• Exploration is a fundamental driving force in the human species.
• Exploration is motivated and supported by multiple factors.
• Science is the exploration of the unknown.
• Engineering is fundamental to successful exploration.

• Exploration return is optimized by Science and Engineering synergism.
Exploration

• Why do we go?
• Where do we go?
• How do we get there?
• What do we do when we get there?
• What is the lasting legacy, what did we learn?
Exploration Environments

- Active volcanoes on Earth (Hawaii, MSH).
- Seafloor exploration (bottom of the Pacific).
- Antarctica (Antarctic Dry Valleys).
- Apollo Exploration of the Moon.
- The President’s Vision:
  - Return to the Moon and on to Mars.
Exploration “Reference Mission”

- Goals: Why, what, when and where?
- Access: How do we get there?
- Support: What infrastructure is needed?
- Exploration Mode: What do we do and how?
- Relative Roles:
  - Human and automated probes.
- Results and legacy: What do we learn?
Landings on the Moon
Soviet planetary missions

Mars
- Марс 1
- Марс 4, 5, 6, 7
- Фобос 1, 2
- Марс 96

Venus
- Венера 1
- Венера 9, 10
- Вега 1, 2

The Moon
- Луна 1
- Зонд 3
- Луна 24

Red – successful    Blue - failed
Luna 9 – first soft lunar lander

Fragment of Luna 13 TV panorama
E8 module – lander for late lunas and lunokhods

Luna 16 – first robotic sample return
Lunar Ranger
1961 - 1965

Ranger 7: July, 1964
Ranger 8: Feb., 1965
Ranger 9: Mar., 1965
Lunar Orbiter

1966 - 1967

Orbiter 1: Aug., 1966
Orbiter 2: Nov., 1966
Orbiter 3: Feb., 1967
Orbiter 4: May, 1967
Orbiter 5: Aug., 1967
Lunar Surveyor
1966 - 1968

Surveyor 1: May, 1966
Surveyor 2: Sep., 1966
Surveyor 3: Apr., 1967
Surveyor 4: Jul., 1967
Surveyor 5: Sep., 1967
Surveyor 6: Nov., 1967
Surveyor 7: Jan., 1968
Lunokhod and Apollo Traverses to Scale

Apollo 14 (1971)
Apollo 12 (1969)
Apollo 15 (1971)
Apollo 16 (1972)
Apollo 17 (1973)
Lunokhod 1 (1970-1971)
Lunokhod 2 (1973)

Pathfinder Sojourner traverse is not visible at this scale
Exploration “Reference Mission”

- Goals: Why, what, when and where?
- Access: How do we get there?
- Support: What infrastructure is needed?
- Exploration Mode: What do we do and how?
- Relative Roles:
  - Human and automated probes.
- Results and legacy: What do we learn?
President’s Exploration Vision

- Goals: Why (??), what (??), when (now) and where (Moon and Mars)?
- Access: How do we get there? (??)
- Support: What infrastructure is needed? (??)
- Exploration Mode: What do we do and how? (??)
- Relative Roles:
  - Human and automated probes. (??)
- Results and legacy: What do we learn? (?????)
What are the lessons?

• Definitions are important:
  – Explore: “To make or conduct a systematic search for the purposes of discovery.”
  – Discover: “To find out something not previously known; to obtain knowledge for the first time.”

• Science is the exploration of the unknown.

• Human and automated science exploration missions have taught us that the Moon and Mars hold the clues to Earth’s past and future.
What are the lessons?

• Engineering is fundamental to successful exploration.
• Exploration return is optimized by Science and Engineering synergism.
• The President’s Vision: Why are we going?
  – Scientific exploration of the unknown on the Moon and Mars.