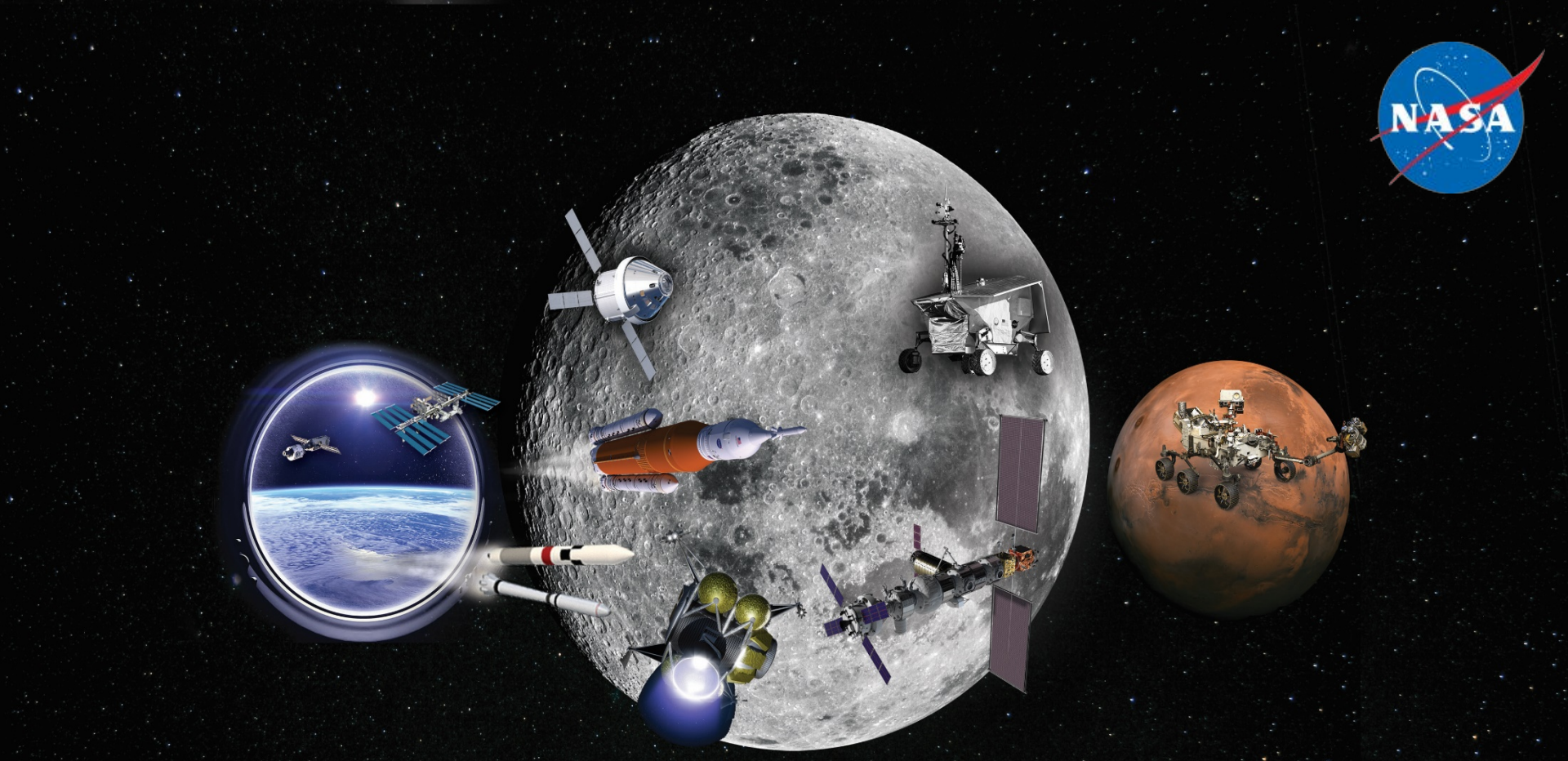


In Space Manufacturing: From Low Earth Orbit to Deep Space Exploration

R.G. Clinton Jr., PhD
Associate Director
Science and Technology Office
NASA Marshall Space Flight Center

International Astronautical Congress
October 25, 2019
Washington DC

In Space Manufacturing Path to Exploration
Key Thrust Areas

FabLab

MSFC

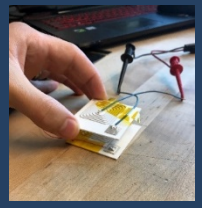
First Plastics Printer

Made In Space

2nd Generation Plastics Printer

Made In Space

Printed Electronics



MSFC

Recycler/ Printer

Tethers Unlimited

Metals

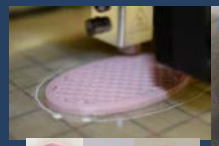
Techshot

Made In Space

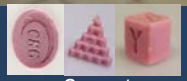
UltraTech

Tethers Unlimited

Common Use Recyclable Materials



Tethers Unlimited

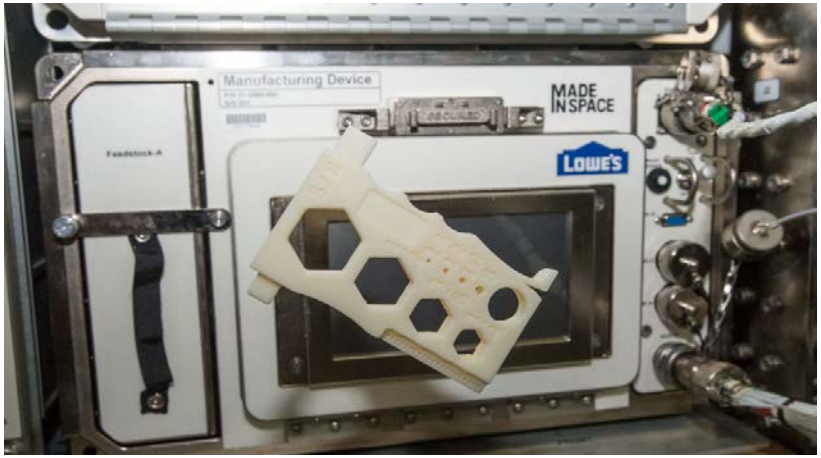


Cornerstone Research Group

Health & Medical

Tethers Unlimited

ISM Utilization and the Additive Manufacturing Facility (AMF): Material Characterization and Functional Parts

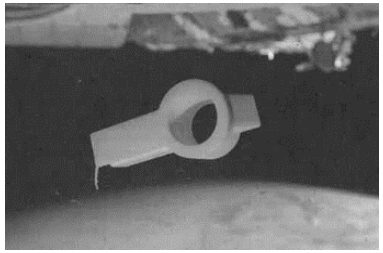


AMF on ISS with printed multi-purpose tool floating in front (photos courtesy of MIS)

SPHERES Tow Hitch

Antenna Feed Horn

REM Shield Enclosure



OGS AAA Adapter

- Additive Manufacturing Facility (AMF), the second generation printer, is a commercial, multi-user facility developed by Made in Space, Inc.
- Upgrades beyond 3DP include:
  a) Print with multiple material (ABS, ULTEM 9085, and HDPE
  b) Integral cameras/sensors for automated monitoring
  c) Maintenance procedures reduce crew time
  d) Leveling and calibration with on-board systems
- Materials characterization task developing baseline mechanical properties on ABS (test matrix below)

AMF Mechanical Property Test Matrix

Type, Orientation	Qty (ground)	Quantity (flight)	ASTM #	Properties
Tension, 0	10	10	D638	Modulus, strength, strain, Poisson's
Tension, 90	10	10	D638	Modulus, strength, strain
Compression, 0	10	10	D695	Modulus, "strength," strain
Compression, 90	10	10	D695	Modulus, "strength," strain
Tension, +/-45 (shear)	10	10	D3518	Modulus, strength, strain, Poisson's
Flatwise tension	10	10	C297	z-direction (through-thickness) tensile strength
Range coupon	2	2	n/a	n/a
EMU fan cap	1	1	n/a	n/a
Total	63	63		

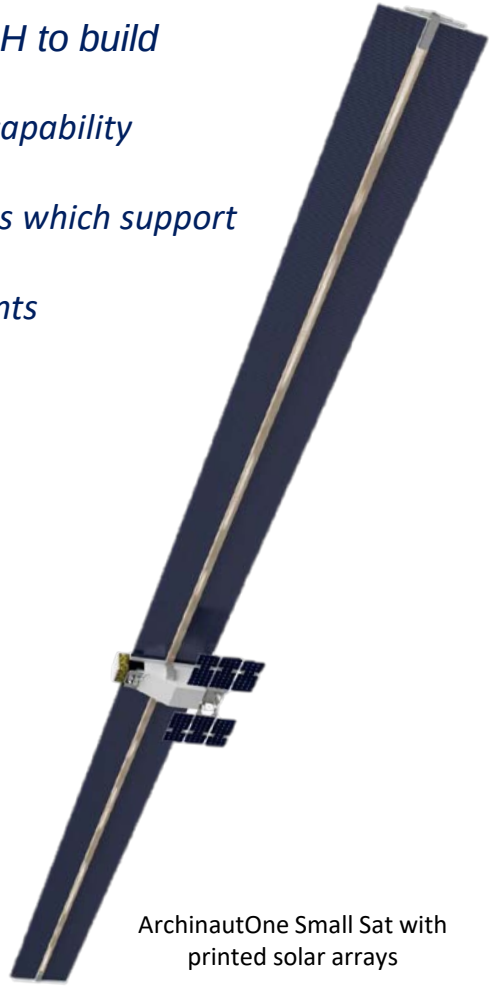
Made In Space (MIS)
Archinaut – Phase II

MIS CEO Andrew Rush with a demonstration of the ArchinautOne Solar array

Objectives:

- *Continue success of ESAMM and GBMASH to build ArchinautOne*
  - *Small satellite with best in class power capability*
  - *Operate in LEO*
  - *ESAMM unit will produce 2x 10 m beams which support 10 m^2 flexible solar panels each*
  - *Robotic arm will position vital components*
  - *In-situ V&V ensures quality product*

ArchinautOne Small Sat

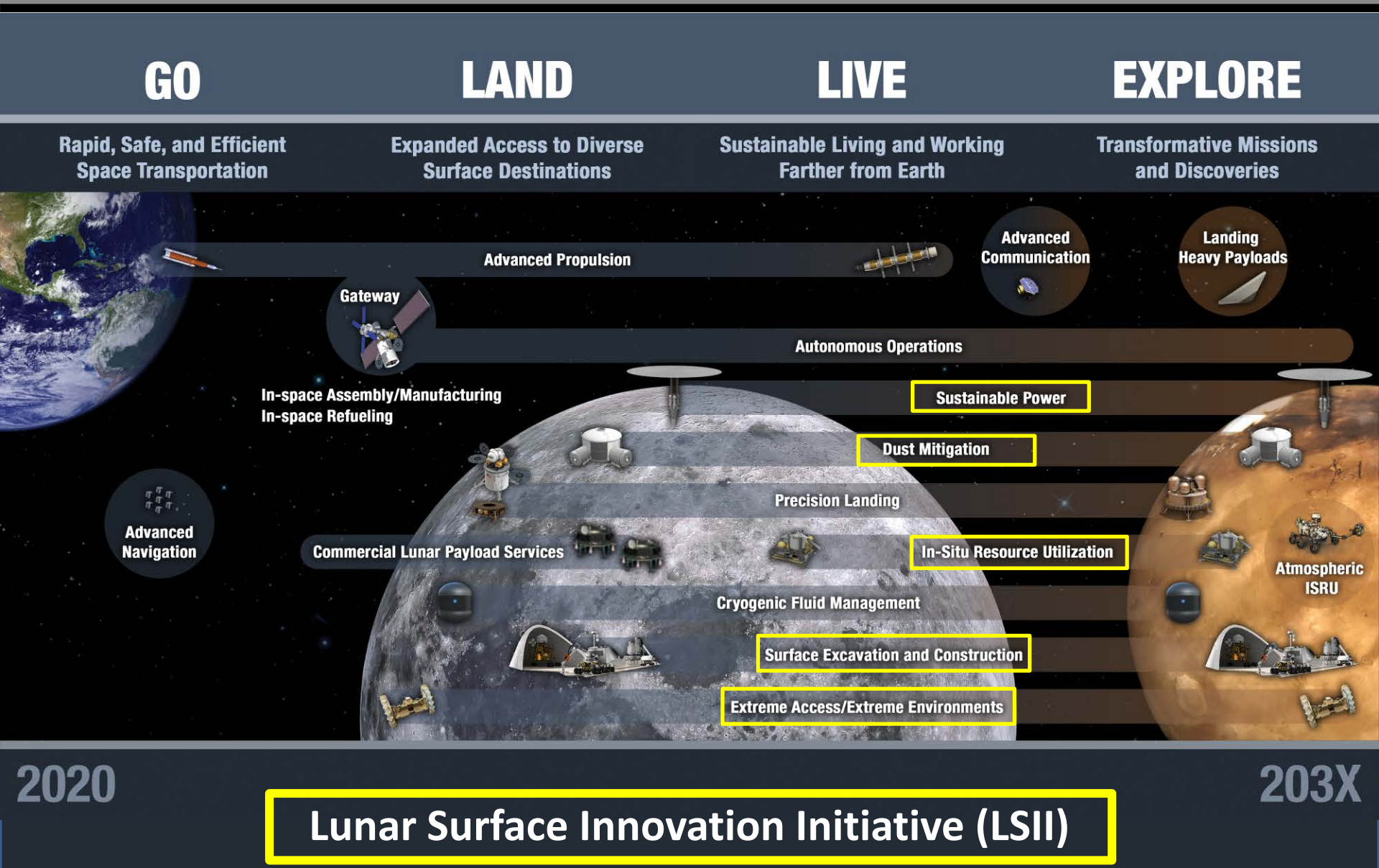


ArchinautOne Small Sat with printed solar arrays

Demonstration of small satellite with >2kW power

Lunar Surface Innovation Initiative

Space Technology Thrust Areas



Lunar Surface Innovation Initiative (LSII)

Lunar Surface Innovation Initiative Elements

In Situ Resource Utilization

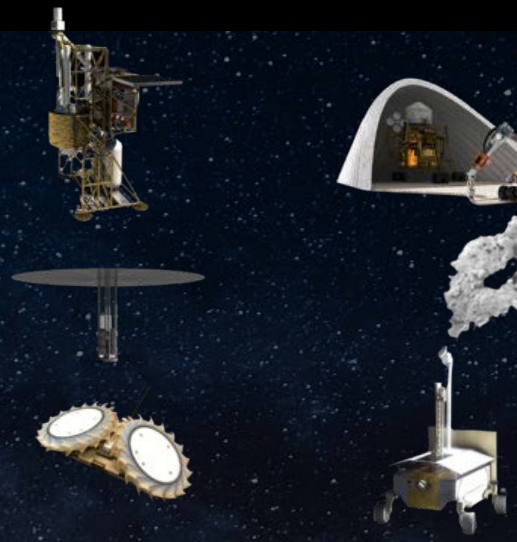
Collection, processing, storing and use of material found or manufactured on other astronomical objects

Sustainable Power

Enable continuous power throughout lunar day and night

Extreme Access

Access, navigate, and explore surface/subsurface areas



Surface Excavation/Construction

Enable affordable, autonomous manufacturing or construction

Lunar Dust Mitigation

Mitigate lunar dust hazards

Extreme Environments

Enable systems to operate through out the full range of lunar surface conditions

- Spurs the creation of novel technologies needed for lunar surface exploration
- Accelerates technology readiness of key systems and components.
- Addresses technology development needs for lunar surface operations, including surface payloads.
- Implements development through a combination of unique in-house activities, competitive programs, and public-private partnerships.
- Coordinates across Agency stakeholders in order to identify priorities.

ISRU Development and Demonstration Timeline

Science & Technology Office

NASA

Reconnaissance, Prospecting, Sampling	Resource Acquisition & Processing	Pilot Consumable Production

Sub-system Demonstrations: ***Investigate, sample, and analyze the environment for mining and utilization.***

Follow The Natural Resources: ***Demonstrations of systems for extraction and processing of raw materials for future mission consumables production and storage.***

Sustainable Exploration: ***Scalable Pilot - Systems demonstrating production of consumables from in-situ resources in order to better support sustained human presence.***

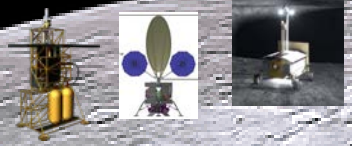
Oxygen from Lunar Simulant Ground Demos

High-fidelity Simulant Production

CLPS Drill Down Select

Polar Resources Ice Mining Experiment (PRIME-1) on CLPS

ISRU Subsystem Consumables Extraction Demos



Scalable Pilot - ISRU Systems for Consumable Production

2019	2022	2024	2028+


NASA
Technology Drives Exploration