Lunar Development Lab (LDL) Concept

Leading to the First Human Lunar Outpost

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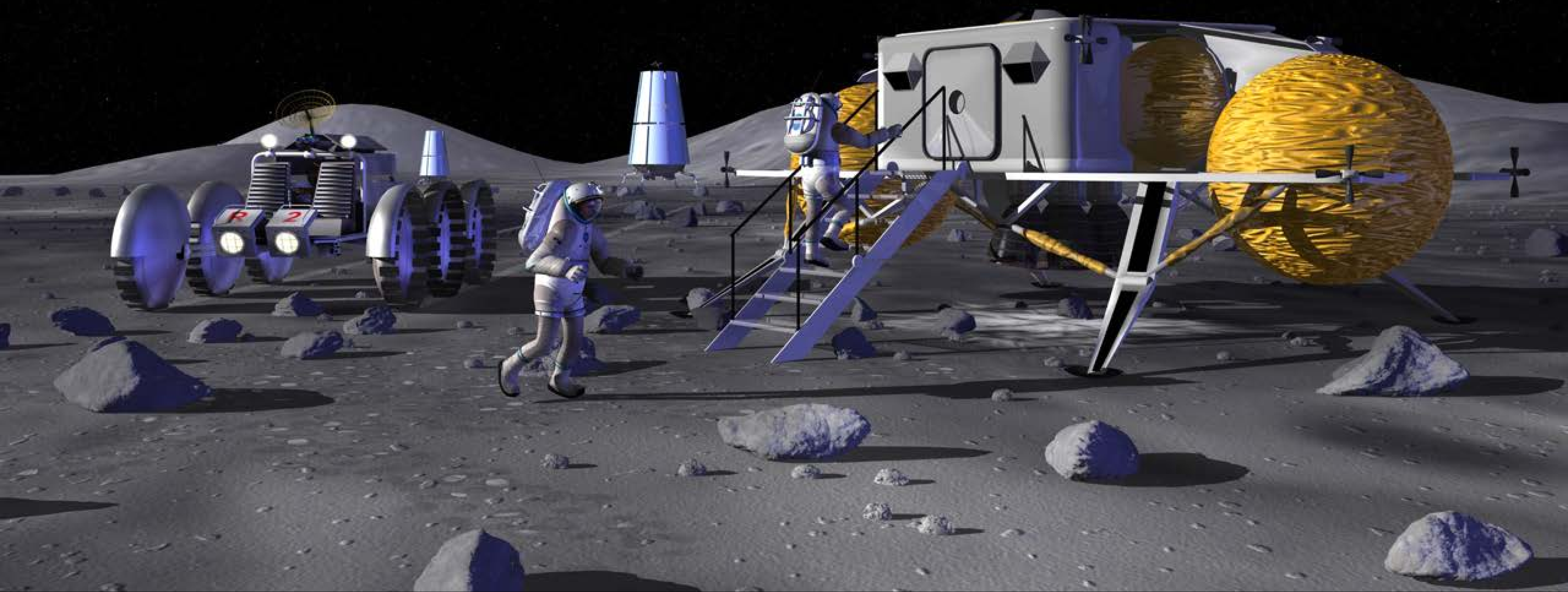


Background -NASA Frontier Development Lab (FDL)

- **FDL is an applied AI research accelerator** that uses interdisciplinary teams to solve challenging problems for space science and exploration.
- **FDL is a PPP between NASA, SETI and the commercial sector** with key partners in AI/ML such as, Google, Intel, IBM, and Nvidia.
- **FDL is in its 4th year and has established an impressive success rate for research output.** Research outcomes are regularly accepted to respected journals and scientific conferences.
- **Over this time, FDL has developed 17 AI applications** in heliophysics, exoplanet discovery, lunar exploration, astrobiology, earth science and planetary defense.

AI for Lunar Development and Exploration

NASA FDL has a growing suite of AI tools for lunar development and exploration:

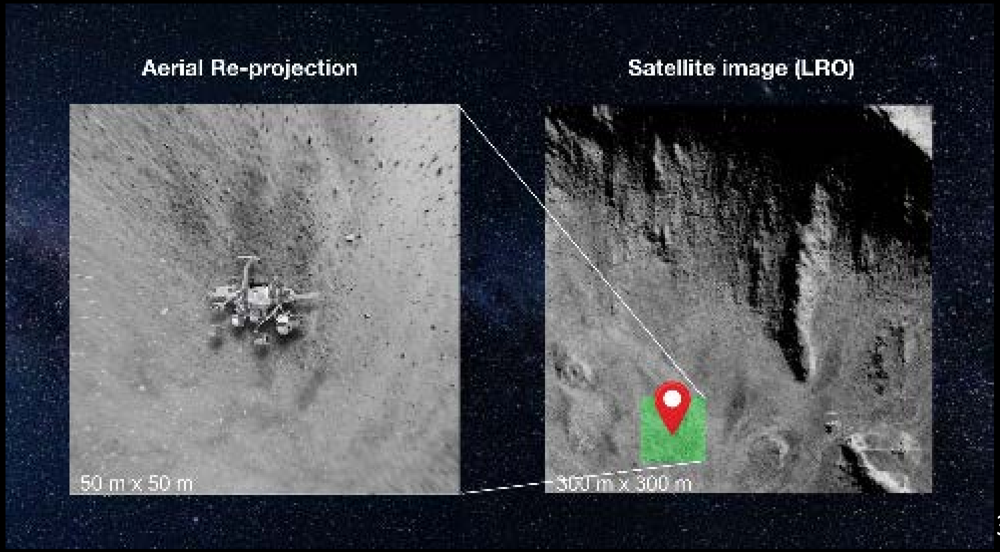
- Automated crater identification for lunar mapping
- Rover localization using onboard cameras
- Co-operative robotic methodologies for polar prospecting/traverse planning

Challenges are chosen to identify closely with the National Space Exploration Campaign's strategic goals, specifically:

- Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space

Partners in FDL's past Lunar AI projects included:

- Intel, Google and HP
- Luxembourg Space Agency/Space Resources
- XPRIZE Foundation



Lunar Resource Mapping Challenge for 2019

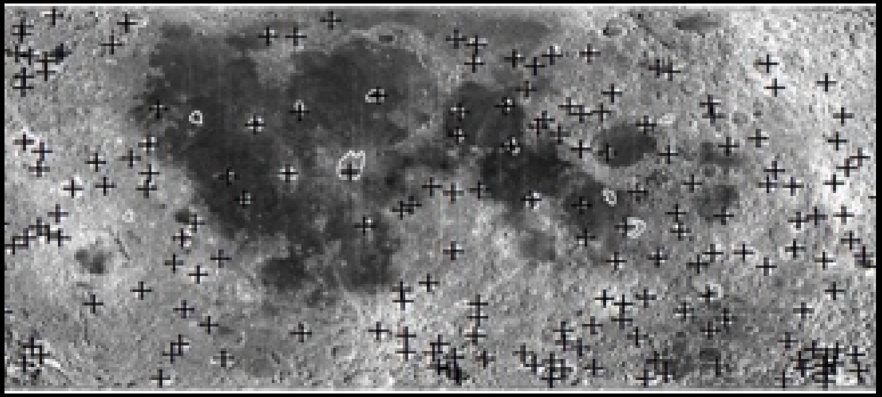
FDL Opportunity

- **It is estimated that billions of tons of metal (nickel-iron-cobalt) meteorite fragments could exist on the Moon.** There also have not been any missions that specifically looked for evidence of M-class impactors.
- **These lunar resources may be exploited through ISRU capabilities to build infrastructure** on the Moon, such as lunar habitats.
- **Higher resolution resource maps can aid mission planners to locate resources for ISRU** in future robotic and human lunar missions.

FDL Challenge

Investigate existing data sets from multiple missions to develop a high-resolution resource map of potential metallic deposits from M-class impactors.

- LRO’s LROC WAC and NAC visible images
- LRO’s Diviner imaging radiometer datasets
- LRO’s Mini-RF data
- Clementine’s UV-VIS dataset
- CNSA Change’E-1 and Chang’E-2 microwave radiometer data
- ISRO Chandrayaan-1 Mini-SAR
- JAXA Kaguya Radar Sounder

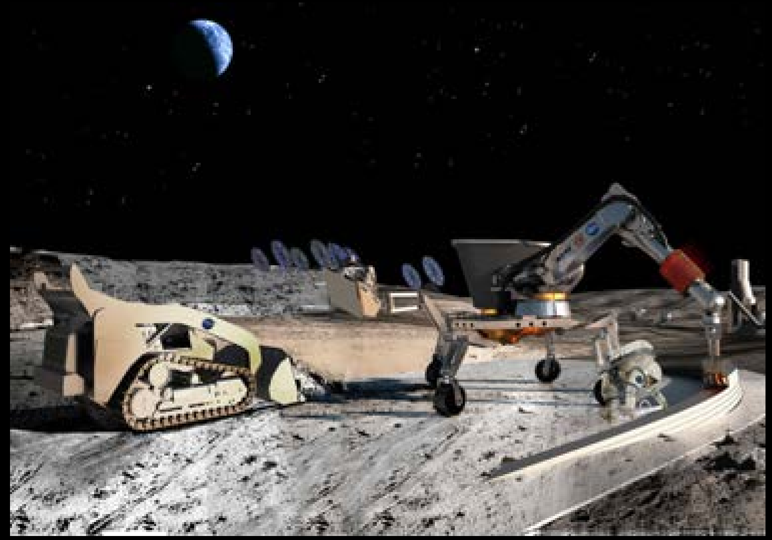


Lunar Thermal Anomaly Distribution shows 266 hot/cold spots, from 60N to 60S (Zheng, et al, 2014)

Lunar Development Lab (LDL)

Purpose:

- To bring together experts from academia, industry and NASA in an accelerator environment to advance lunar development sufficiently that leads to a **sustainable and economical human lunar outpost** as well as the **creation of a new thriving, cislunar economy.**



Approach:

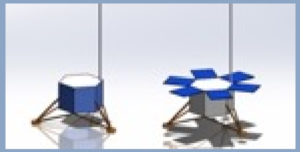
- **Generate** new design solutions, technologies and architectures leveraging lunar resources as much as possible.
- **Develop design solutions and architectures for infrastructure systems** including power generation and storage, communications, navigation, surface mobility and life support systems
- **Build and test prototype hardware** in a simulated environment to reduce technical and operational risk.
- **Use AI and machine learning technologies** and other advanced tools to quickly process data and optimize design solutions
- **Use economic analysis tools to compare designs and architectures** to work towards economic and sustainable solutions

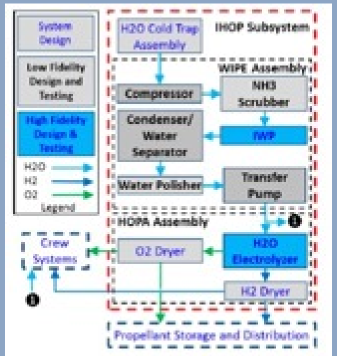
Draft Challenge Areas

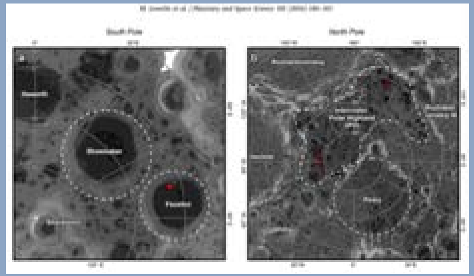
1. **Lunar architecture designs** which integrate lunar resources into the design of surface systems, human habitats and life support systems.
2. **Infrastructure system designs** for power generation, communications, navigation, thermal management, landing pads and radiation shielding.
3. **Lunar mining techniques** and resource production estimates for key raw elements, e.g. H2O, O2, Si, Ti, Al
4. **High-definition lunar resource mapping** and modelling of minerals, metals and rare-earth elements.
5. **Economic analysis of resource production techniques** and competing lunar architectures
6. **Lunar base radiation 'safe haven' architectures** which uses supercomputer simulations of lunar magnetic anomalies

Road From LDL to First Human Lunar Outpost

Integrated Design Solutions

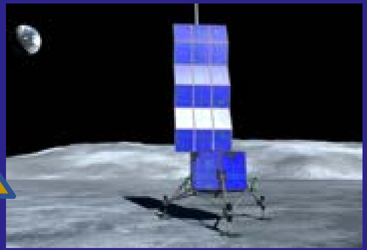






Prototype Hardware and Ground Testing

Low-Cost Flight Demonstrations



Buildup of Initial Elements Human Lunar Outpost

Next Steps

- **Define lunar resource challenge areas** for initial LDL 1.0
- **Establish public-private partnerships** to help sponsor teams in an accelerator environment
- **Select PI's to lead research objectives** challenge problems and technical team.
- **Solicit highly-qualified and motivated researchers and mentors** to participate in LDL 1.0
- **Prepare data and tools** that researchers will need to address challenge problems
- **Implement LDL research sprint sessions by FY 2020**

THANK YOU!

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https://www.nasa.gov/ames/partnerships/spaceportal/LCOTS