JPL

Decision-Making for a Robotic Architecture

Tara Estlin, Forest Fisher, and Issa Nesnas
JPL IS Focused Technology PIs

Overview of IS Focused Effort

JPL

- Goal: Develop onboard decision-making capabilities to support an autonomous rover
- Capabilities include:
  - Creating a rover-command sequence based on science and engineering goals
  - Executing sequence by interfacing to rover control software
  - Monitoring the execution of that sequence
  - Dynamically adjusting the sequence based on current state and resource information

Focused Task Collaboration

Work represents collaboration of three IS Focused Elements in Automated Reasoning:

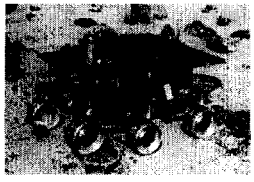
- CLARAty Rover Autonomy Architecture (PI: Issa Nesnas)
  - Developing a unified and reusable framework for robotic control
  - Enables use of high-level decision-making capabilities onboard multiple robotic platforms
- CLEaR Unified Planning and Execution (PI: Forest Fisher)
  - Developing robust, onboard planning and execution system
  - Balances reactive and deliberative types of decision-making capabilities
- Integrated Resource and Path Planning (PI: Tara Estlin)
  - Developing an integrated approach for performing AI planning and scheduling with robotic motion and path planning
  - Enables activity planning system and path planning system to share information on path options, waypoints, resource constraints, etc.

Addressed Mission Needs

- Lower ground operation costs
  - Significantly reduce time spent on manual sequence generation
  - Decrease number of command cycles required
- Increase robustness to failures and terrain elements
  - Handle significantly more unexpected situations onboard
  - Dynamically adjust sequence and path due to unexpected obstacles, events, or failures
  - Increase capabilities for intelligent navigation
- Increase in science return
  - Reduce rover idle time, thus increased time for science
  - Increase capabilities for traverse and opportunistic science
    - Collect more science during long traverses
    - Select paths that consider multiple science objectives
    - Take advantage of more science opportunities (including those that require a quick reaction)

Accomplishments & Status

- Demonstrated scenario for accomplishing multiple science targets
  - Software had to react dynamically to unexpected state changes
  - Performed several live demonstrations of autonomy software on rover hardware
  - Used Rocky 7 and Rocky 8 rovers in JPL Mars Yard
  - Demos co-funded through IS ARREX, Mars Tech and IPN-ISD programs
- Work has been integrated with ROAMS simulation tool
  - Provides simulation of rover kinematics and terrain
  - Same interface used to interact with simulator and rover hardware

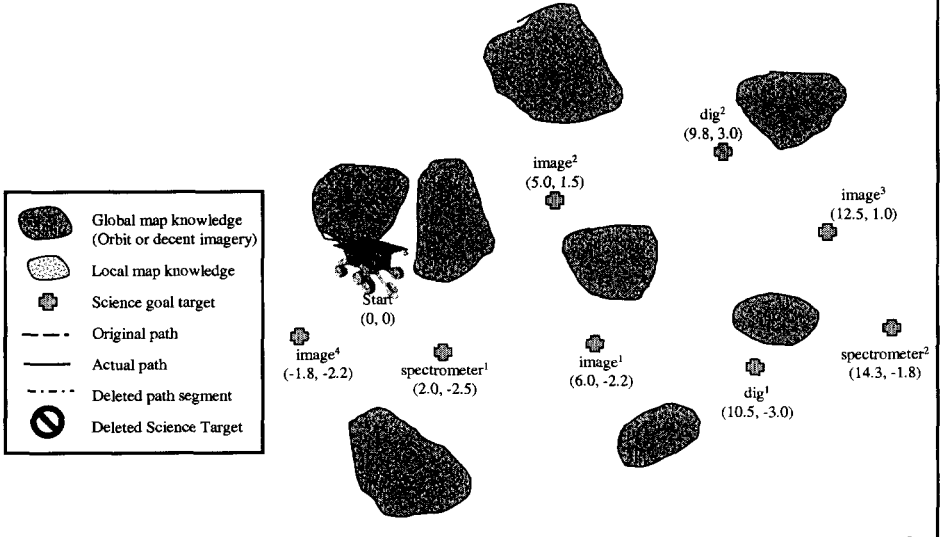


Demo Scenario Description

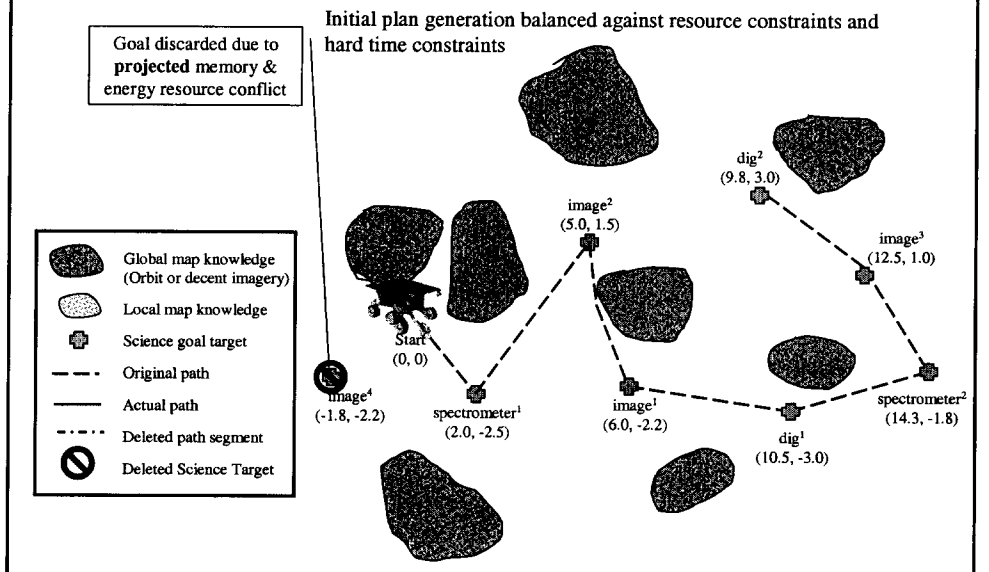
Scenario Overview

- Initial plan generation based on input science goals
  - Uses global map and path planner to determine best sequence for visiting science targets
  - Science target selection influenced by science operation priorities
- Plan execution and monitoring of states/resources (e.g., rover position, power levels)
- Dynamic re-planning handles:
  - Obstructed path / activity completion-time conflict
  - Memory oversubscription
  - Energy oversubscription
- Reactive exec behavior handles:
  - Resource and state monitoring
  - Path waypoint generation

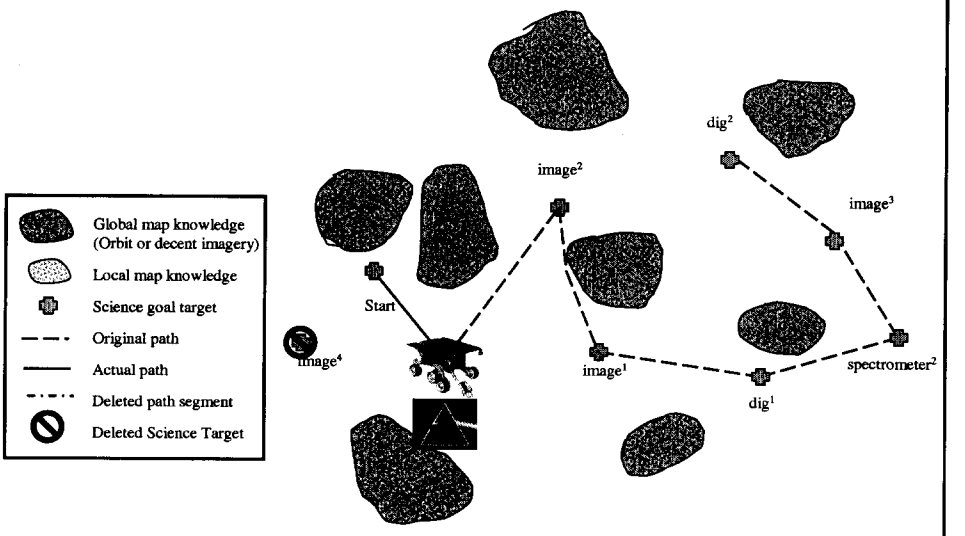
Initial Science Targets



Initial Plan Generation

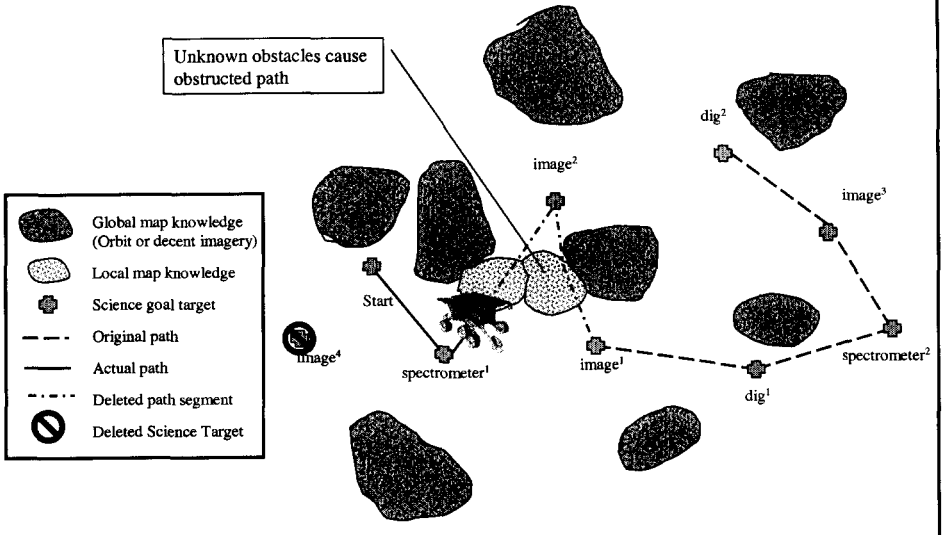


Spectrometer Read (1st Target)

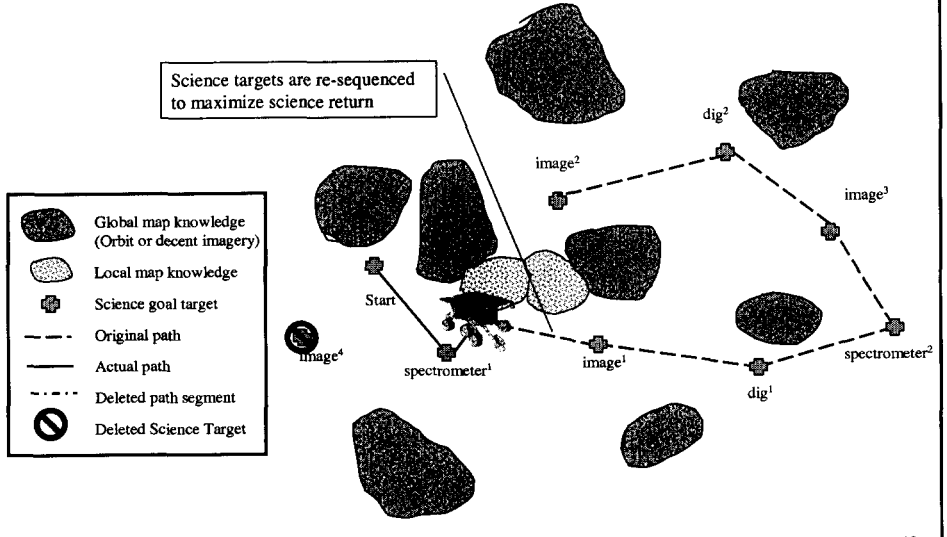


Obstructed Path Detected

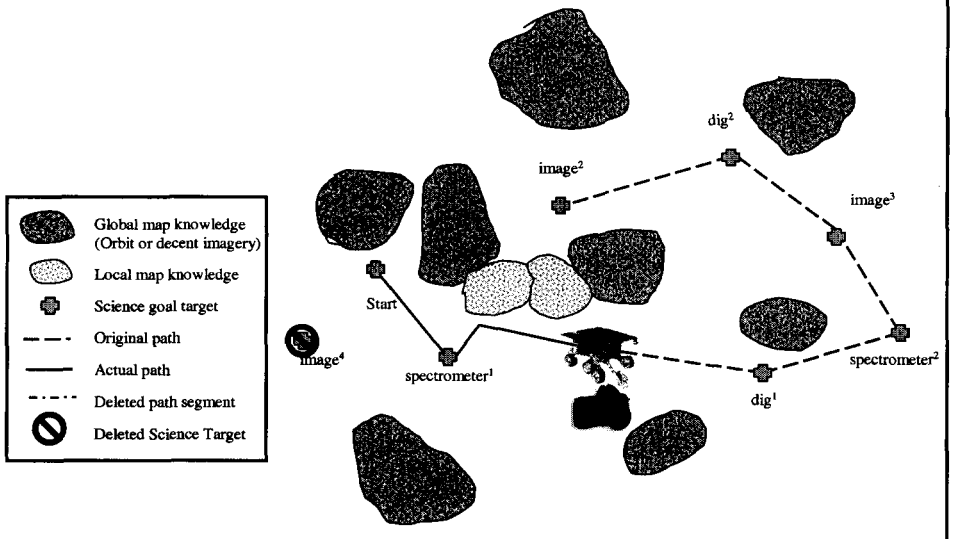
Requires decision making within context of global plan



Science Targets Re-Sequenced



Imaging Activity (2nd Target)

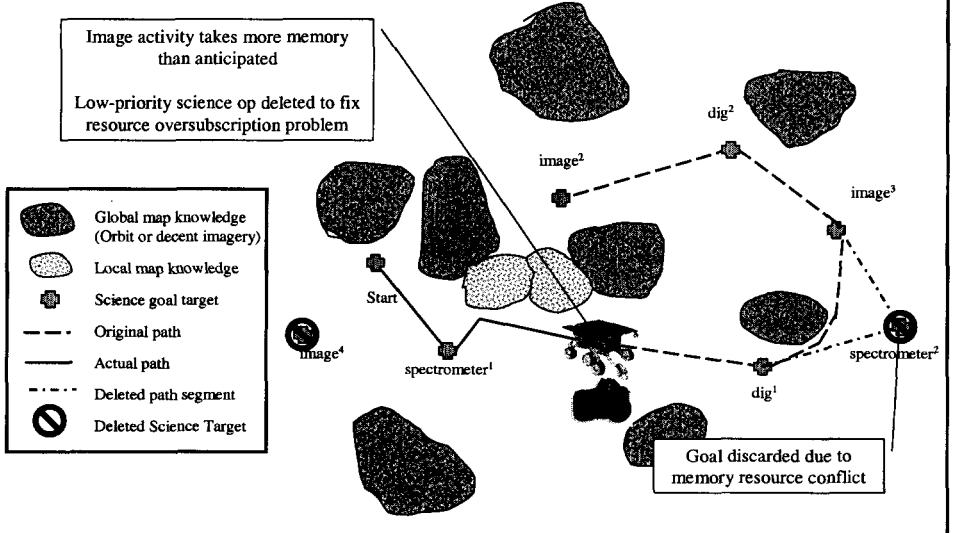


Replanning due to Projected Memory Resource Violation

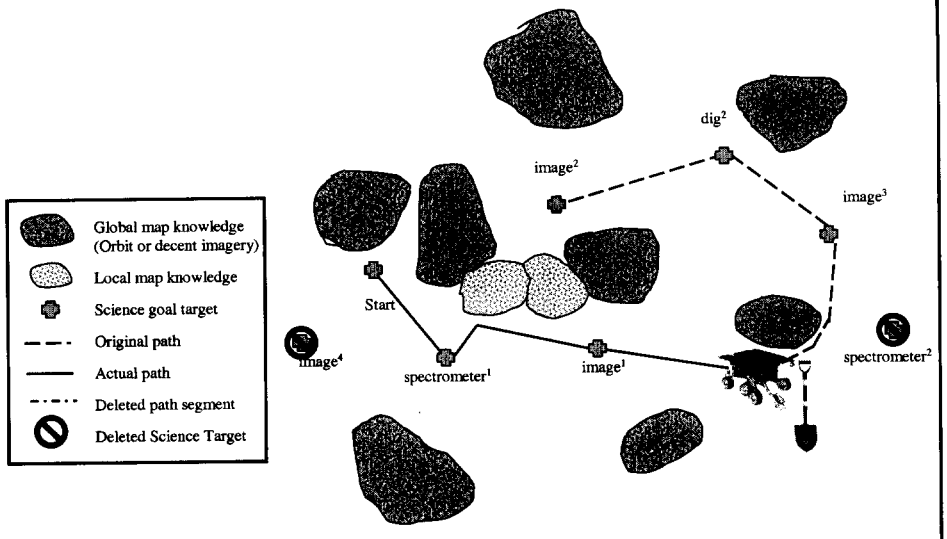
Replanning occurs to ensure higher priority science operations will complete

Image activity takes more memory than anticipated

Low-priority science op deleted to fix resource oversubscription problem



Dig Activity (3rd Target)



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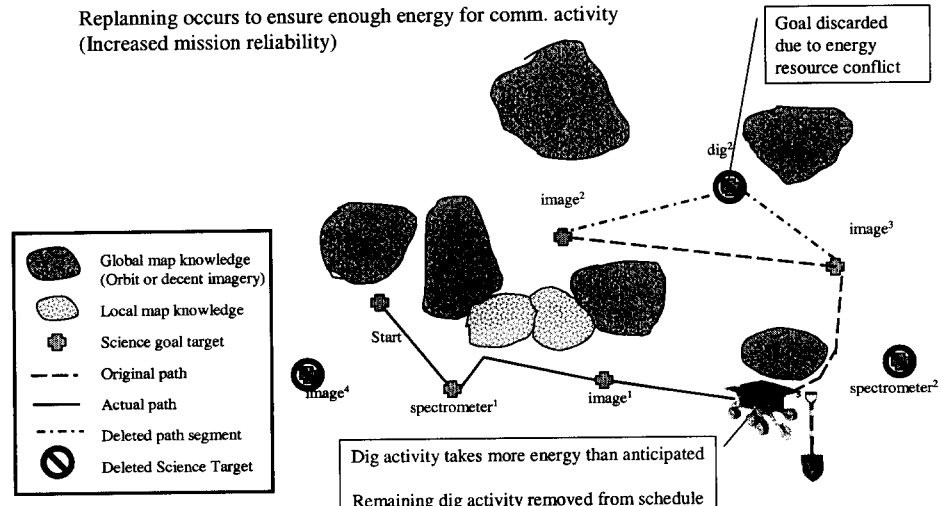
15

Replanning due to Projected Energy Resource Violation

Replanning occurs to ensure enough energy for comm. activity
(Increased mission reliability)



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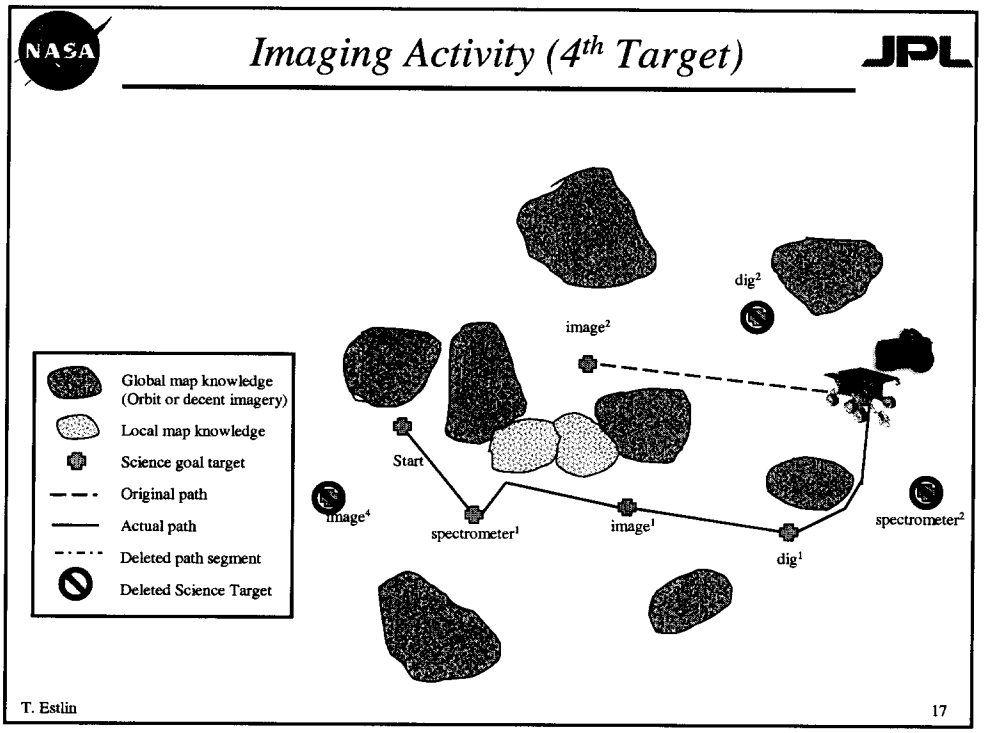
16


Imaging Activity (4th Target)
JPL
Global map knowledge (Orbit or decent imagery)
Local map knowledge
Science goal target
Original path
Actual path
Deleted path segment
Deleted Science Target
dig2
image2
Start
image4
spectrometer1
image1
dig1
spectrometer2
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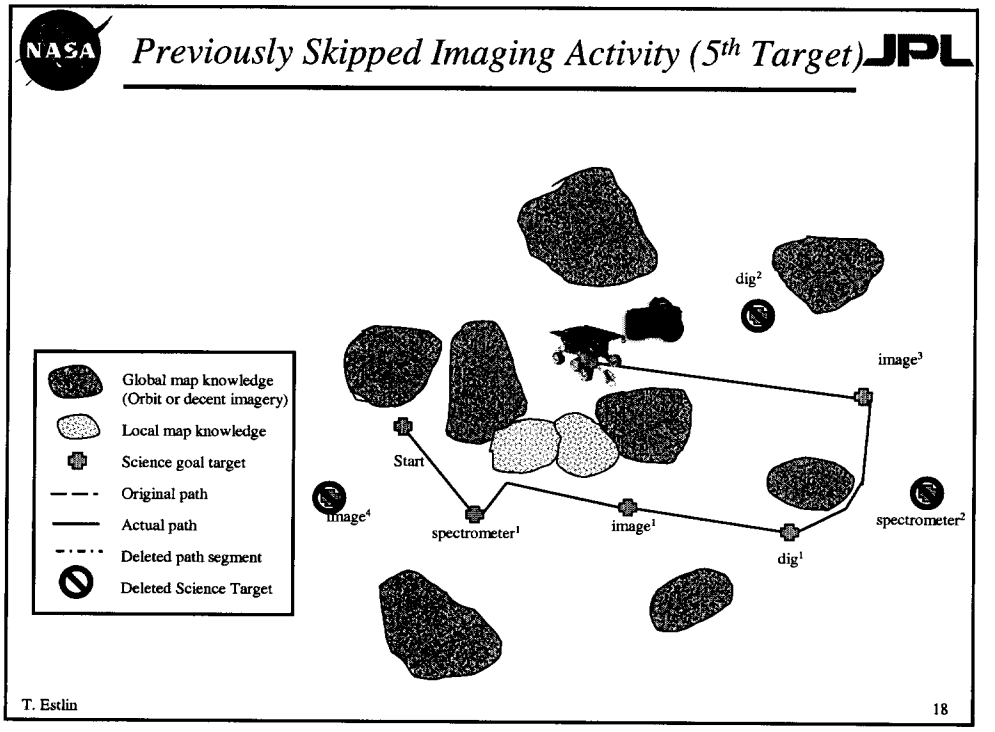
17


Previously Skipped Imaging Activity (5th Target)
JPL
Global map knowledge (Orbit or decent imagery)
Local map knowledge
Science goal target
Original path
Actual path
Deleted path segment
Deleted Science Target
dig2
image3
Start
image4
spectrometer1
image1
dig1
spectrometer2
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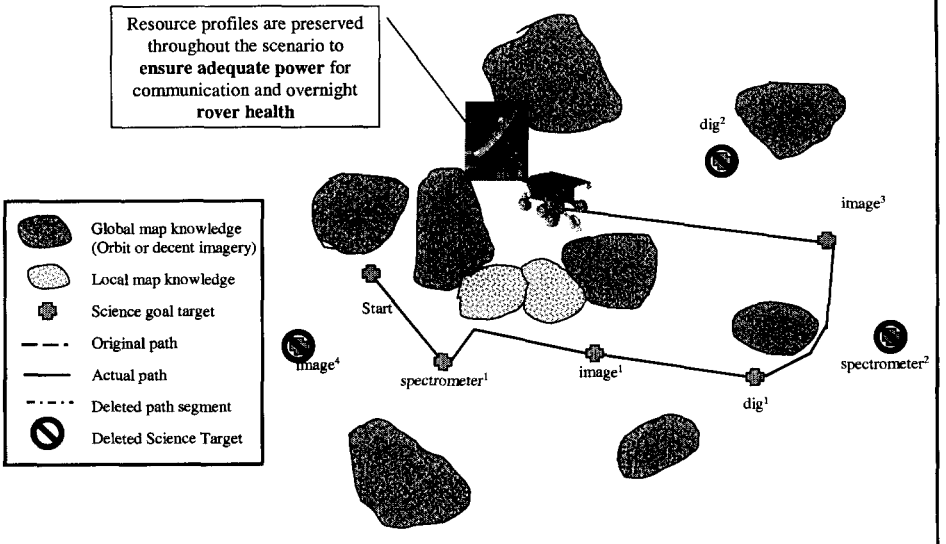
18

End of Day Communication



Additional Information

Team Members

CLARAty Team:

- Issa Nesnas (34)
- Tara Estlin (36)
- Caroline Chouinard (36)
- Max Bajracharya (34)
- Edward Barlow (34)
- Gene Chalfant (34)
- Dan Gaines (36)
- Mehran Gangianpour (34)
- Won Soo Kim (34)
- Dan Helmick (34)
- Richard Petras (34)
- Matt Robinson (34)
- Kevin Watson (34)

CLEaR Team:

- Forest Fisher (36)
- Tara Estlin (36)
- Dan Gaines (36)
- Steve Schaffer (36)
- Caroline Chouinard (36)

TDL Collaboration:

- Reid Simmons (CMU)

Contact Information

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- Web sites:
  - CLARAty Rover Architecture
    - http://claraty.jpl.nasa.gov
  - CLEaR Planning and Execution System
    - http://www-aig.jpl.nasa.gov/public/planning/CLEaR/