



State of ISRU Construction at NASA

Presented by Rob Mueller, NASA KSC Swamp Works
On Behalf of NASA's In-Situ Construction Community

July 31, 2020
LSIC Excavation & Construction monthly meeting



ESTABLISHING PRIORITIES

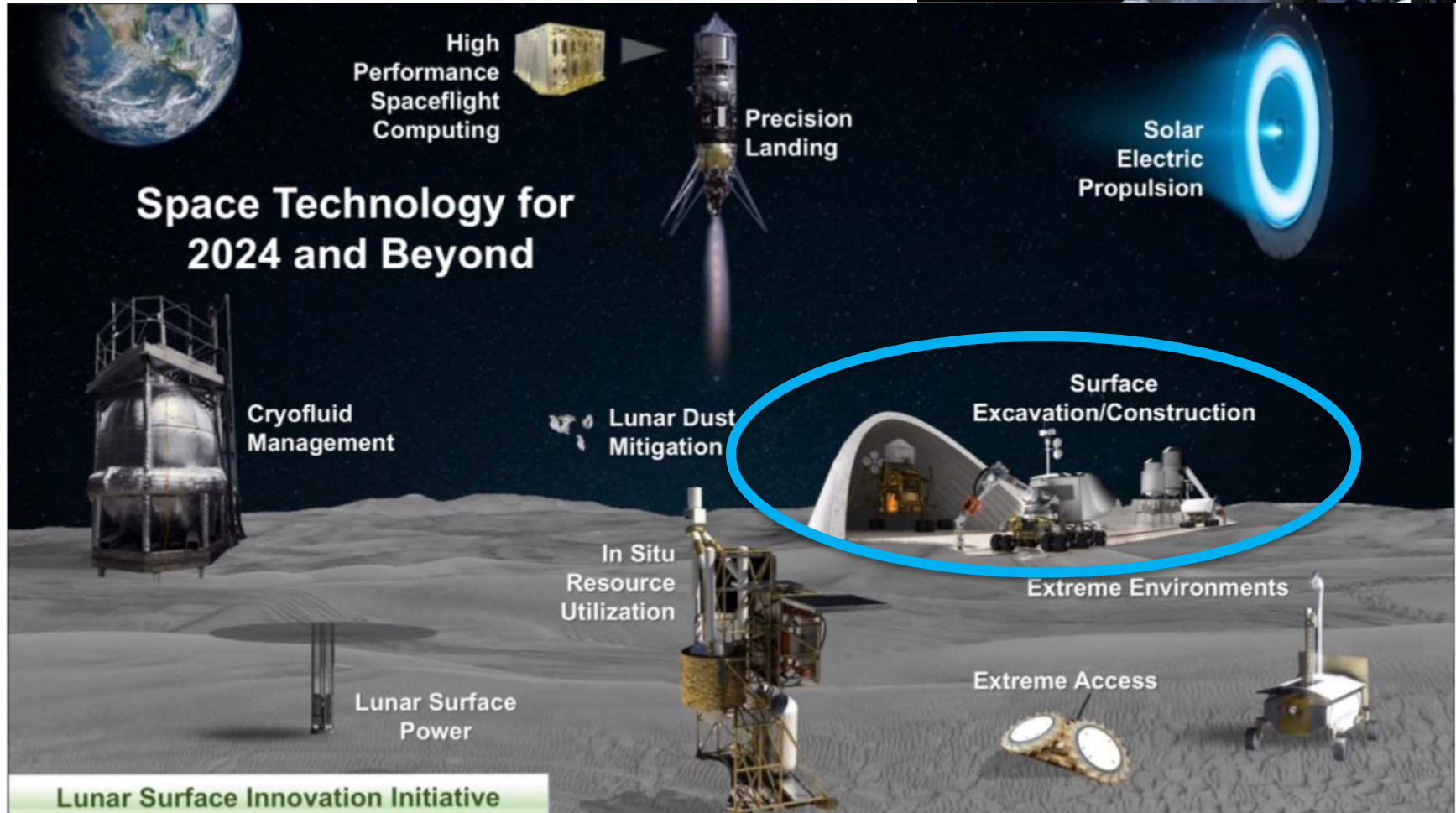
Artemis:

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

FORWARD TO THE MOON:

NASA's Strategic Plan for
Lunar Exploration

Updated 5/30/2019





THE WHITE HOUSE

A New Era for Deep Space Exploration and Development

Product of
THE WHITE HOUSE
NATIONAL SPACE COUNCIL

JULY 23, 2020

This focus on further extending an extraterrestrial human and robotic presence and on the development of commercial space industries makes the Artemis Program much more than a repeat of the Apollo Program. A serious, determined approach to lunar development requires a series of pre-positioned logistics packages. ***A combination of 3-D printing, telerobotics, and artificial intelligence could enable pre-positioning the equivalent of a small Antarctic scientific station. Newly arrived astronauts should have a substantial amount of resources already available and be able to spend their initial weeks building out the initial infrastructure for larger, future development teams***

Field Station Analog-McMurdo, Antarctica



British National Antarctic Expedition 1902
R.F. Scott's "winter quarters hut"

Emplacement



~100 Years of
Development



**Accelerate these
timelines with
commercial
partnerships**

Permanent occupation - 1955

Consolidation



McMurdo Station Today

Utilization



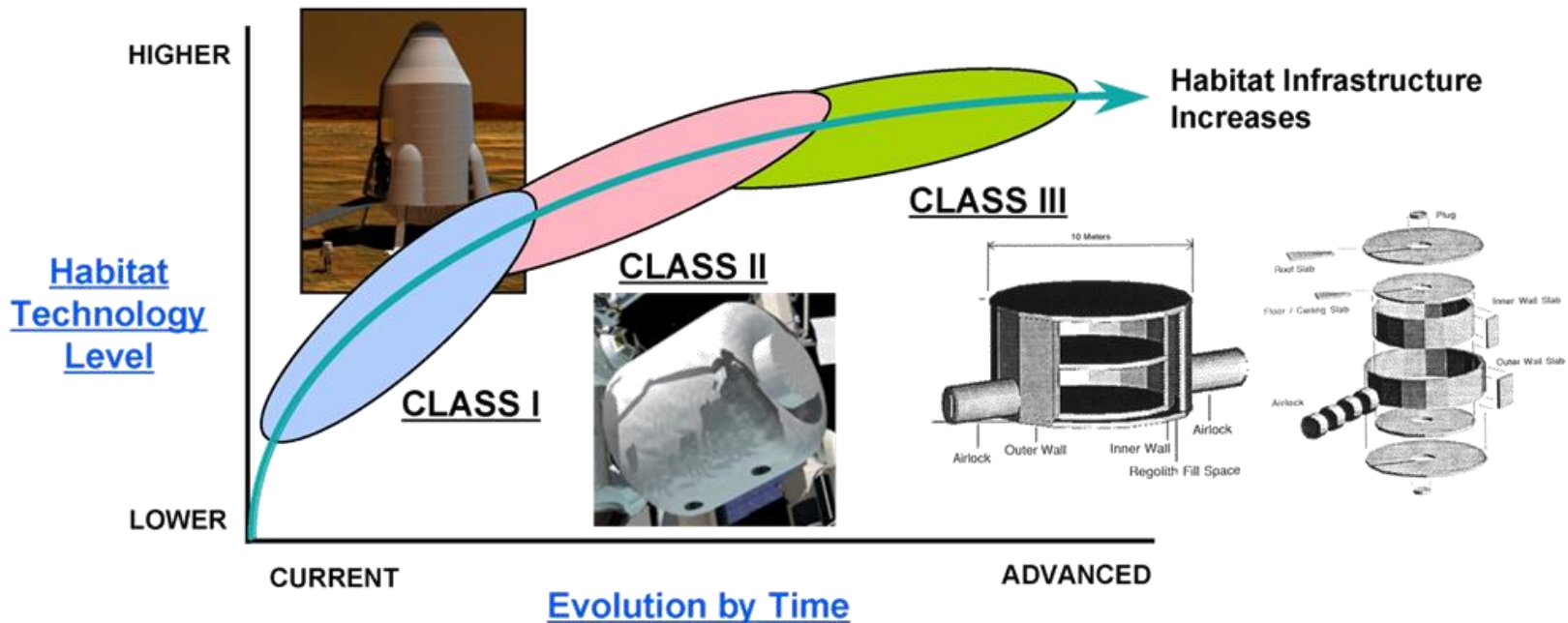
International Antarctica Bases Today: South Pole



Classification of Lunar Construction



- **CLASS I:**
 - Preintegrated, Hard Shell Module
- **CLASS II:**
 - Prefabricated, Surface Assembled
- **CLASS III:**
 - ISRU Derived Structure w/ Integrated Earth components



Ref: Scott Howe et al

Getting Started on REQUIREMENTS VS CAPABILITIES



INFRASTRUCTURE: WHAT'S NEEDED? (DEFINED BY ARCHITECTURE)

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

RESOURCES: WHAT'S THERE? (ENERGY, GEOLOGICAL MATERIALS & GEOTECHNICAL CHARACTERISTICS)

- **Natural Resources**
 - Abundant Solar Energy
 - Water & other volatiles
 - Regolith
 - Bulk material for construction
 - Extracted metals from minerals
 - Basalt glass fiber for composites
 - Thermal Deltas, Vacuum, Location etc
- **Capabilities, Tools & Processes**
 - Regolith Simulants
 - Cone penetrometer/ shear vane
 - Seismic
 - Ground Penetrating Radar
 - Borings
 - Sample Assays
 - Mining & Size sorting, beneficiation
 - Production & Storage
 - Other capabilities & tools being developed

Functional Capabilities Needed

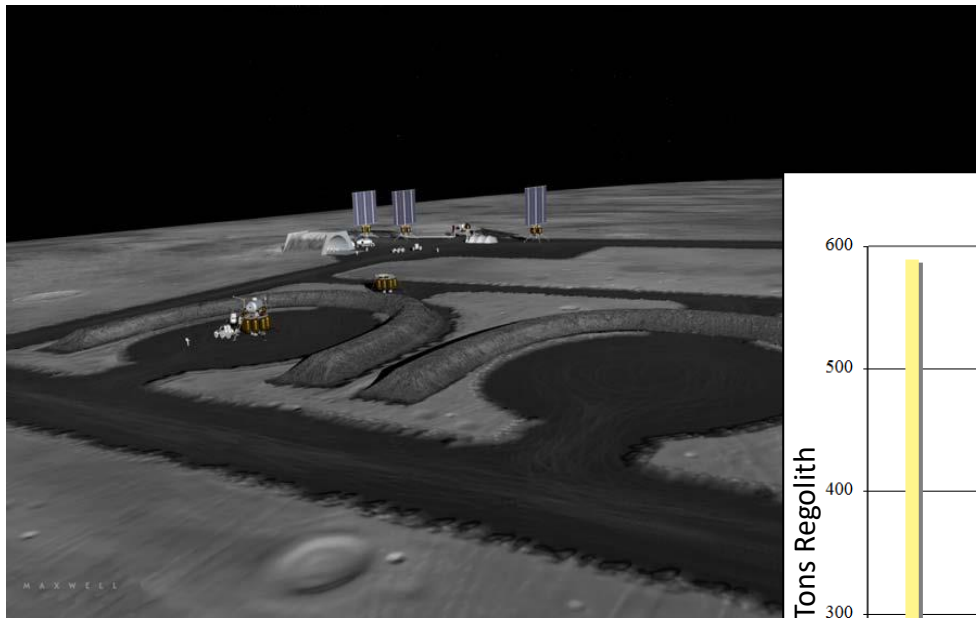


- Long-distance communication, monitoring, and control
- Increased autonomy/automation of operations
- Improved user experience/ease of operation (i.e. reduced training load)
- Multi-material printing & related control systems
- Increased transportability / mass reduction
- Expanded environmental range
- Design for field reparability
- Software Design Platform
- Dust mitigation
- Shielding / Ballistic Protection
- Jobsite Mobility
- Off-foundation construction / foundation delivery

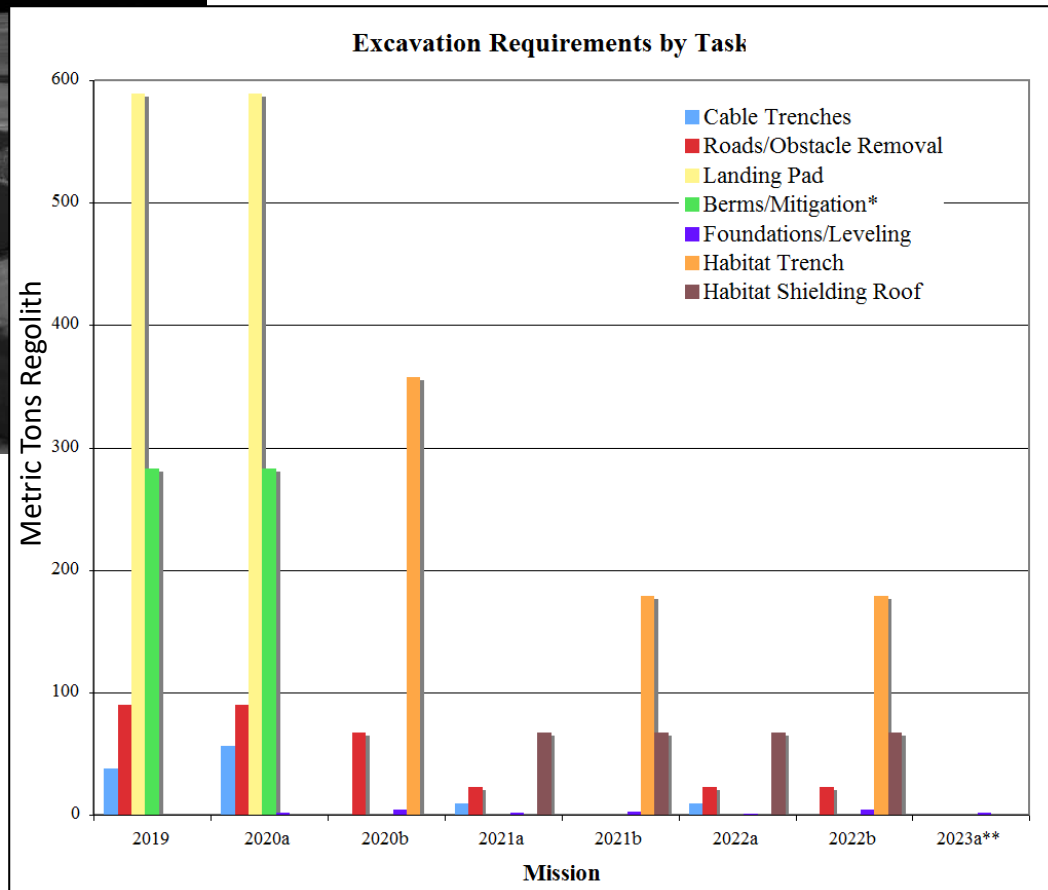
Scale of Lunar Surface Construction Tasks: Moving Regolith



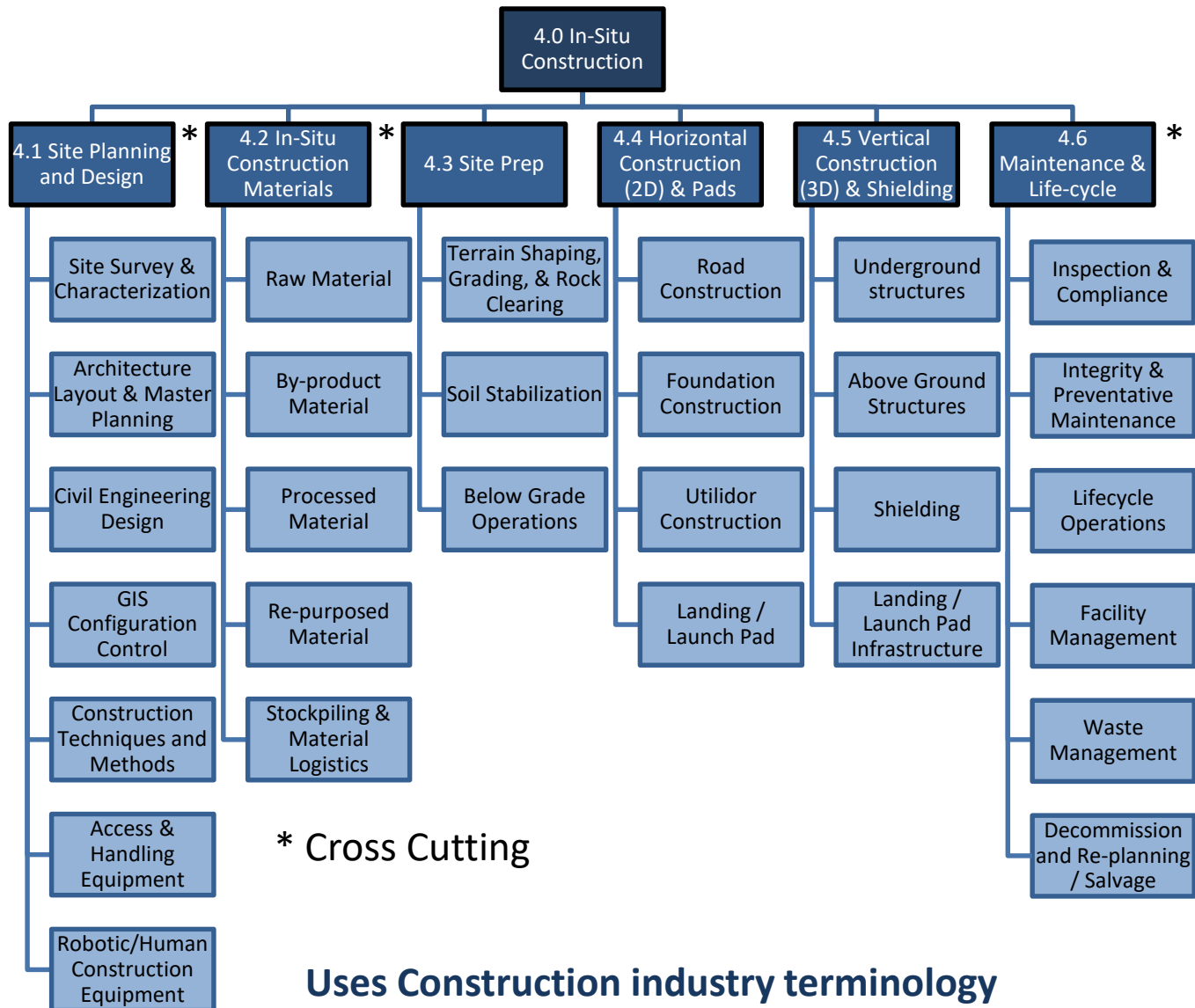
Criteria for Lunar Outpost Excavation
 R. P. Mueller and R. H. King
 Space Resources Roundtable –SRR IX
 October 26, 2007
 Golden, Colorado



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



PROPOSED NEW FUNCTIONAL CAPABILITIES WBS



Current NASA In-Situ Construction Projects



- **Several Game Changing Development (GCD) Programs, some new starts for FY21, focused on “Lunar Surface to Stay”**
 - Moon-to-Mars Planetary Autonomous Construction Technologies (MMPACT) (MSFC Led): Broad Effort using Applicable Technologies
 - In-Situ Construction (KSC Led): Focused on Polymer Concrete Construction
 - Lunar Safe Haven (LaRC Led): Developing NASA system level requirements
- **Several ACO / Tipping Point proposals currently in review**
- **NASA Centennial Excavation, Manufacturing & Construction “EMC” Challenge currently focusing on an “E” Challenge**
- **SBIR subtopics being considered now**
- **STMD continues its gap analysis for functional capabilities that include Surface Construction**
- **International Space Exploration Coordination Group (ISECG) is conducting a separate gap analysis for In Situ Resource Utilization (ISRU) that includes Construction & Manufacturing elements (Sanders & Moses participate for NASA)**



- **University Collaborations**

- MSFC Cooperative Agreement Notice (CAN's) Efforts

- University of Mississippi – Ionics Liquids Extraction for Lunar Concrete Binder Materials
 - University of Mississippi – Effects of Lunar Seismic Activity on Landing Pads
 - Mississippi State University – Lunar Steel Production
 - University of Nevada Las Vegas – Ionic Liquids Extraction of Metals from Lunar Regolith
 - Drake State Technical School – Development of an Additive Construction Workforce
 - University of Alabama in Huntsville – Testing of Large Scale Structures
 - Kappler – Environmental Control During Curing of Lunar Concretes



Thank you for your attention!

**NASA is looking forward to collaboration with
industry, academia and other government
agencies**