

FACTORIES-IN-SPACE

Establishing Extraterrestrial Manufacturing Operations for Sustainable Exploration and Habitation for the 21st Century

Harsha & Ajay Malshe, June 2018



Drivers for Urgency

Survival

Exploration

Democratization

Driver 1: Survival

- The world is expected to add another billion people within the next 15 years, bringing the total global population from 7.3 billion in mid-2015 to 8.5 billion in 2030, 9.7 billion in 2050, and 11.2 billion by 2100

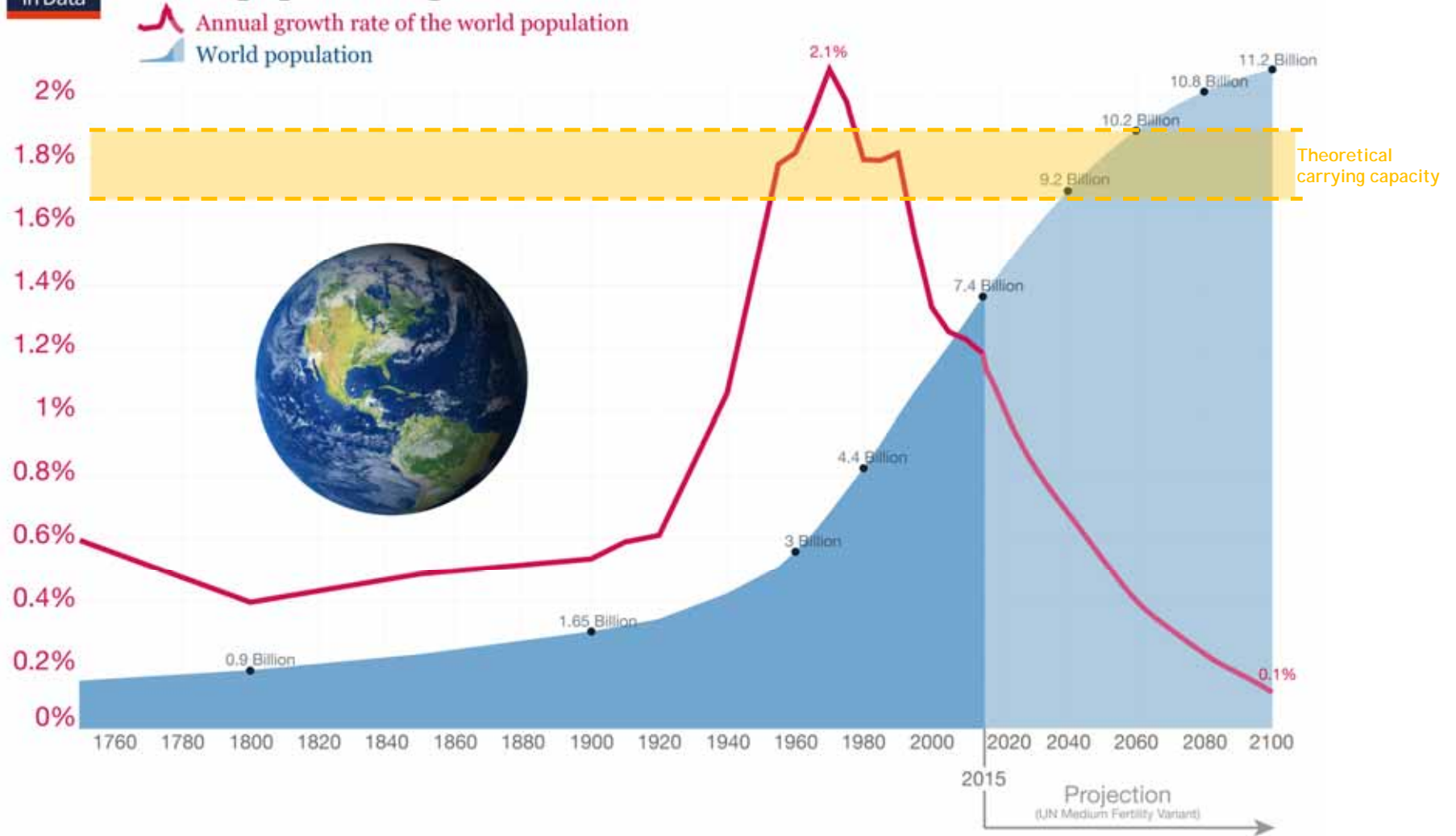
(Ref: https://esa.un.org/unpd/wpp/Publications/Files/Key_Findings_WPP_2015.pdf)

"There is enough on Earth for everybody's need, but not enough for everybody's greed" - Gandhi

"Mankind must colonize space or die out" - Stephen Hawking



World population growth, 1750-2100



Data sources: Up to 2015 OurWorldInData series based on UN and HYDE. Projections for 2015 to 2100: UN Population Division (2015) – Medium Variant. The data visualization is taken from OurWorldInData.org. There you find the raw data and more visualizations on this topic.



Driver 2: Exploration

- Transition from a consumer to an exploration driven economy for continued human progress
- Transition from risk-averse to risk-seeking society
- Making space habitable through exploration driven by curiosity and discovery
- Calling back to the great explorers

Driver 3: Democratization

1. Space exploration is funded by sovereign nations (powerful countries)
2. Space is commercialized by independent actors (ultra-wealthy)
3. In the future, Space must be accessible to large democracy and not in the hands of few

"Competition is not only the basis of protection to the consumer, but is the incentive to progress." Herbert Hoover



Recent exponential growth globally in public & private space missions and interest

"I'm intrigued with the notion that the man in the moon is pretty soon going to be a gas station attendant," Ross said.

The Space Age and a New Age for Health Care:
The Technology of Saving Lives (Op-Ed)
By Mackenzie Thompson, Space.com Contributor | June 1, 2018 07:38am ET

EXPERT VOICES

DARPA to Begin New Effort to Build Military Constellations in Low-Earth Orbit

By Sandra Erwin, Space News | June 2, 2018 09:00am ET

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The Defense Advanced Research Projects Agency is planning to build a constellation of satellites in low-Earth orbit.
Credit: Darpa

The Trump Self-Defense Doctrine for the New Space Era

By Brian G. Chow, Space News | June 7, 2018 07:00am ET

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Satellite servicing spacecraft, such as the ESA De-orbit concept shown here, could also be used to destroy satellites, raising thorny preemption questions for defense planners.
Credit: ESA

Americans Feel That the US Should Remain a Global Leader in Space Exploration

By Chelsea Gohd, Space.com Staff Writer | June 6, 2018 10:00am ET

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Apollo 15 astronaut Jim Irwin works in the Hadley-Apennine region of the moon during his mission in 1971.
Credit: NASA



An ultrasound examination of the hand of an astronaut aboard the International Space Station. The station's ultrasound machine is a direct line to doctors if help diagnoses sick people in space.

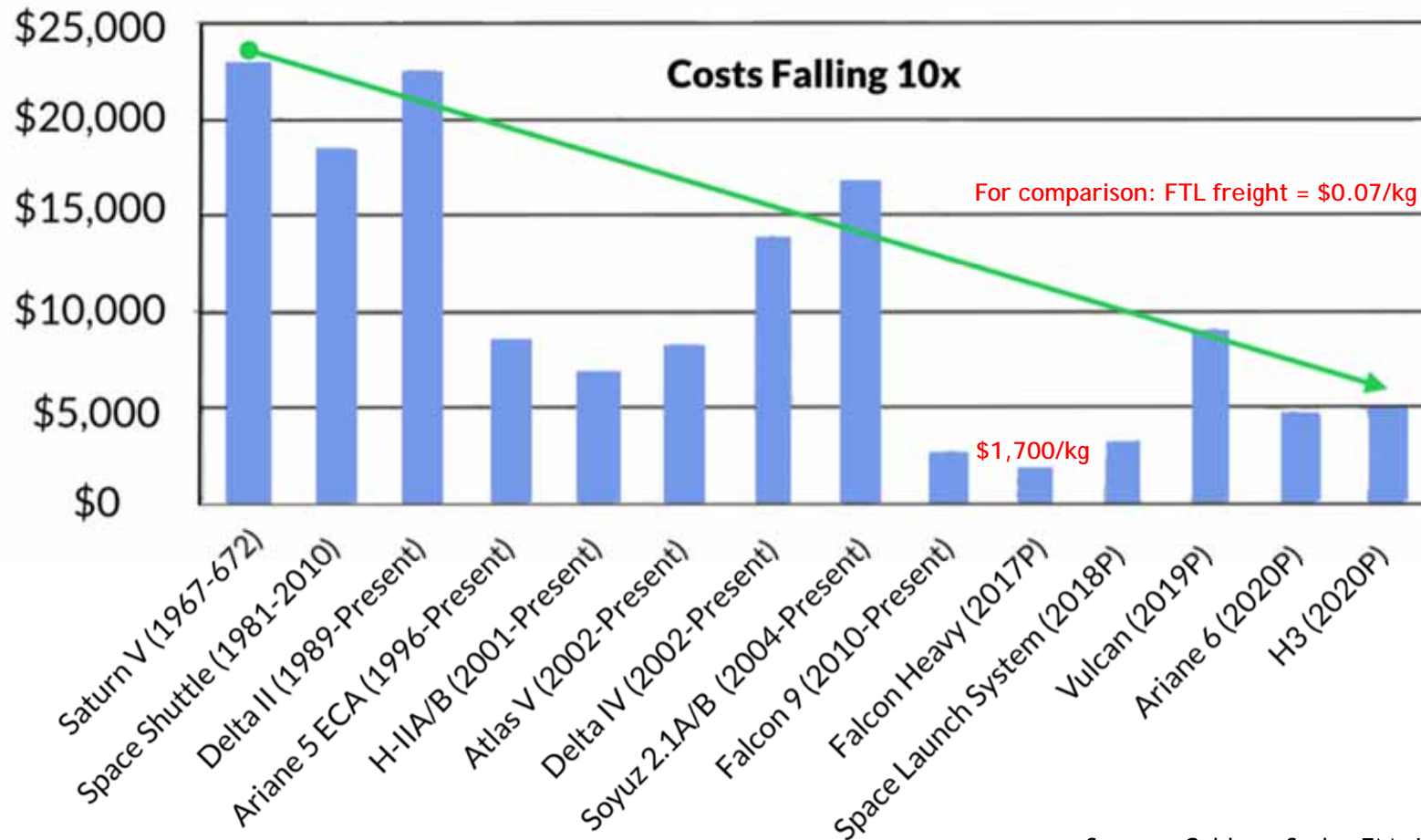
Limitations

At the cocktail party, Ross agreed about the limitless potential of space exploration but described the challenges there in more specific terms. He said operating in space will be enormously costly and that our interests in space are enormously vulnerable.

- Today, space-based objects, like satellites or spacecraft, are manufactured & assembled in factories on Earth and then launched into space on rockets, which is inefficient and expensive
- Satellites are rapidly growing - manufacturing in space enables a better economy-of-scale for affordability and accessibility to common citizens
- Current model is unsustainable for growth, democratization and reliable space infrastructure required for human colonization



“Cost-to-LEO: cost to for one rocket to launch 1kg of cargo into low earth orbit (LEO)”



Sources: Goldman Sachs, FAA, University of Kentucky
Ref: <https://www.equities.com/news/sticking-the-landing>



Vision

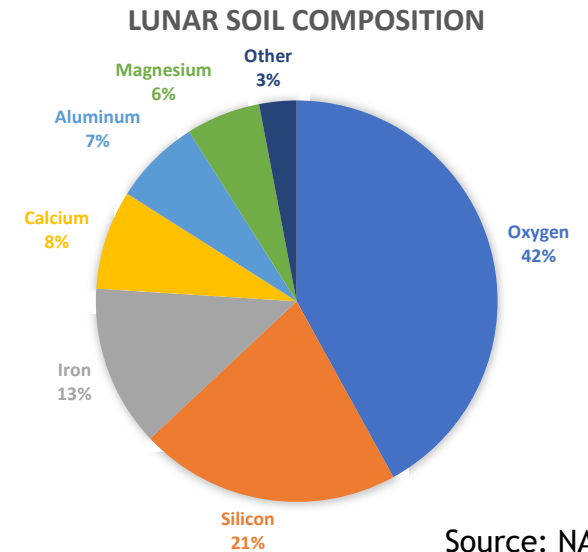
Manufacturing science and engineering research to support the development of “factories-in-space” and an *intramodal extraterrestrial supply chain* for sustainable exploration and habitation.

Manufacturing in Space 101

A long-term vision of success for building “Factories-in-Space” mandates that we start asking fundamental questions today:

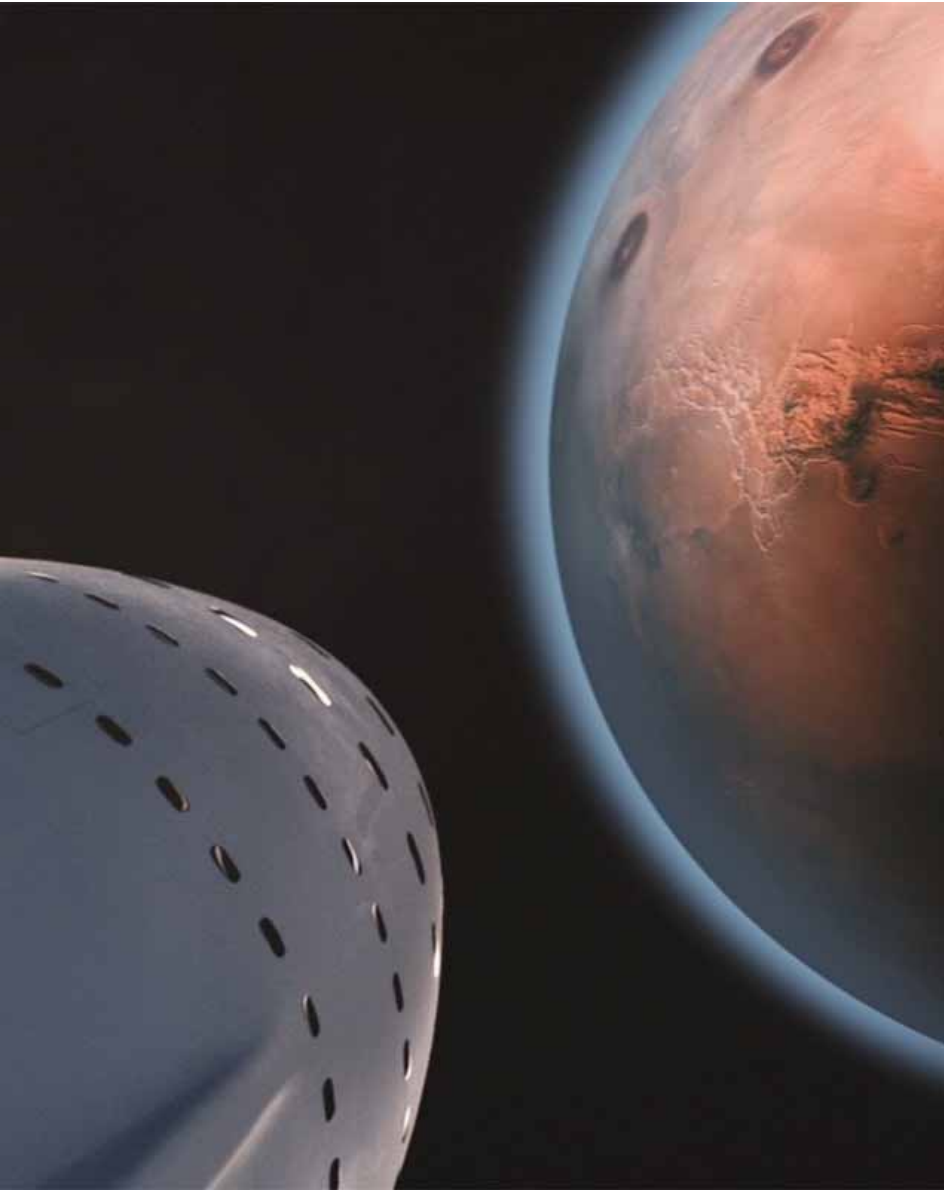
- *What type of products and services should be manufactured?*
- *What type of factories will be required to produce such products?*
- *What kind of energy and material extraction systems need to be developed?*
- *What type of processes will be required to produce these products?*
- *What fundamental advancements in our understanding of manufacturing science and engineering are required to scale these processes economically?*
- *What autonomous systems need to be developed, like robonauts and AGVs, that can maneuver to assemble components in these extraterrestrial factories?*

Space-based solar arrays could generate 40x more energy than similar earth-based systems. (Business Insider)



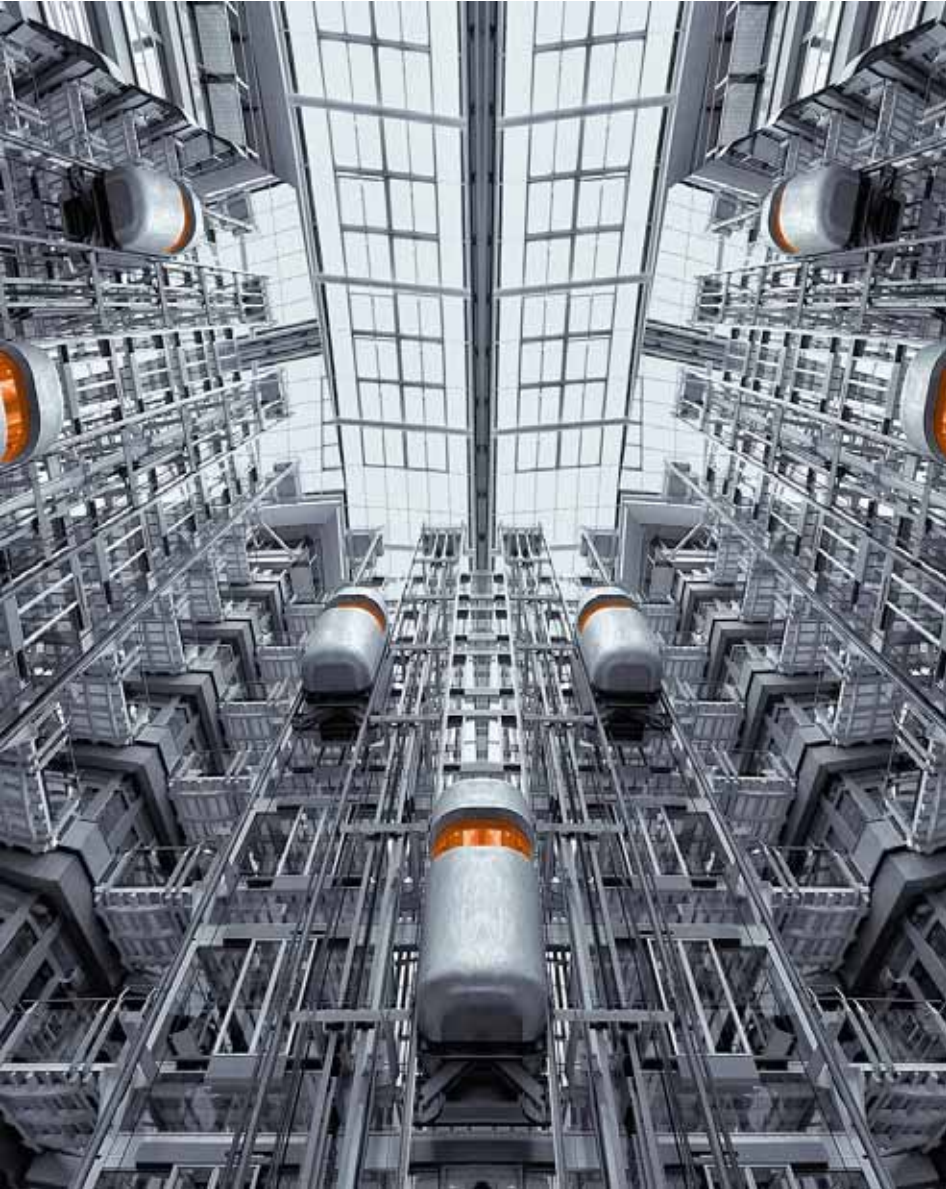
Source: NASA





Locations

- Earth orbit
- Surface of the moon
- Asteroids and comets
- Surface of planetary bodies
- Interplanetary space



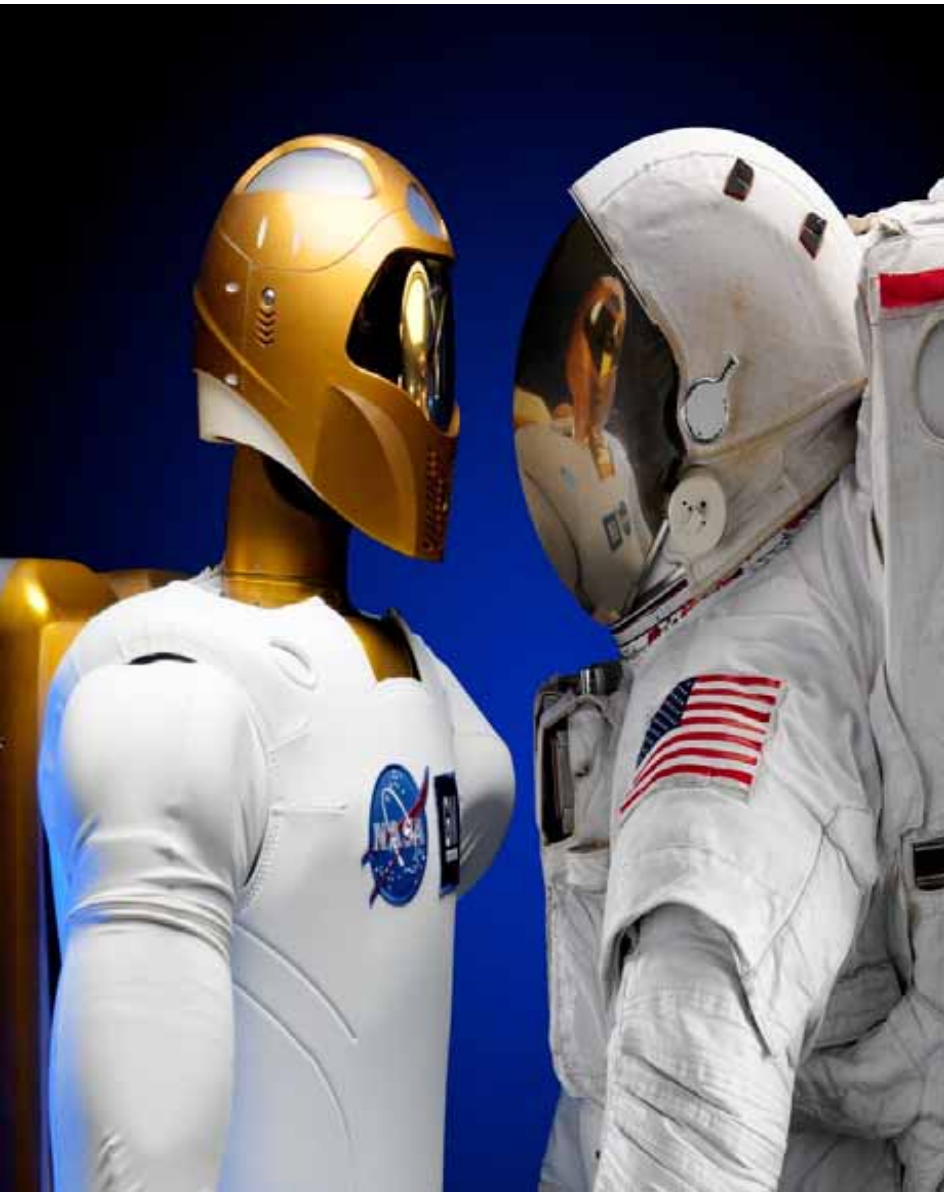
Industry Coverage

- Energy
- Communications
- Mining
- Transportation
- Medicine
- Housing
- Infrastructure
- Food and air
- And more...



Factory Operations

- Fabrication
- Assembly
- Repair
- Storage
- Distribution
- Reclamation
- Maintenance



Common Concerns

- Safety & Well-being of human operators
- Protection from extreme environments
- Security of physical, data and earth-links
- On-site, on-demand, and custom maintenance and back-up systems
- Human-machine robotic interfaces
- High-density and high-speed computing
- Sustainable energy utilization

Establishing a “Manufacturing in Space Program” for Convergent Systems Research & Development

Examples of platform projects:

(1) Autonomous space/surface based production technology; (2) Metamaterials; (3) Factory design and planning; (4) Logistics (transport/conveyance); (5) Power distribution/data systems; (6) Advanced satellite assembly and development (micro, degradable, etc.); (7) Space-based autonomous repair; (8) Reclamation of space-junk; (9) Safety/security systems; (10) Factory maintenance; and more...



“The fact that we live at the bottom of a deep gravity well, on the surface of a gas covered planet going around a nuclear fireball 90 million miles away and think this to be normal is obviously some indication of how skewed our perspective tends to be.”

— Douglas Adams

"The greatest gain from space travel consists in the extension of our knowledge. In a hundred years this newly won knowledge will pay huge and unexpected dividends."

— Professor Wernher von Braun

“Freedom lies in being bold.”

— Robert Frost