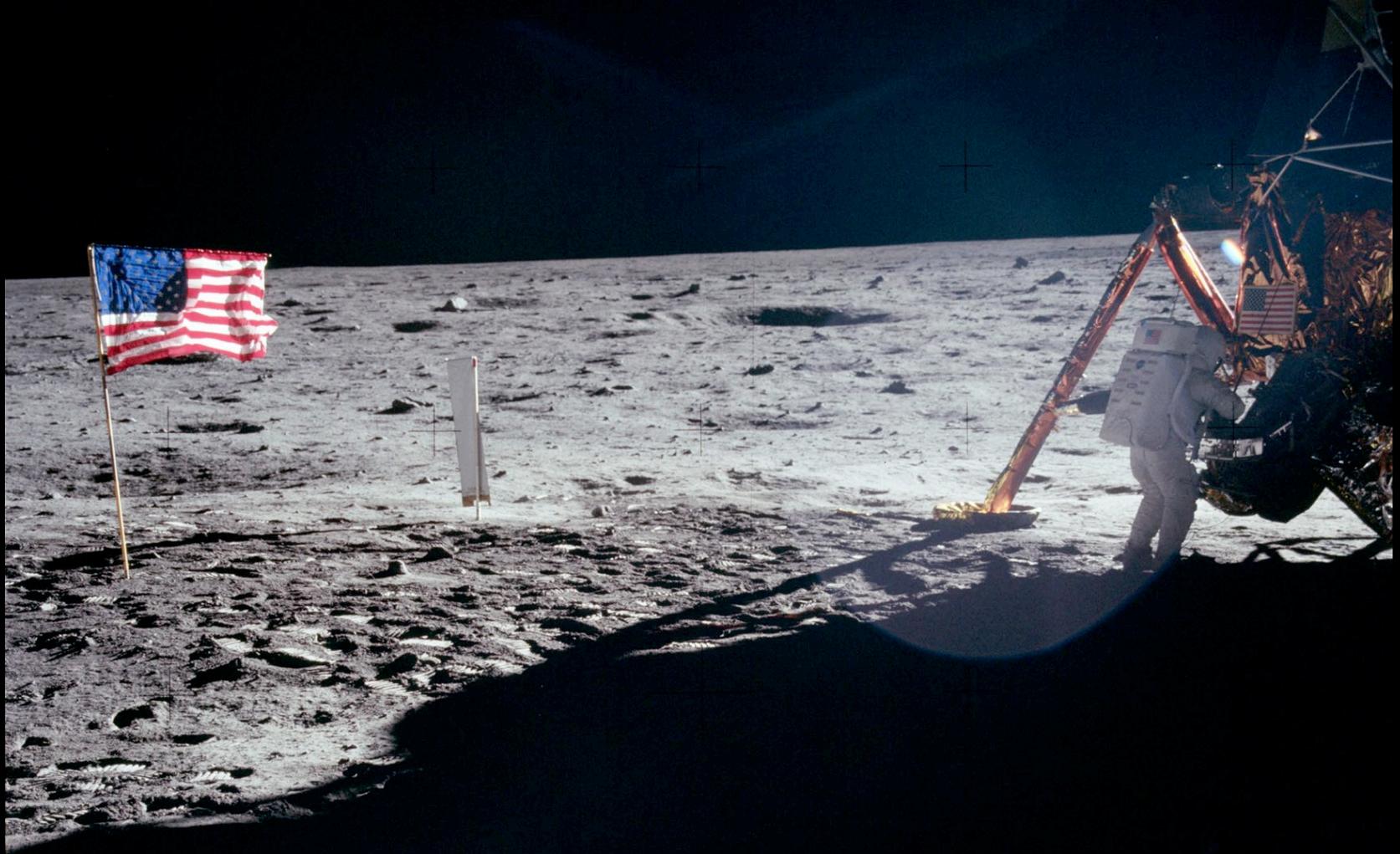


Apollo 11: Science and Future Operational Significance

A black and white photograph of an astronaut in a full space suit walking across the lunar surface. The astronaut is carrying a large backpack and is positioned in the middle ground, walking away from the viewer. The terrain is rocky and uneven, with several large boulders in the foreground. The background shows a vast, flat lunar landscape under a dark sky. The overall scene is desolate and emphasizes the isolation of the moon.

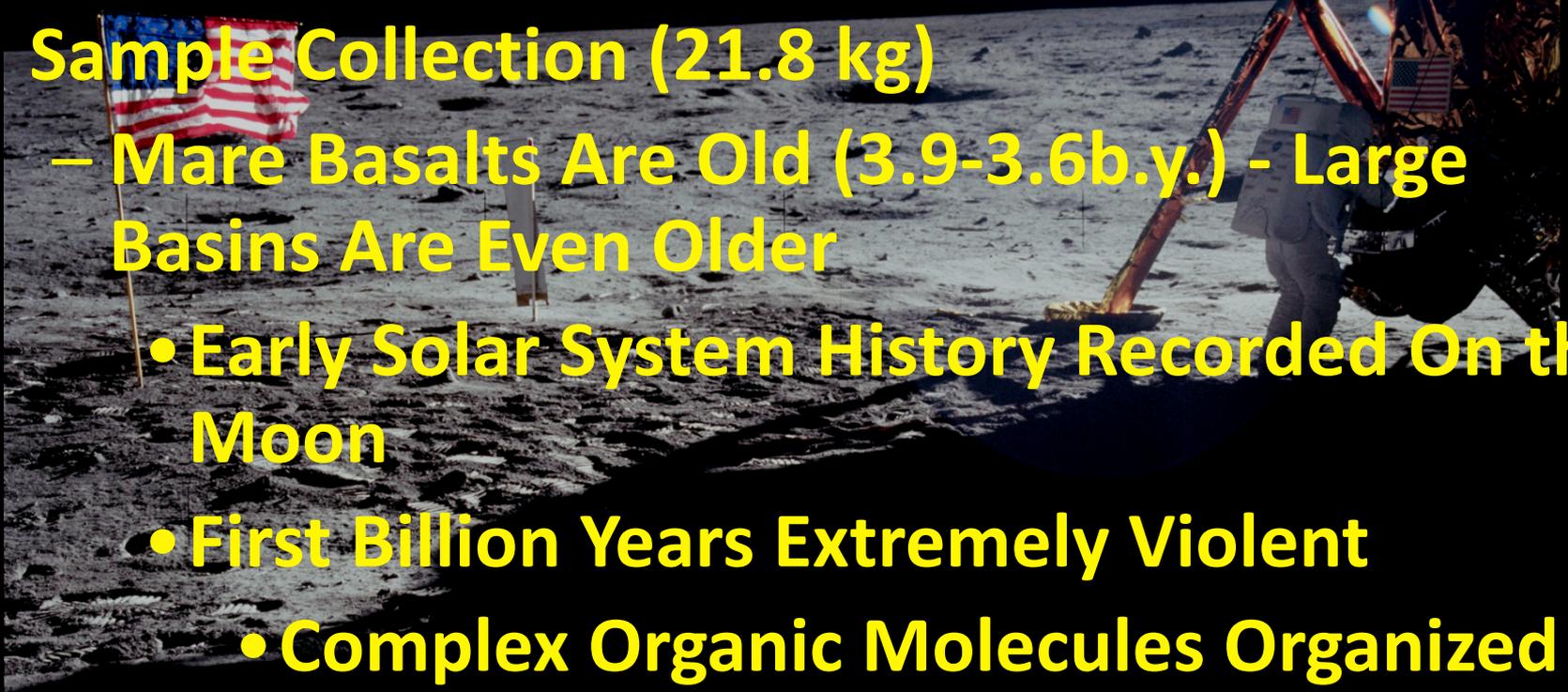
Harrison H. Schmitt
SSERVI 2019
Ames Research Center
July 24, 2019

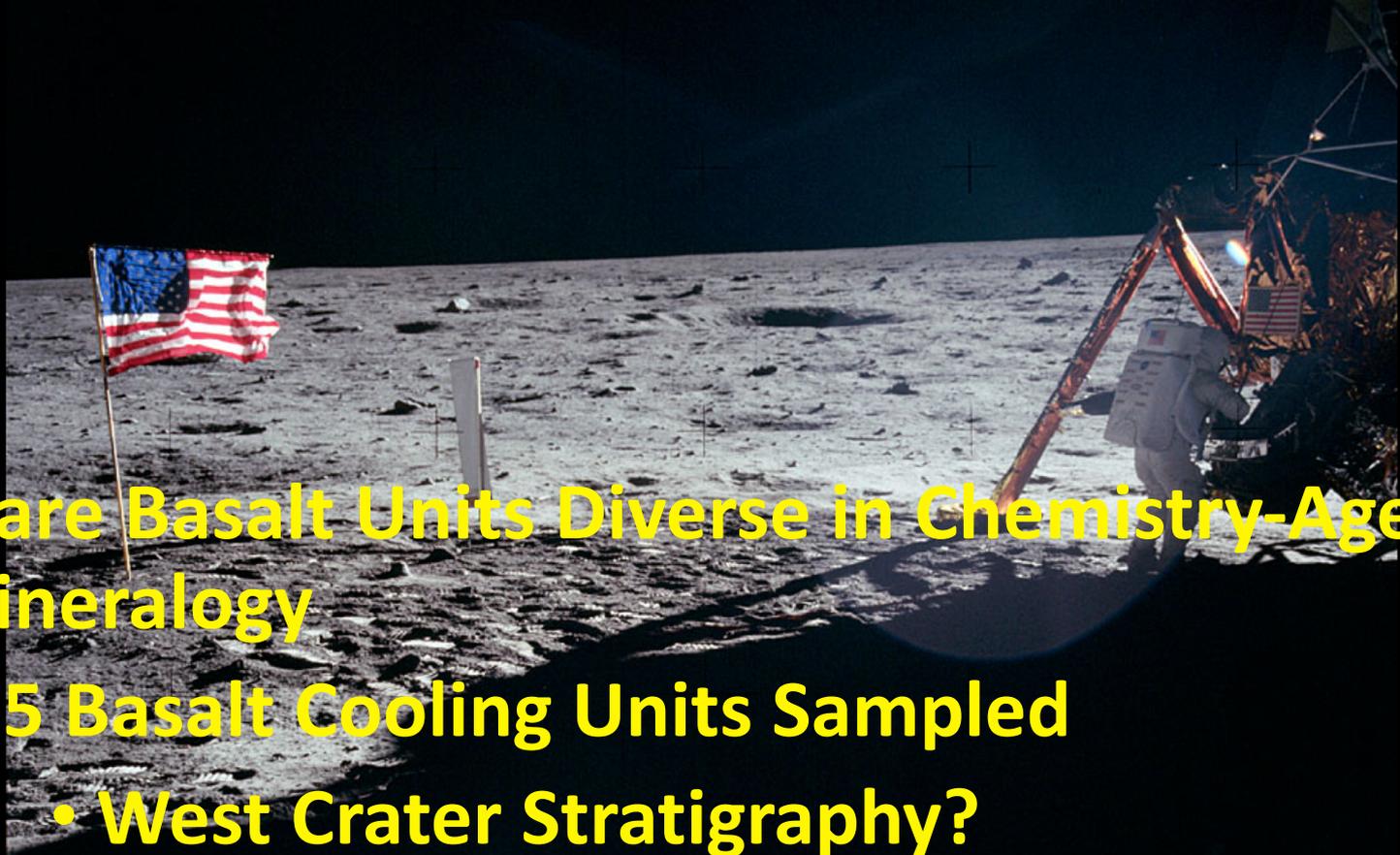




Apollo 11 Science Conclusions Had There Been No Other Landings

- Sample Collection (21.8 kg)
 - Mare Basalts Are Old (3.9-3.6b.y.) - Large Basins Are Even Older
 - Early Solar System History Recorded On the Moon
 - First Billion Years Extremely Violent
 - Complex Organic Molecules Organized
- Water-Rich Regolith Would Alter to Clay
 - Templates for Organic Molecules on Earth and Mars



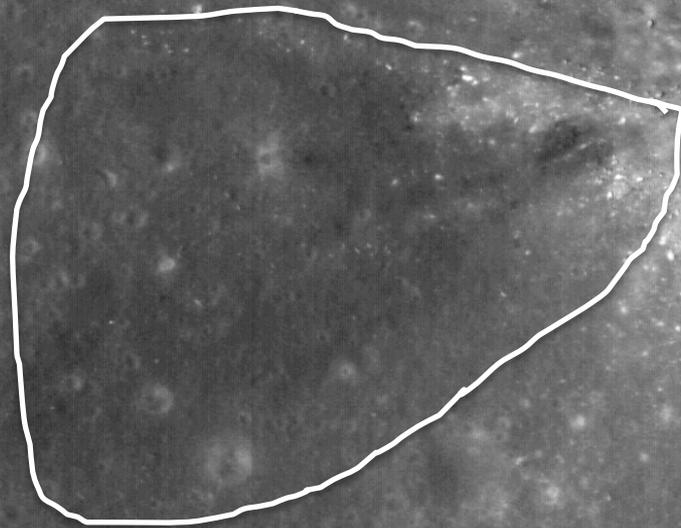


- **Mare Basalt Units Diverse in Chemistry-Age-Mineralogy**
 - **5 Basalt Cooling Units Sampled**
 - **West Crater Stratigraphy?**
 - **9 Separate Vesicle Assemblages**
 - **Unique Flows and/or Intra-flow Differentiation**
 - **2 Varieties of Pyroclastic Glasses**

Apollo 11 Site



**Sampling Area.
Note Ray from
West Crater**



West Crater

Source of Pyroclastics ala Shorty??

- **Magma Ocean-Fractional Crystallization-Remelting Hypothesis**
 - **Anorthositic Fragments**
 - **Differentiated Source Region for Basalt**
 - **Specific Titanium-rich Source or Assimilation Region**
 - **Vesicles Indicate Hydrogen in Source Region**
 - **Eventual KREEP Detection?**
 - **Eventual Pyroclastic Water Detection?**
- **Mineralogy**
 - **6 New Titanium-bearing Minerals**
 - **Low Defect Crystallization**
- **Isotopic Geochemistry**
- **Moon As Old as Solar System**

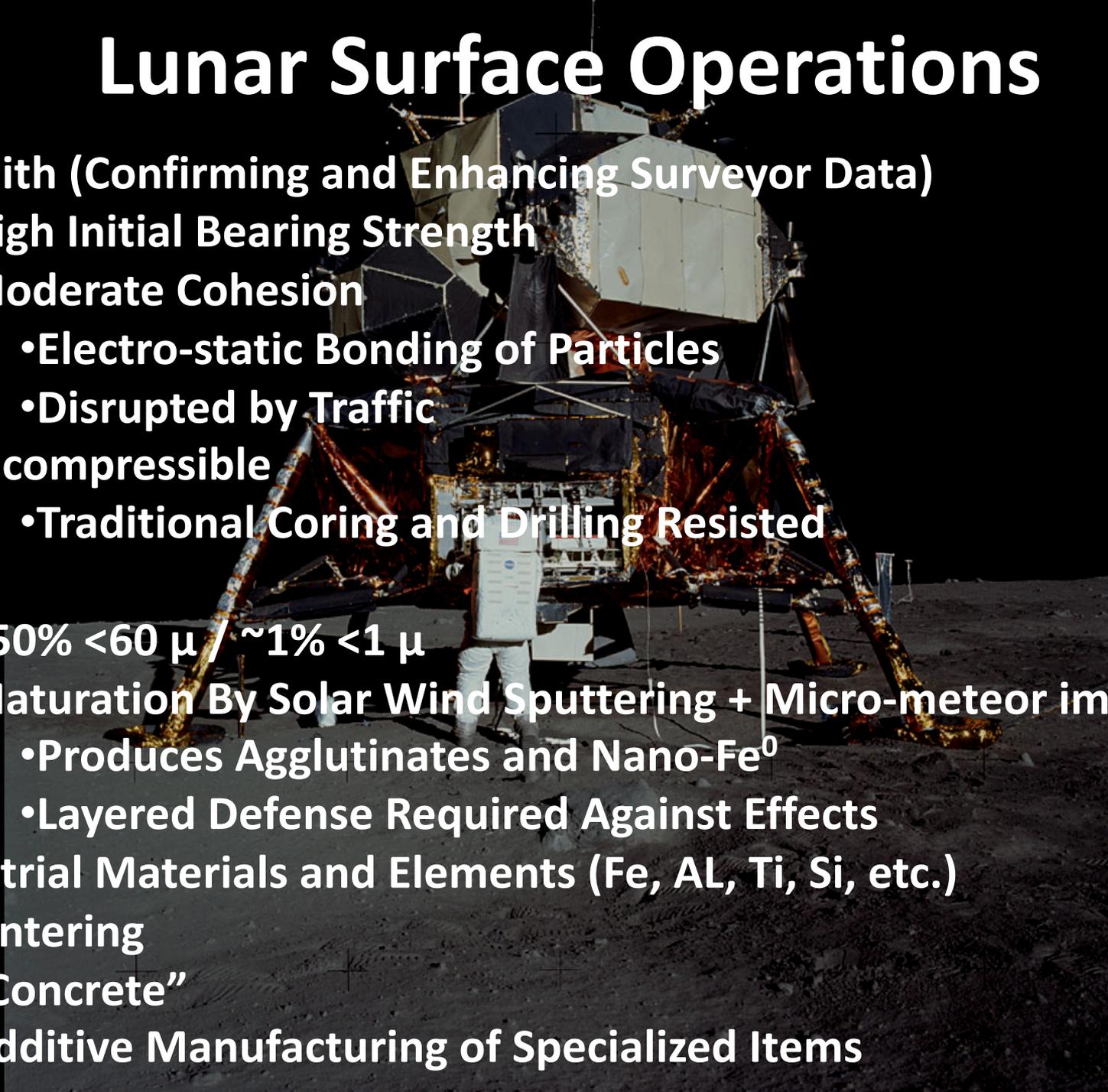


- Solar Wind Volatile Resources in Regolith
- H, He, N, C
 - Heating Produces H₂O
 - ~50%(?) Agitation Losses vs. Regolith Breccias
- ³He Fusion Fuel
- Lunar Settlement and Mars Expedition Consumables



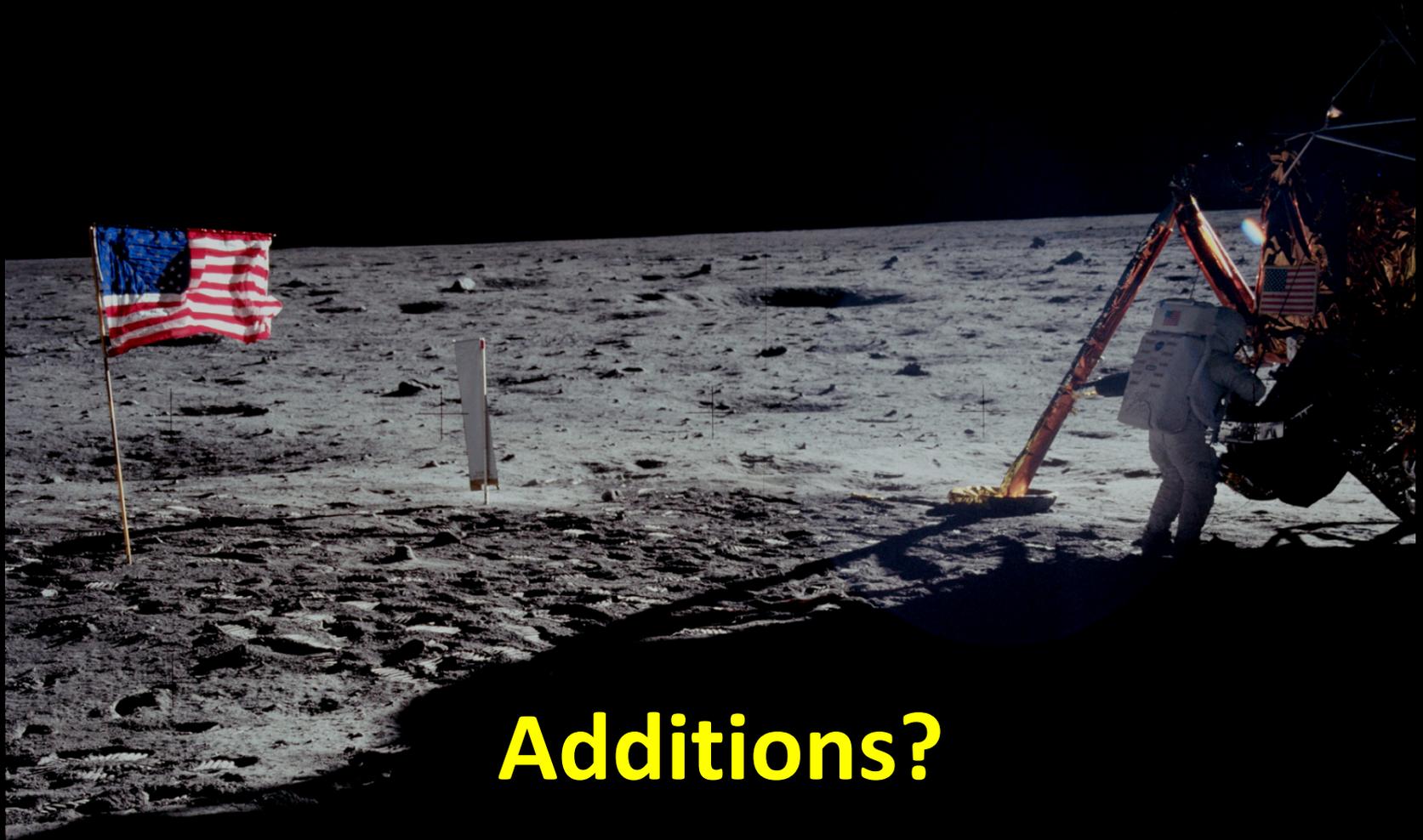
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Lunar Surface Operations

- Regolith (Confirming and Enhancing Surveyor Data)
 - High Initial Bearing Strength
 - Moderate Cohesion
 - Electro-static Bonding of Particles
 - Disrupted by Traffic
 - Incompressible
 - Traditional Coring and Drilling Resisted
 - Dust
 - ~50% 60μ / ~1% 1μ
 - Maturation By Solar Wind Sputtering + Micro-meteor impacts
 - Produces Agglutinates and Nano-Fe⁰
 - Layered Defense Required Against Effects
 - Industrial Materials and Elements (Fe, AL, Ti, Si, etc.)
 - Sintering
 - “Concrete”
 - Additive Manufacturing of Specialized Items
- 



- **Experiment Data**
 - **Solar Wind Composition**
 - **Very High Seismic Q of Crust = Dry Mega-regolith**
 - **Thermal Insulation Allows Mare Magma Generation**
 - **Very Low Seismic Noise from Lunar Interior**
 - **High Precision Earth-Moon Distance Through Laser Ranging**
 - **Lunar Motion Dynamics**
 - **Lunar Core Detection and Size**



Additions?

