Decision Making for Rover Autonomy

(From a Technologist Viewpoint)

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Outline

- Outline
- Why Should the Mission Care?
- What Does the Mission Want?
- How Do We get There?
- High-Level Decision Making
- How is This Done?
- Command Sequence Modification
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Why Should the Mission Care?

- **HQ has said it is about the science!**
  - But we also know that it is about staying within (or near) some budget.
- **With that in mind – what do we think the missions want?**
  - Increased science return
  - Reduced missions operation complexity
    - Either doing it cheaper, or
    - Doing more with the same
- **How does this technologist think we can get there?**
  - Increased level of autonomy
    - Both low level autonomy and high level autonomy
      - High level autonomy == decision making and robust execution
    - Both onboard and on the ground system side

Why Should the Mission Care?

- **HQ has said it is about the science!**
  - But we also know that it is about staying within (or near) some budget.

As Matt Golombek likes to say, *"Find me the dinosaur bone."*

image of dinosaur bone

This implies, *"react to the unexpected,"*
and do so *reasonable* and safely.

What Does the Mission Want?

- **With that in mind – what do we think the missions want?**
  - Increased science return
    - More data collected
    - More valuable data on the ground
    - Less (risk of) missed opportunities
  - Reduced missions operation complexity
    - Either doing the same with less, or
    - Doing more with the same

rover dragging bag

Result: more bang for the buck

How Do We Get There?

- **How does this technologist think we can get there?**
  - Increased level of autonomy
    - Both low level autonomy, and
      - Increased rover navigation capabilities
      - Increased instrument placement capabilities
    - High level autonomy
      - decision making and
      - robust execution
    - Both onboard and on the ground system side

High Level Decision Making

- **High-Level Autonomy == Decision Making & Robust Execution**
  - Command sequence:

    Generation

    Execution

    Execution Monitoring

    Modification
    - Adaptation of command sequence resulting from changing environment
    - Safe and robust halting of command sequence from triggered event
    - Construction of a new sequence based on modified or new goals
      - Either ground (mission) or
      - Rover induced

How Is This Done?

Goal-based commanding

*State **what** you want done,*
*not **how** it needs to be done*

data base of puzzel pieces

- **Declarative Model Based System**
  - System model defines:
    - System capabilities
      - What actions can be taken and under what conditions
        - » Preconditions and effects
      - Valid state transitions
      - Resource availability and consumption
    - System limitations
      - Flight rules
      - margins

How Is This Done? (cont.)

Continuous Planning and Execution

- **Generate a command sequence**
  - or digest command sequence generated on the ground by the mission

- **Execute the command sequence**
  - Monitor the command sequence execution
  - Apply runtime updates (project/predict future state)
    - State Updates: including Time and Resource updates

- **Replan – Modify command sequence**
  - If runtime updates have introduced projected inconsistencies
    - Things go worse than expected
    - Things go better than expected (including unexpected opportunity)
  - Introduction of new goals

Command Sequence Modification

- **Things go better than expected**
- **Things go worse than expected**
- **Ways of addressing these cases:**

- **New Goals:**
  - Changes in mission objective
  - Detection of a runtime triggered event (OASIS) & Closing the Loop Onboard
    - Finding the dinosaur bone {bone}
    - Finding water (how to detect water is a different matter) {rain drop}
    - Finding something we have never seen before (Novelty) {Martian}
    - Detecting some significant change compared to what we have seen before (change detection) {sand dune → rock field}

Related Work

- MDS – Mission Planning and Execution (MPE)
- ST6 – Autonomous Science Experiment (ASE)
- NASA ARC

Summary

- **High-Level Autonomy can contribute to:**

  Increased Science Return

  Reduced missions operation complexity
  - Increased Reliability

- **Applicability to other areas of NASA work:**
  - Free Flying spacecraft
  - Landers
    - Including mobile landers == Rovers
  - DSN Communication Antenna Station Automation

Contact Information

- **Contact**

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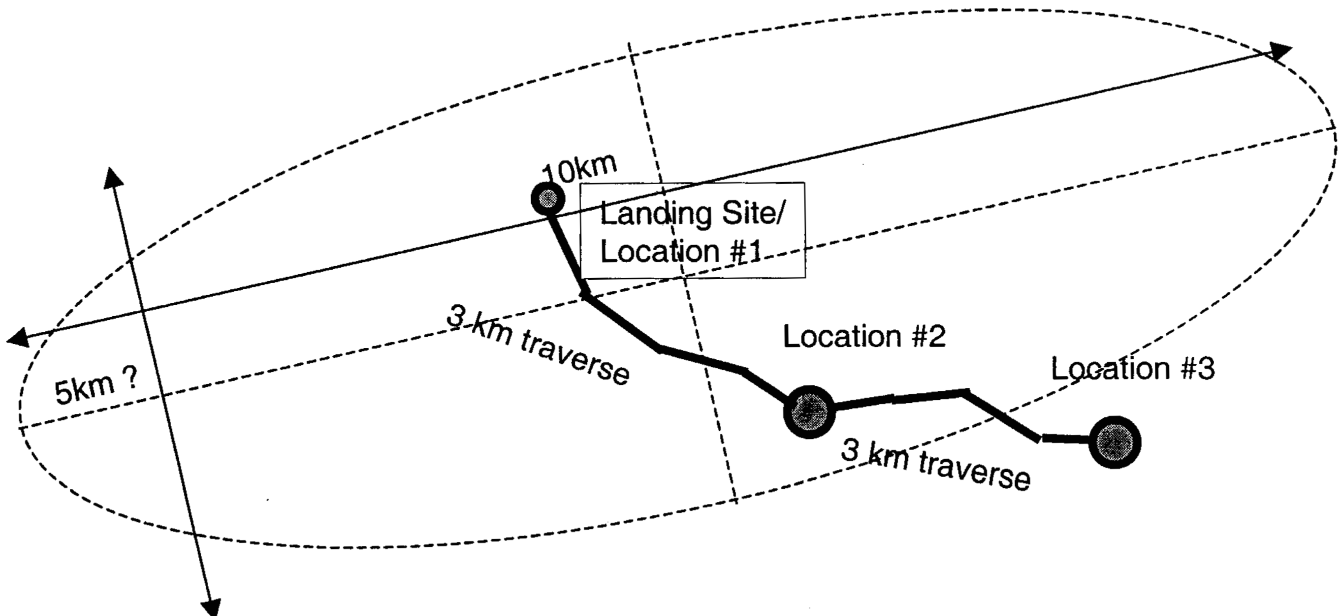
Autonomy assumptions

- **A1 - MER-like autonomy scaled for larger rover size**
  - Limited traverse distances without "ground-in-the-loop"
  - 3-sol cycle to approach a rock or soil target
  - Assume can only traverse 80 m/sol

- **A3 - Desired MSL autonomy**
  - Includes
    - Traverse autonomy - ability to safely drive outside of Navcam images
      - Allows traverse distance to be 230-450 m/sol
    - Location science autonomy
      - Allows approach of rock or soil to occur from 10m distance to within 1 cm of target in about 1 hour (no "ground-in-the-loop")

Reference Mission – Big Picture

- **Total duration of mission = 1000 sols**
  - 33% margin held on mission duration, so available # of sols = 667
- **Landing season Ls = 160-180**
- **Total distance traversed = ~69 km**
- **23 locations total including landing site**
  - 3 km traverse between locations



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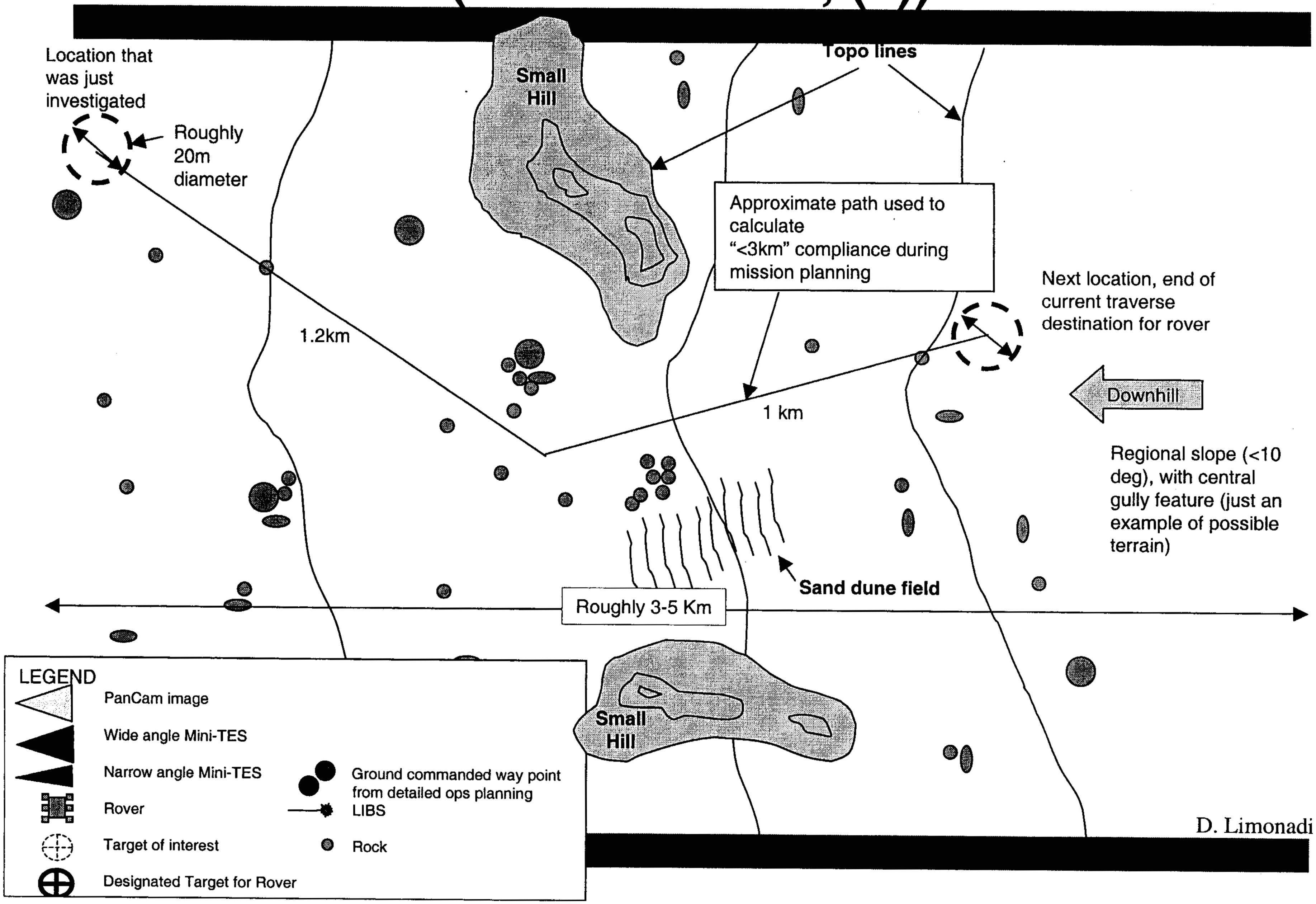
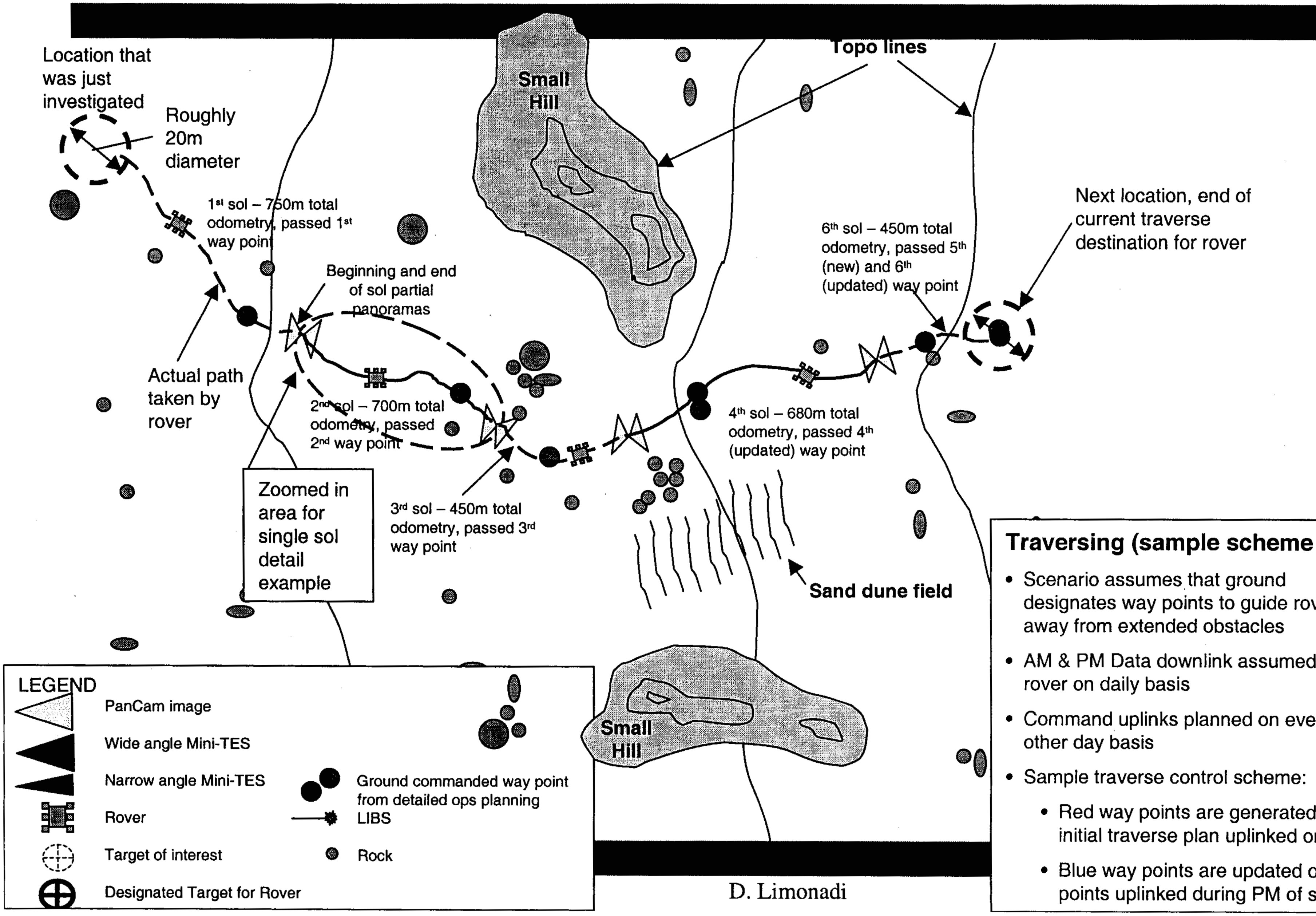
Traverse Operations (multi-sol view, (1))



Traverse Operations
(multi-sol view, (2) sample mission)



Traversing (sample scheme only)

- Scenario assumes that ground designates way points to guide rover away from extended obstacles
- AM & PM Data downlink assumed from rover on daily basis
- Command uplinks planned on every other day basis
- Sample traverse control scheme:
  - Red way points are generated during initial traverse plan uplinked on Sol 1
  - Blue way points are updated or new points uplinked during PM of sol 3

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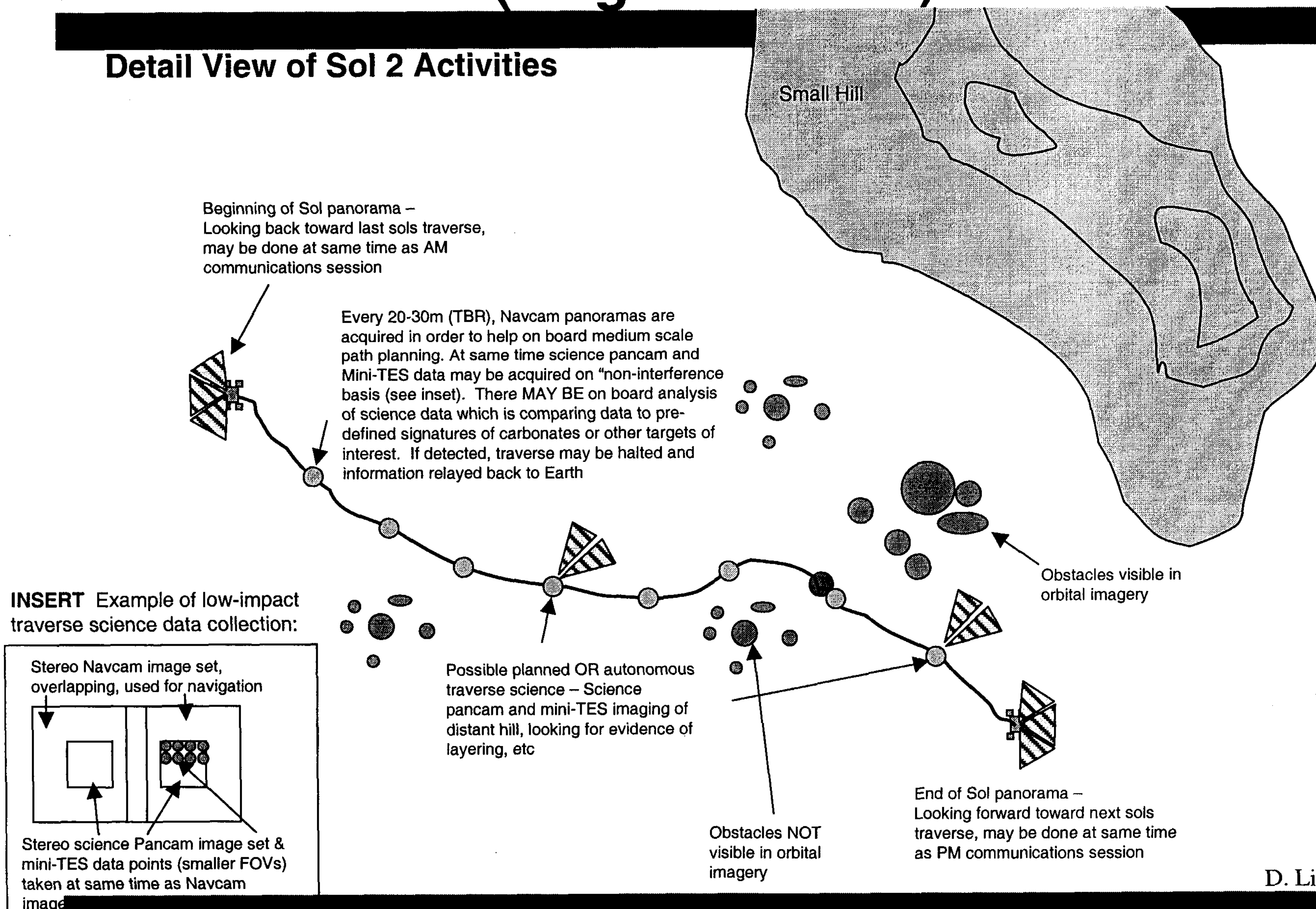
Traverse Operations (single-sol view)

Detail View of Sol 2 Activities



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