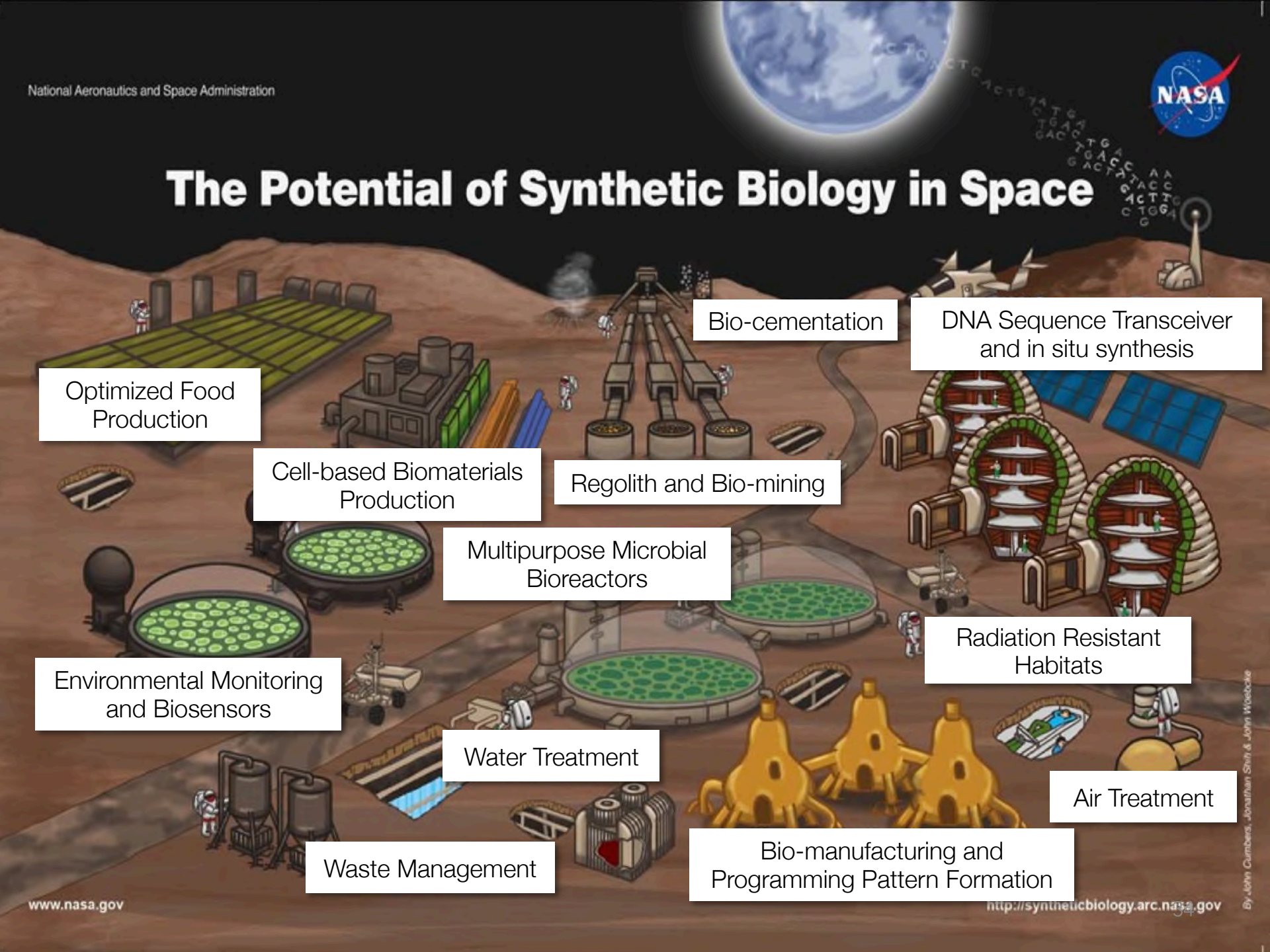
SYNTHETIC BIOLOGY

Providing robust biological tools and technologies to sustain human activities across the solar system for the benefit of exploration, science and the economy.

Combining disciplines such as:

- Biotechnology
- Evolutionary biology
- Molecular biology
- Systems biology
- Biophysics
- Computer engineering
- Genetic engineering

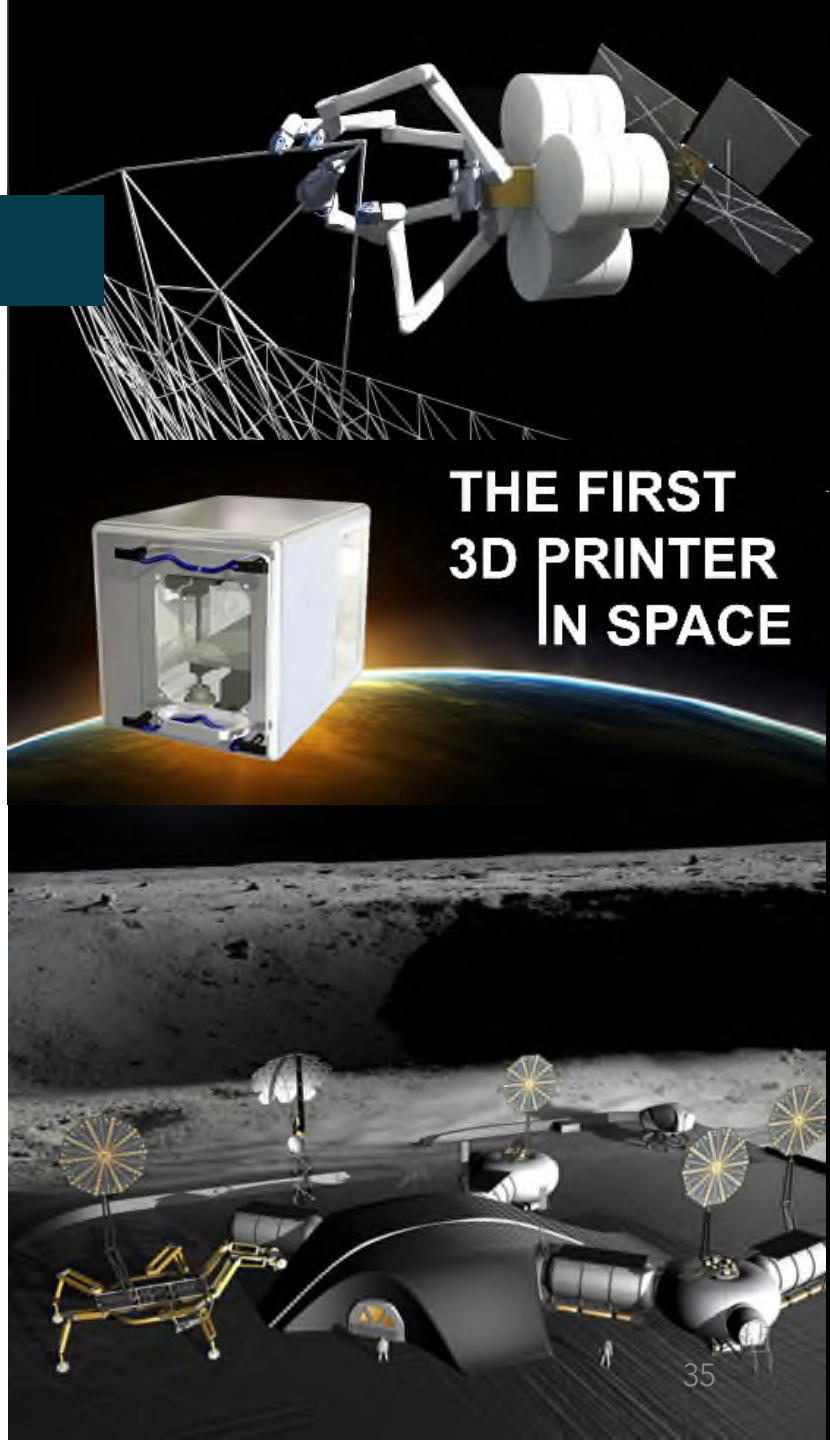



National Aeronautics and Space Administration
NASA
The Potential of Synthetic Biology in Space
Optimized Food Production
Cell-based Biomaterials Production
Multipurpose Microbial Bioreactors
Environmental Monitoring and Biosensors
Water Treatment
Waste Management
Bio-cementation
Regolith and Bio-mining
DNA Sequence Transceiver and in situ synthesis
Radiation Resistant Habitats
Air Treatment
Bio-manufacturing and Programming Pattern Formation
www.nasa.gov
http://syntheticbiology.arc.nasa.gov
By John Cumbers, Jonathan Shih & John Woelbcke

SPACE MANUFACTURING AND ISRU

3D printing or “additive manufacturing” offers a range of potential advantages:

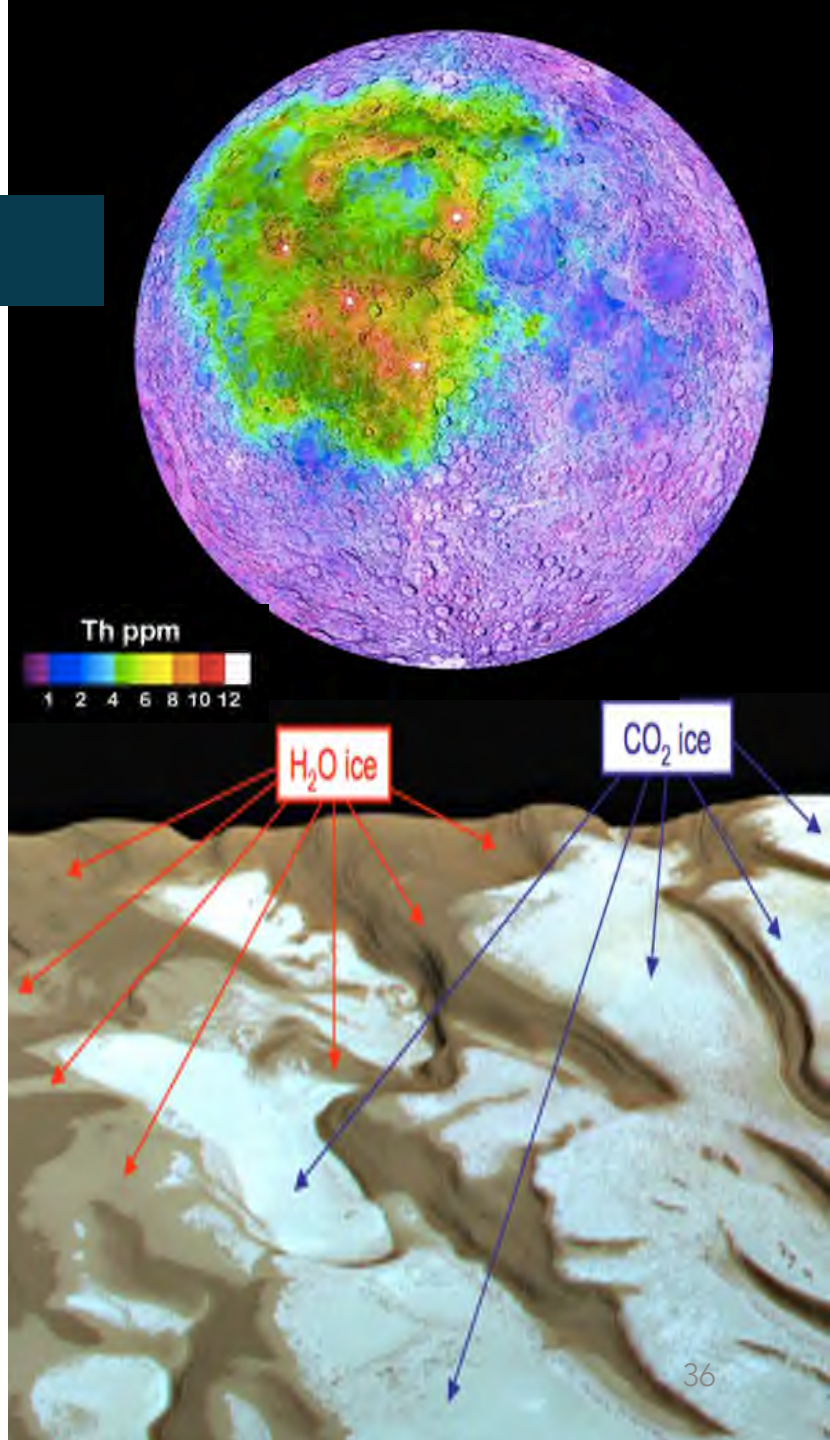
- Crew in space can ‘print’ new or replacement items
- Spacecraft could be printed and assembled in orbit rather than launched
- In-situ resources could be used as feedstock, reducing mass that has to be delivered



SPACE MANUFACTURING AND ISRU

In-Situ Resource Utilization (ISRU)

- Extraterrestrial resources are crucial for supporting human crews
- Oxygen, water, and inert gases are examples of high-value resources for life support.
- Metals, pure or alloyed, glass, ceramics and simple hydrocarbons are required to fabricate new parts or complete repairs for habitats and spacecraft.



SPACE MANUFACTURING AND ISRU

What is the smallest number of machines and resources that future pioneers will need to create a self-sustaining settlement?

WRAP UP

You should be able to:

1) List some examples of areas where entrepreneurial companies are developing new markets;
2) Name a few companies that are examples of the commercial space revolution;
3) Discuss how governments can facilitate the birth of this new industry; and
4) Describe a range of disruptive technologies in the space sector.

ORGANIZATIONS PROMOTING NEWSPACE

Students for the Exploration and Development of Space (SEDS)

1980 founded by the same 3 founders as ISU, to promote space exploration and development.

National Space Society

1987 promotes living in and working in space. The organization is located in many countries.

Space Frontier Foundation

1988, dedicated to free enterprise and human settlement of the Solar System

Space Access Society

1992, dedicated to reducing the cost for commercial access to space.

Commercial Spaceflight Federation

2005, promotes commercial human spaceflight, high levels of safety, and shares best practices and expertise throughout the industry.

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- Page 5: NewSpace definition: http://en.wikipedia.org/wiki/NewSpace and http://www.hobbyspace.com/NewSpace/index.html
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