Definition and Rationale

- What is an Outpost?
  - Series of Linked Missions
  - Logistical Support
  - Continuous, Long-Term Presence

- Why Create Outposts?
  - Collection of Long-Term Data Sets
  - Flexibility to Respond to New Discoveries
  - Emplacement/Maintenance of Infrastructure
  - Preparation for Human Exploration
  - Public Engagement
Formulation and Design

- Multi-Mission Trades
- Technology Projection

- Long-Term Commitment
- Scientific/Operational Factors

- Overall Strategy
- Flexibility

- Single vs. Multi-Mission
- Long-Term Support
Outpost Study: Assumptions and Drivers

- Focus: Subsurface Characterization
- Operational Assumptions
  - Long-Lived Equipment
  - Autonomy
  - Mature Precision EDL
- Element Assumptions
  - Nuclear Reactor
  - Launch Vehicles
  - Continuous HDTV
Elements by Opportunity

<table>
<thead>
<tr>
<th>Launch Opportunity</th>
<th>Primary Payload(s)</th>
<th>Operational Objective(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Long Range Rover</td>
<td>Locate initial outpost site</td>
</tr>
<tr>
<td></td>
<td>Navigation Beacon</td>
<td>Provide location signal for future landings</td>
</tr>
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<td></td>
<td>HDTV Camera</td>
<td>Establish virtual presence</td>
</tr>
<tr>
<td>2011</td>
<td>Mars Towing Rover</td>
<td>Transport seismic lab and the drill, replace batteries for all rovers (using a robotic arm)</td>
</tr>
<tr>
<td></td>
<td>Mobile Seismic Lab</td>
<td>Begin high-resolution subsurface mapping</td>
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<tr>
<td></td>
<td>Communication Hub</td>
<td>Expand communication capability, support climate sensors to obtain continuous, long-term data sets</td>
</tr>
<tr>
<td>2014</td>
<td>Space Nuclear Reactor</td>
<td>Power the drill and other equipment</td>
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<tr>
<td></td>
<td>Deep Drill</td>
<td>Calibrate seismic data and produce core samples</td>
</tr>
<tr>
<td></td>
<td>In-situ sample analysis equipment</td>
<td>Analyze core samples from drill</td>
</tr>
<tr>
<td></td>
<td>Logistics Supplies</td>
<td>Provide additional drill stems and tether</td>
</tr>
<tr>
<td></td>
<td>Comm. Satellite</td>
<td>Expand communication capability</td>
</tr>
<tr>
<td></td>
<td>Science Rover</td>
<td>Enhance mobile science capability</td>
</tr>
<tr>
<td></td>
<td>In-Situ Science Instruments</td>
<td>Enhance science capability</td>
</tr>
<tr>
<td></td>
<td>Logistics Supplies</td>
<td>Provide additional drill stems and tether</td>
</tr>
<tr>
<td>2016</td>
<td>Sample Return Orbiter</td>
<td>Provide Earth Return Vehicle for samples</td>
</tr>
<tr>
<td></td>
<td>Mars Ascent Vehicle</td>
<td>Transfer samples from the surface to the orbiter</td>
</tr>
<tr>
<td>2020</td>
<td>Human Precursor Demos</td>
<td>Prepare for human exploration</td>
</tr>
<tr>
<td></td>
<td>ISRU Equipment</td>
<td>Demo In-Situ Resource Utilization</td>
</tr>
<tr>
<td>2022</td>
<td>Advanced Robotic or Human Operations Gear</td>
<td>Enhance robotic capability and/or prepare for human arrival</td>
</tr>
<tr>
<td></td>
<td>Advanced Mobile Units</td>
<td>Expand current outpost and/or traverse to new site</td>
</tr>
</tbody>
</table>

### H₂O Contingency Scenario

<table>
<thead>
<tr>
<th>Launch Order</th>
<th>Primary Payload(s)</th>
<th>Mission Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wet Chemical Analysis Instruments</td>
<td>Add capability for analysis of liquid samples</td>
</tr>
<tr>
<td>2</td>
<td>Wet Sample Return Orbiter and Ascent Vehicle</td>
<td>Add capability for return of liquid and/or frozen samples</td>
</tr>
<tr>
<td>3</td>
<td>ISRU Systems</td>
<td>Add capability for utilizing H₂O resource</td>
</tr>
</tbody>
</table>
Mission I: Reconnaissance

- **Objective:** Pinpoint outpost site
- **Elements**
  - Long-Range Rover
  - Nav Beacon, HDTV Camera
- **Rover Characteristics**
  - Based on previous rover concept
  - Speed Range: 1-2 km per sol
  - Mass Range: 200-400 kg
  - Primary/rechargeable batteries
  - Launch Vehicle: Delta II class
Mission II: Seismic Survey

- Objectives
  - Begin Subsurface Characterization
  - Select Drilling Site
  - Enhance Communications

- MSL Characteristics
  - Active sounding
  - 25 UBB seismometers
  - 100 charges
  - L-shaped array deployment

- Elements
  - Mobile Seismic Lab
  - Mars Towing Rover
  - Communications Hub
Mission II: Seismic Survey (2)

• Mars Towing Rover Tasks
  – Deployment of Seismic Lab, Power Tether
  – Transportation of Deep Drill, Communications Hub, Supplies and other Elements
  – Replacement of Rover Batteries

• MTR Characteristics
  – Mass Range: 800-1000 kg
  – Robotic arm lifting capability: ~50 kg
  – 1500+ kg towing capability
  – Rechargeable Batteries
  – Includes HDTV camera
Mission II: Seismic Survey (3)

• Communications Hub
  – Design Driven by 20 Mbps HDTV Data Stream
  – 5-m High Gain Antenna
  – X- or Ka-band for communication with DNS
  – Initially Battery/Solar Powered
  – Ultimately Tethered to Reactor
Mission III: Drilling Campaign

- Objectives
  - Intensify Subsurface Characterization
    - Acquire core samples for analysis
    - Provide ground truthing for seismic survey
  - Expand Communications Capability

- Elements
  - Deep Drill
  - Nuclear Reactor
  - Communication Satellite
  - Logistical Supplies
Mission III: Drilling Campaign (2)

- Nuclear Reactor Concept from NASA Glenn

- Characteristics:
  - Deployable Radiators
  - Safety Rods
  - Neutron Reflectors
  - Instrument Shadow Shielding
  - Brayton Power Conversion
  - Power: 20 kWe (variable)
  - Total Mass: 1700+ kg
Lession III: Drilling Campaign (C)

- Deep Drill Characteristics
  - Core Retrieval: 1-cmØ, 1-m L
  - Drill Rate: 1 m per sol
  - Target Depth: 1 km
  - Power Range: 3-5 kW
  - Mass Range: 1500-2000 kg

Down-Hole Motor

Image Credit: Baker Hughes
Mission III: Drilling Campaign (4)

- Communications Satellite
  - Areostationary Orbit
  - 5-m High Gain Antenna
  - Provides Relay to DNS
  - Possible Libration Point Augmentation

- Logistical Supplies
  - Drill Stems and Casing
  - Replacement Batteries
  - Power Tether
Mission IV: Expanded Science

- **Objective:** Expand Science Capabilities
- **Elements**
  - Science Rover
  - Modular Science Packages
  - Logistical Supplies (2 Flights)
- **Science Rover**
  - Athena Class Rover
  - Carries/Deploys Science Modules
  - Rechargeable Batteries
Mission V: Sample Return

- **Objective**: Return Scientifically Interesting Samples
- **Elements**
  - Mars Ascent Vehicle
  - Earth Return Vehicle (orbital)
- **Rationale**
  - All sample collection assets (rovers, drill, sample analysis equipment) exists already
  - Scientifically selected caches can be launched upon arrival of MAV/ERV or later
Missions VI and VII

- Objectives:
  - Prepare for human exploration
  - Enhance robotic capability and/or prepare for humans
- Elements
  - ISRU Equipment and other Human Precursor Demos
  - Advanced Robotic of Human Gear
  - Advanced Mobile Units
- Rationale
  - At this stage, the outpost should also be rigorously scrutinized and assessed. The decision to expand robotic activities, intensify preparation of the site for human arrival or move to another site determines the future missions.
Water Contingency

- Objectives
  - Shift outpost focus upon discovery of H₂O
  - Understand how to utilize the resource
  - Return “wet” samples

- Elements
  - Wet Chemical Analysis Instruments
  - Wet Sample Return Orbiter and Ascent Vehicle
  - ISRU Systems
Mars Exploration Goals

- Does/did life exist on Mars?
- Search for past/present water

- What is the past/present climate?
- Study atmosphere and deposits

- What is the geological history?
- Characterize the surface/subsurface

- What is needed for humans?
- Acquire environmental data sets
- Engineering/science demos
Outpost Capabilities (2)

- MEPAG List
- Enables 30% of investigations
  - Deep Subsurface Access
  - Emplacement of high power systems
- Facilitates another 30%
  - Long-term surface presence
  - Surface mobility
  - Sample return
Findings: Technology Needs

- General Issues
  - EDL Constraints
  - Launch Vehicle Constraints
  - Energy Storage/Transmission Concerns

- Element Specific
  - Reactor
  - Deep Drill
  - Rovers
  - Communications Infrastructure
  - Sample Return Implementation
Findings: Logistics

• Lessons Learned
  – Launch Vehicles Constraints
  – Logistical Mass Drivers
    • Drill Rods
    • Drill Casing
    • Power Tether
  – Life Drivers
  – Reliability Assessment
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