National Aeronautics and Space Administration

State of ISRU Construction at NASA

Requirements Generation For The Moon and Mars

Presented by Bob Moses & Rob Mueller
On Behalf of NASA's ISRU Construction Integrated Steering Group

In-Situ Construction vs Manufacturing Defined?

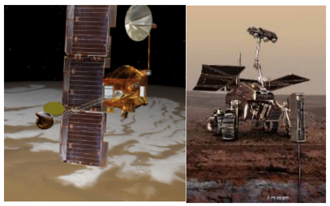
- **We offer the following definitions:**
- **In Situ "Construction" =**
  - "large elements, low dimensional tolerances, not necessarily 3D printed, possibly sintered in place"
  - i.e., bulky, clunky, mostly regolith-based production

- **In Situ "Manufacturing" =**
  - "high tolerance, small components, typically 3D printed"
  - i.e., spare parts out of plastics and metals

Within the Scope of ISRU

ISRU involves any hardware or operation that harnesses and utilizes 'in-situ' resources to create products and services for robotic and human exploration

Resource Assessment (Prospecting)

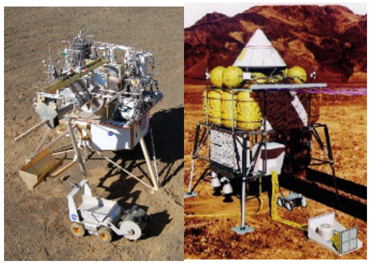


Assessment and mapping of physical, mineral, chemical, and water resources, terrain, geology, and environment

Resource Acquisition

Atmosphere constituent collection, and material/volatile collection via drilling, excavation, transfer, and/or manipulation before Processing

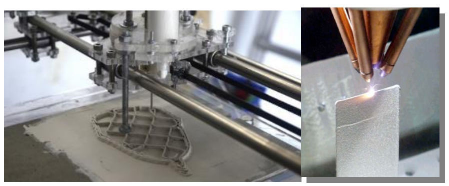
Resource Processing/ Consumable Production



Conversion of acquired resources into products with immediate use or as feedstock for construction & manufacturing

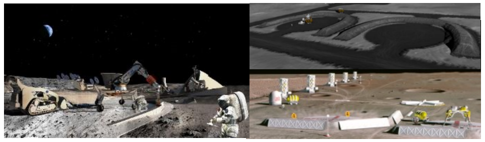
- Propellants, life support gases, fuel cell reactants, etc.

In Situ Manufacturing



Production of replacement parts, complex products, machines, and integrated systems from feedstock derived from one or more processed resources

In Situ Construction



Civil engineering, infrastructure emplacement and structure construction using materials produced from *in situ* resources

- Radiation shields, landing pads, roads, berms, habitats, etc.

In Situ Energy

Generation and storage of electrical, thermal, and chemical energy with *in situ* derived materials

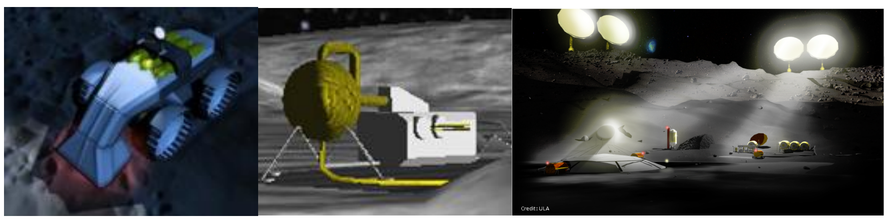
- Solar arrays, thermal storage and energy, chemical batteries, etc.

- **ISRU is a capability involving multiple elements to achieve final products**
- **ISRU does not exist on its own.** By definition it must connect and tie to users/customers of ISRU products and services

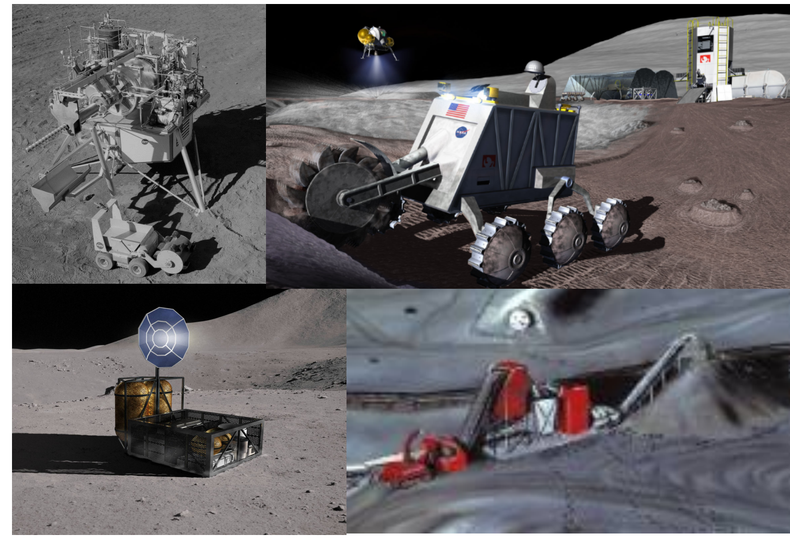
Lunar ISRU Mission Capabilities

Resource Prospecting – Looking for Water

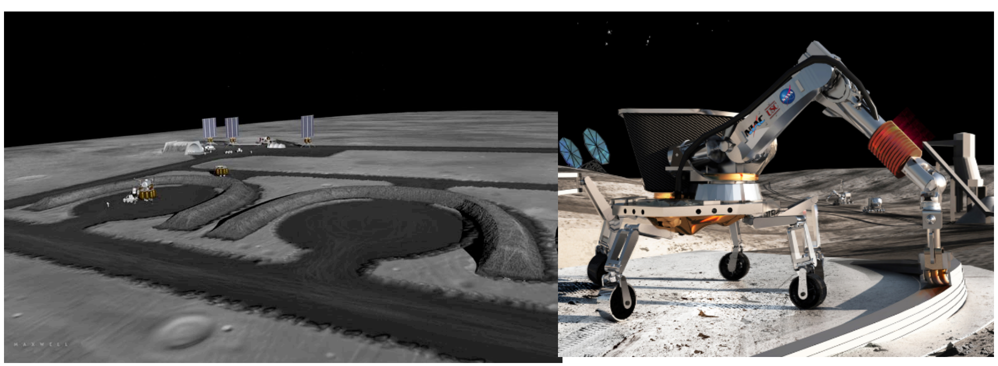
Mining Polar Water & Volatiles



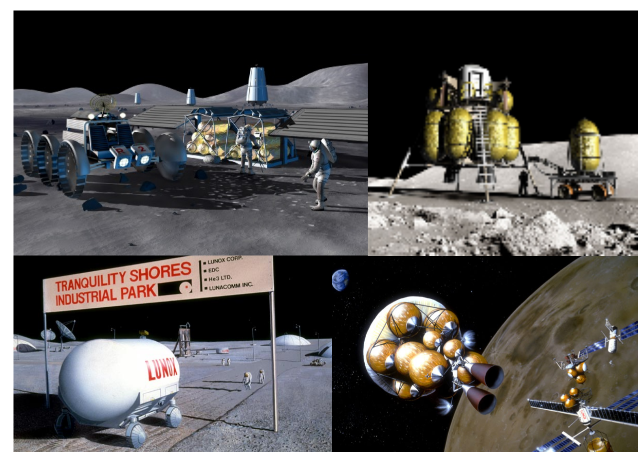
Excavation & Regolith Processing for O_2 Production



Landing Pads, Berms, Roads, and Structure Construction



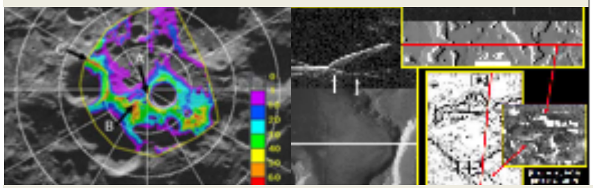
Refueling and Reusing Landers & Rovers



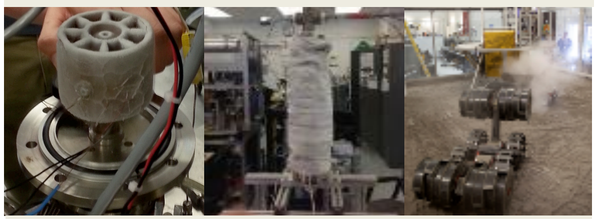
In Situ Resource Utilization (ISRU) Strategic Vector

Today
(Technology & Feasibility)

Significant Uncertainty with Water Resource

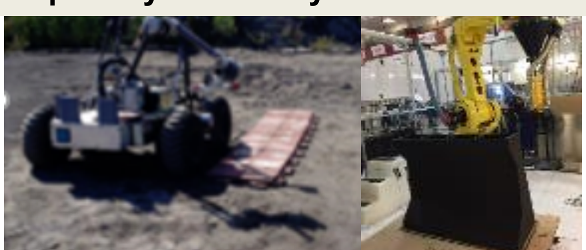


Technology/Concept Evaluation



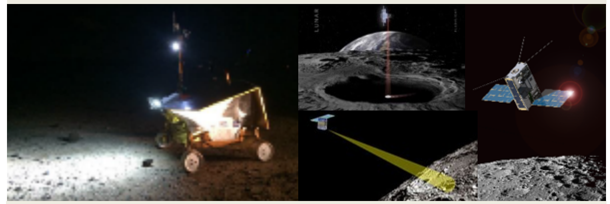
Short Duration System Tests

Capability Feasibility Demonstrated



Near-Term
(Ground Dev. & Flight

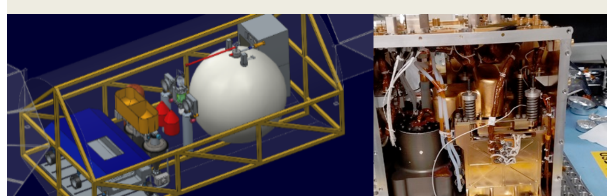
Resource & Water Characterization/Prospecting



Environmental & Long-Duration Ground Testing

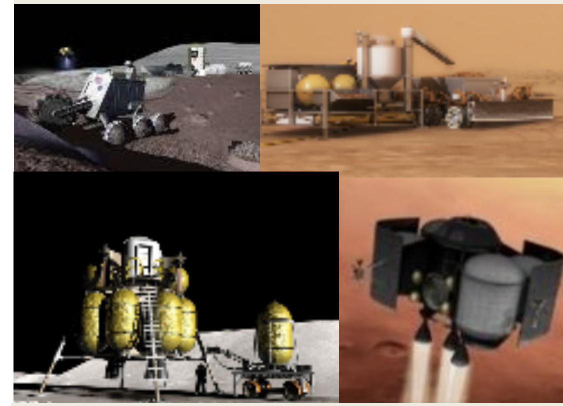
Technology Selection & System Development

Flight Demonstrations & Pilot Plants for Mission Enhancement



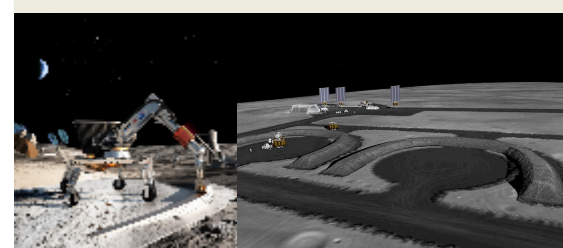
Goal
(Mission Utilization)

Oxygen & Propellant Production for Transportation



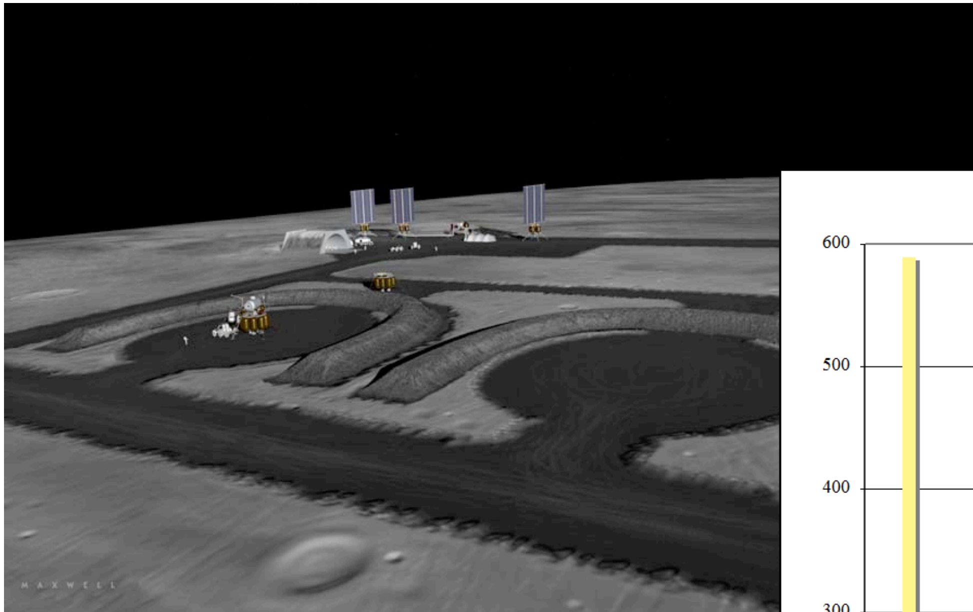
Consumables for Regenerative Power & Life Support

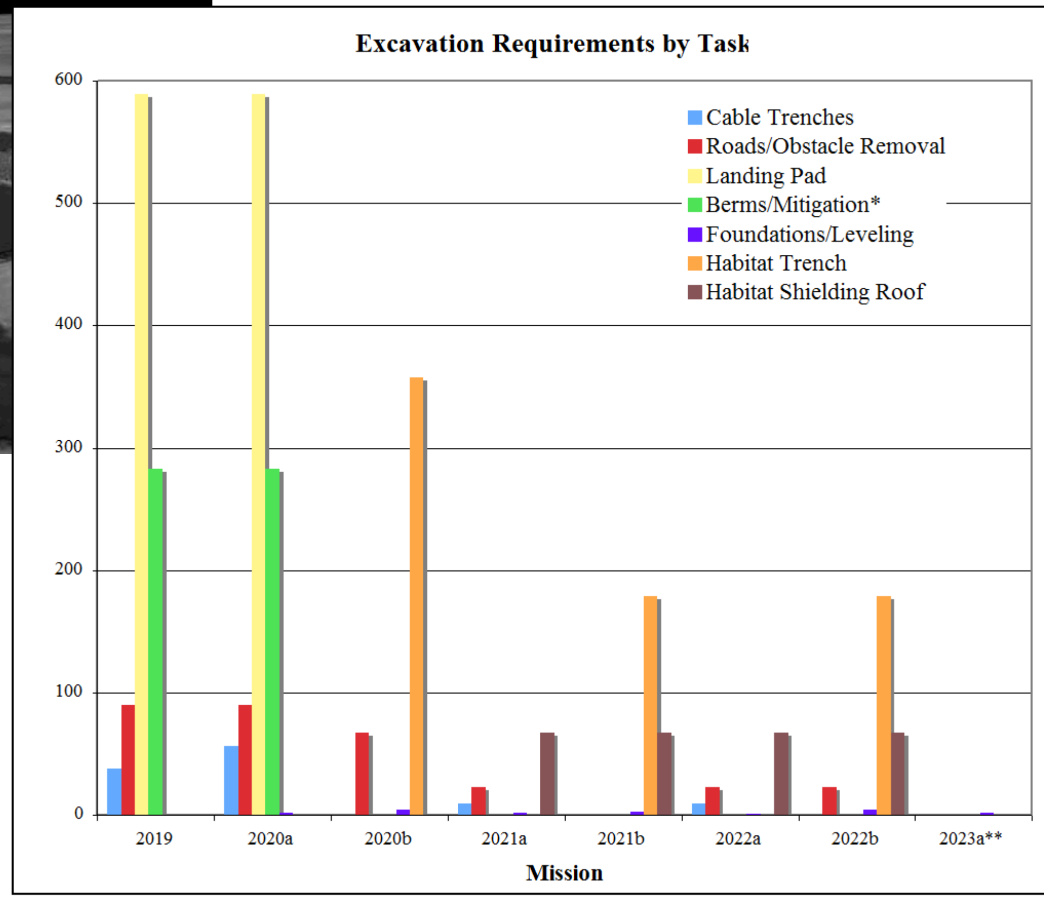
Manufacturing & Construction w/ In Situ Derived Materials



Lunar Surface Construction Tasks: Moving Regolith

Criteria for Lunar Outpost Excavation
R. P. Mueller and R. H. King
Space Resources Roundtable –SRR IX
October 26, 2007
Golden, Colorado





SUMMARY	
Task	**%**
Trenching	**4**
Clearing and Compacting	**48**
Building Berms	**18**
Habitat Shielding	**31**
	100
Ice Mining	**17**
Regolith Mining	**83**
Construction	**84**
Mining	**16**

GOALS

- Derive a set of Comprehensive Requirements for Infrastructure on the Moon and Mars that require or could benefit substantially from ISRU

- Develop a Framework for In Situ Construction that can help drive mission concepts, vehicle designs, and ISRU investments

- Create a Forum of Experts within NASA to do this
  - →In Situ Construction Integrated Steering Group
    - →Kicked off on 25 October 2018 by Jerry Sanders

- Regular meetings are held to coordinate and discuss NASA activities

- Seek input from the community e.g. SRR, ASCE, AIAA

- Peer review of on-going work

ISRU Construction Integrated Steering Group (ISG) Members & Key Players

- **ISRU SCLT**
  - Bob Moses/LaRC, Rob Mueller/KSC, Eric Fox/MSFC
- **Autonomy SCLT**
  - Terry Fong/GRC and/or rep
- **Materials CLT**
  - Rick Russell/KSC, Dewitt Burns/MSFC
- **ISRU PT**
  - Julie Kleinhenz/GRC
- **Structures/Materials/Nanotechnology PT**
  - Mark Hilburger/LaRC (formerly Keith Belvin/LaRC)
- **Materials & Manufacturing PT**
  - John Vickers/MSFC
- **Robotics PT**
  - Kim Hambuchen/JSC and/or rep.
- **EDL PT**
  - Michelle Munk/LaRC

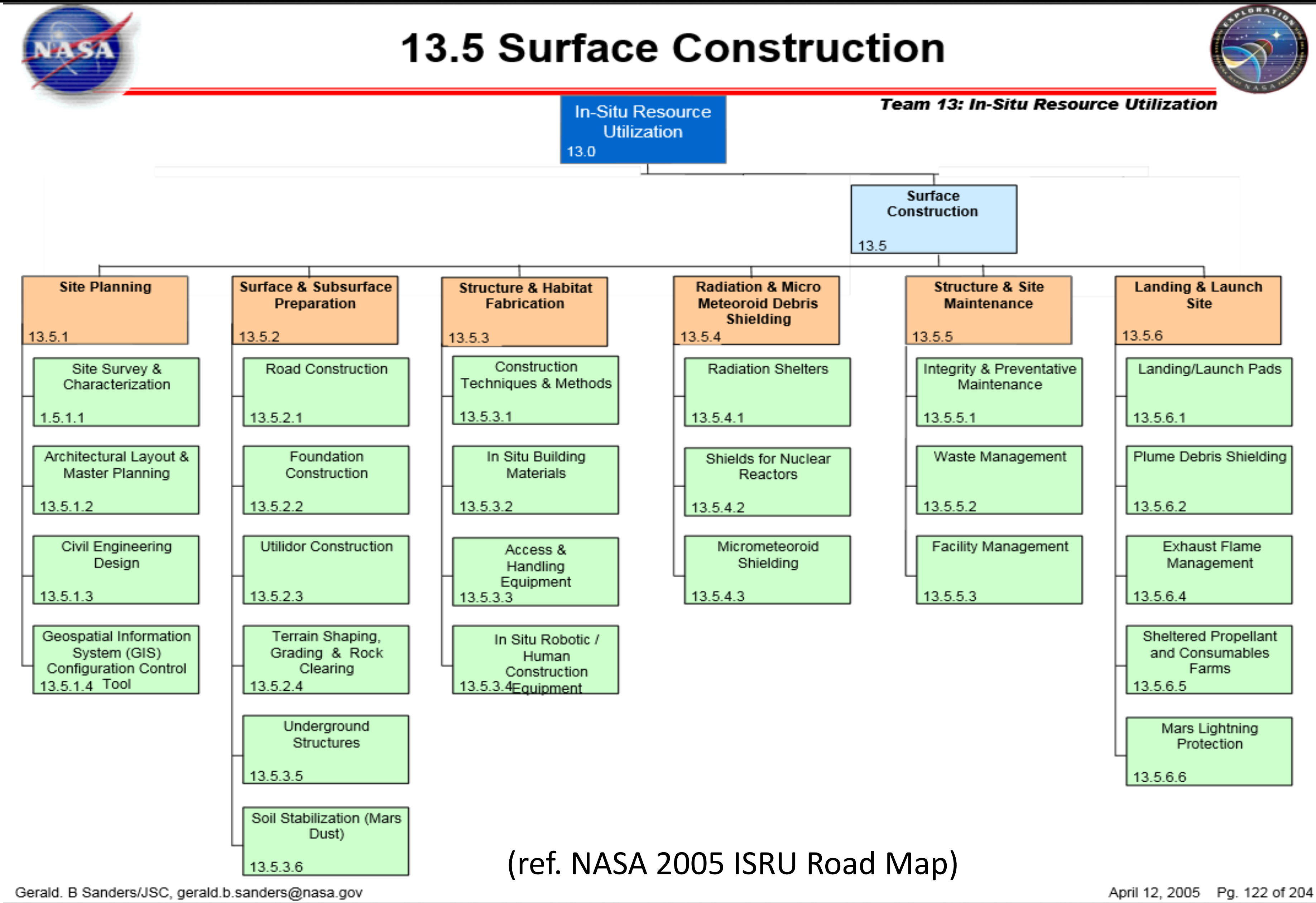
Purpose of ISRU Construction ISG

Each member of the ISRU Construction ISG has separate responsibilities that involve NASA strategic planning and investment/prioritization wrt to *In Situ* Construction which can lead to duplicative/conflicting recommendations to Mission Directorate management, and/or missed opportunities to develop *In Situ* Construction capabilities.

Therefore, the purpose of establishing the ISRU Construction ISG is to provide shared oversite and to provide a Forum for key Agency leads to:

1. **Discuss, coordinate, and develop common goals, objectives, and development/implementation plans for *In Situ* Construction. This includes:**
   - Functional block diagrams and WBS
   - Requirements/Key Performance Parameters
   - Mission needs and insertion timeline (and therefore Mission Directorate needs) for In Situ Construction capabilities
   - Technology/capability assessment and Gap identification
2. **Discuss and coordinate investment recommendations/project new starts to achieve goals, objectives, and implementation plans. This includes:**
   - Ensuring Center roles and expertise is leveraged to the maximum extent possible
3. **Be interface to Commercial, Universities & other government agencies**

Construction in the Context of the 2005 Roadmap



(ref. NASA 2005 ISRU Road Map)

PROPOSED NEW FUNCTIONAL CAPABILITIES WBS

- 4.0 In-Situ Construction
  - 4.1 Site Planning and Design
    - Site Survey & Characterization
    - Architecture Layout & Master Planning
    - Civil Engineering Design
    - GIS Configuration Control
    - Construction Techniques and Methods
    - Access & Handling Equipment
    - Robotic/Human Construction Equipment
  - 4.2 In-Situ Construction Materials
    - Raw Material
    - By-product Material
    - Processed Material
    - Re-purposed Material
    - Stockpiling & Material Logistics
  - 4.3 Site Prep
    - Terrain Shaping, Grading, & Rock Clearing
    - Soil Stabilization
    - Below Grade Operations
  - 4.4 Horizontal Construction (2D) & Pads
    - Road Construction
    - Foundation Construction
    - Utilidor Construction
    - Landing / Launch Pad
  - 4.5 Vertical Constriction (3D) & Shielding
    - Underground structures
    - Above Ground Structures
    - Shielding
    - Landing / Launch Pad Infrastructure
  - 4.6 Maintenance & Life-cycle
    - Inspection & Compliance
    - Integrity & Preventative Maintenance
    - Lifecycle Operations
    - Facility Management
    - Waste Management
    - Decommission and Re-planning / Salvage

Uses Construction industry terminology

Getting Started on REQUIREMENTS VS CAPABILITIES

WHAT'S NEEDED?

(DEFINED BY ARCHITECTURE)

- **Pressurized Structures**
- **Landing & Launch Pads**
- **Fission / Blast Berms**
- **Radiation Shielding for crew and equipment**
- **Road and route ways**
- **Other infrastructure such as trenches and compacted foundations**
- **Non-pressurized structures such as garages, hangars, and refueling depots**
- **Dust-free zones for parking and operations**
- **Access to Energy / Power**

WHAT'S THERE?

(GEOLOGICAL & GEOTECHNICAL)

- **Natural Resources**
  - Abundant Solar Energy
  - Water & other volatiles
  - Regolith
    - Bulk material for construction
    - Extracted metals from minerals
    - Basalt glass fiber for composites
  - Mars Atmosphere
- **Tools & Processes**
  - Seismic
  - Ground Penetrating Radar
  - Borings
  - Sample Assays
  - Mining & Refining
  - Production & Storage
  - Others

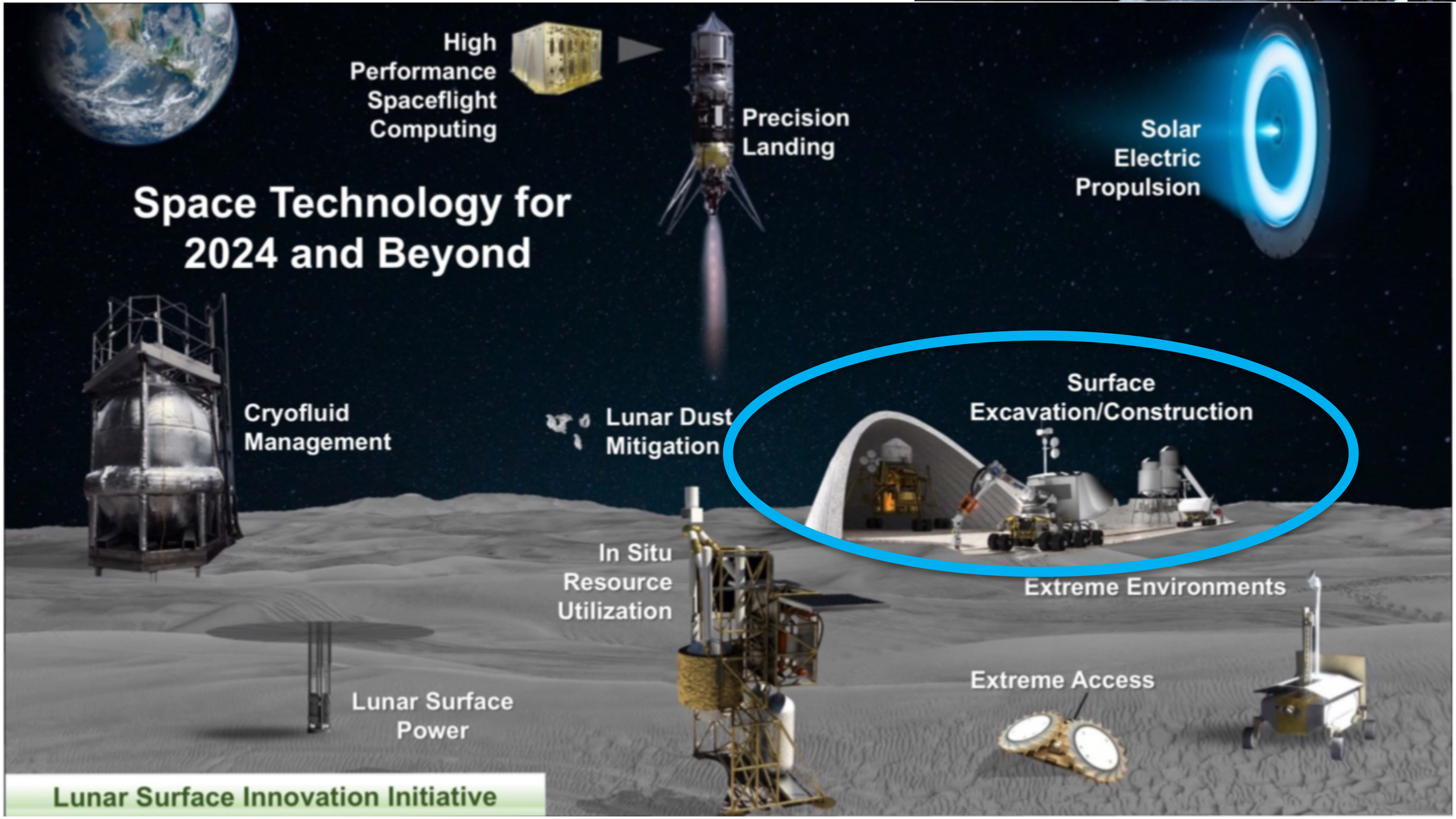
DATA SOURCES FOR DERIVING REQUIREMENTS

- **SURFACE ARCHITECTURE & MISSION PLANNING**
  - YIELDS MINING CONCEPTS OF OPERATIONS & INFRASTRUCTURE DESIGNS
- **LAUNCH AND LANDING PADS**
  - PLUME INTERACTIONS STUDY (EDL AND AEROSCIENCES)
  - DESIGN ANALYSIS CYCLES FOR ASCENT AND DESCENT MODULES
- **BERMS**
  - FISSION REACTORS: Lee Mason
  - BLAST BERMS: see PADS
- **GCR OVERCOATS**
  - ANALYSIS AT LaRC BY SINGLETERRY & MOSES
  - RESULTS UPDATE & REPORT COMING SOON
- **SURFACE HABITATS**
  - GRAVITY LOADS DUE TO OVERBURDEN
- **DRIVE AISLES**
  - MOBILITY DRIVEN
- **TRENCHES**
  - UTILITIES DRIVEN

ESTABLISHING PRIORITIES

Artemis:

https://www.nasa.gov/sites/default/files/atoms/files/america_to_the_moon_2024_artemis_20190523.pdf



ESTABLISHING PRIORITIES continued

- **Timing of NASA HQ Solicitations and ISRU Funding Guidance**

- **Mission Challenges That In Situ Construction Can Help Solve**
  - Ejecta damage to lander & surrounding assets during Landing & Launch
  - Ejecta in orbit
  - Cratering under the lander
  - Reusability
    - Rocket plume Interactions Study is underway
  - GCR Shielding
    - Analysis is well underway at LaRC
  - Habitation Systems

- **WHAT WOULD “THE ROUNDTABLE” RECOMMEND?**

- **COMMENTS & SUGGESTIONS WELCOMED**