Engineering Constraints and Factors in MER Landing Sites Selection

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3rd Mars Exploration Rovers

Landing Site Selection Workshop

Acknowledgement

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Agenda

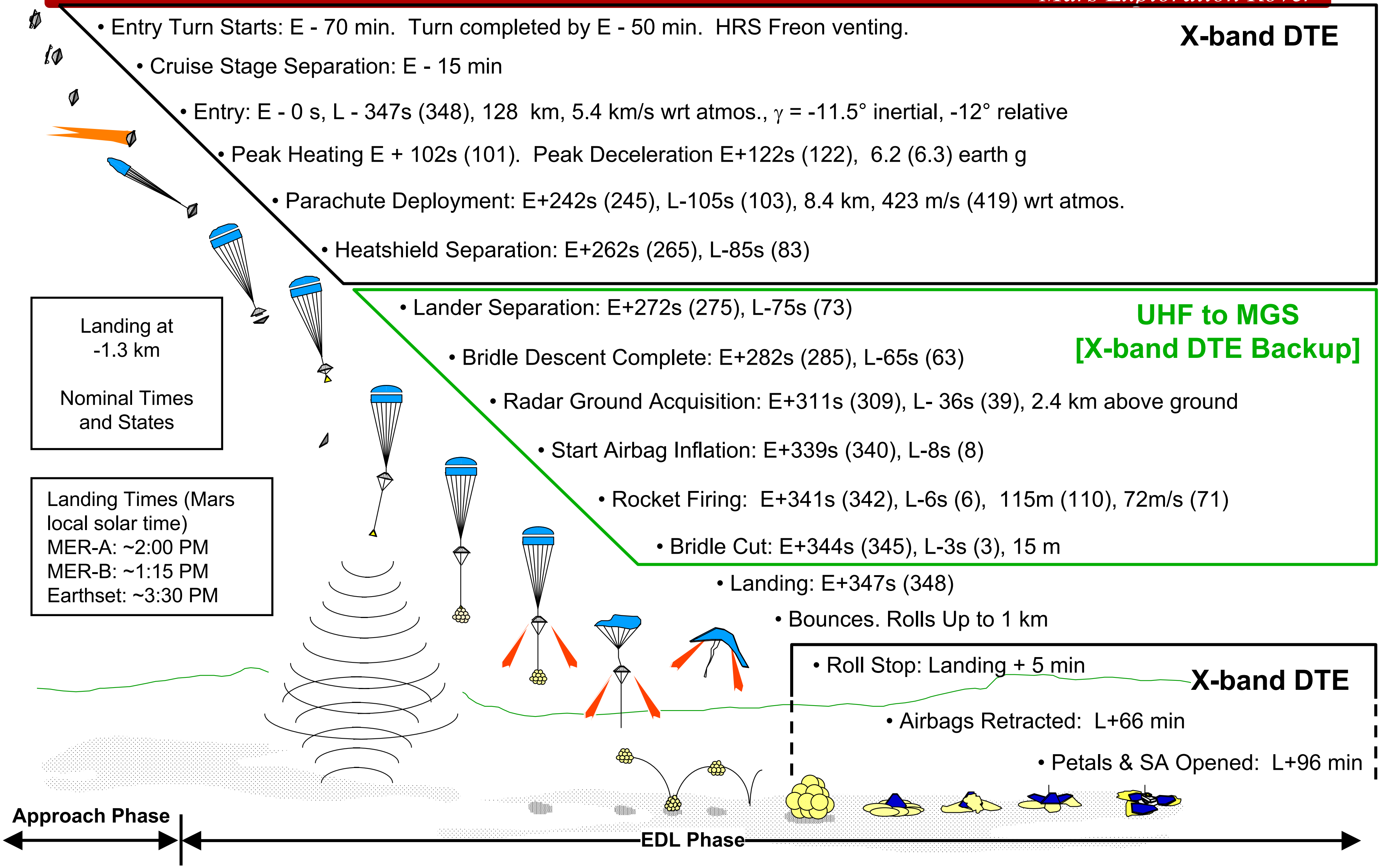
- **Landing Site Selection Factors**
- **A Review of Entry, Descent, and Landing**
- **Entry, Descent, and Landing Constraints**
- **Surface Mission Constraints**
- **Landing Site Strategy Changes and Schedule**
- **Summary and How You Can Help**

Landing Site Selection Factors

- **Landing site-related mission failures result from:**
  - **Failure to properly complete required events before impact**
    - **Altitude**
    - **RADAR reflectance**
  - **Adverse conditions for landing impacts and roll**
    - **Winds increasing impact velocity**
    - **Slopes causing shear on bags, spoofing RADAR, or adding energy on roll**
    - **Rocks tearing bags or impacting lander structure**
  - **Obstacles to deployment and egress due to immediate slope and rocks**
  - **Surface mission lifetime**
    - **Solar latitude over surface mission**
    - **Night-time temperatures and required energy to maintain thermal control**
- **Landing site engineering considerations include:**
  - **Landing latitudes and landing day (MER-A or MER-B)**
    - **Total available energy for surface mission**
    - **Energy cost of direct-to-Earth data return**
    - **Orbiter relay asset conflicts between MER-A and MER-B**
    - **Potential for extended mission**
  - **Rover trafficability with respect to rocks and terrain**

MER Entry, Descent, and Landing Timeline

Mars Exploration Rover



EDL Constraints (1)

- **Assure adequate drag to reach EDL event conditions before impact**
  - ***The altitudes at a landing site shall be less than -1.3 km relative to the MOLA geoid***
- **Assure adequate RADAR reflectivity to get range to actual surface**
  - **(thermal inertia constraint covered by temperature requirement)**
- **Limit variation between RADAR surface altitude eight seconds before landing (used for rocket-firing solution), and actual landing altitude**
  - ***On a 100 m topographic grid horizontal scale, the slopes between grid points shall be less than 5°***
- **Assure an overall decrease in kinetic energy with time while rolling**
  - ***On a 1 km horizontal scale, slopes shall be less than 2°***
  - **2° provides reasonable assurance of decelerating roll**
- **Survive more than TBD [90%] of simulated landing cases**
  - **Combine wind, local slope, and rock effects in a Monte Carlo simulation**
  - **Results of sensitivity studies to be shown by Wayne Lee tomorrow**

EDL Constraints (2)

- **Impact survival conditions (simplified criteria shown)**
  - ***Total impact velocity less than 24 m/s no rocks, 16 m/s up to 0.7 m rocks***
  - ***Normal impact velocity less than 14 m/s*** **(loads and stroke out)**
  - ***Tangential impact velocity less than 21 m/s no rocks, 14 m/s up to 0.7 m rocks***
  - ***Grazing angle of impact greater than 30° or total impact less than 10 m/s***
  - **Benefit from reduced tangential velocities after first impact due to spin up**
- **Drivers on impact survival**
  - **Horizontal and vertical velocity of first impact**
    - **Accuracy of vertical deceleration system RADAR and rockets**
    - **Wind shear not fully compensated by inertial sensing and TIRS**
    - **Sustained winds in bottom few km not fully compensated by DIMES and TIRS**
  - **Normal and tangential impact velocities**
    - **Vertical and horizontal velocity against local slope of each impact**
    - **Conversion between horizontal and vertical components by local slopes**
    - **Loss of energy in system due to inelasticity and gradual loss of gas**
  - **Rock size and coverage**
    - **Largest rock in impact area of 10 to 15 m^2 determines acceptable velocities**

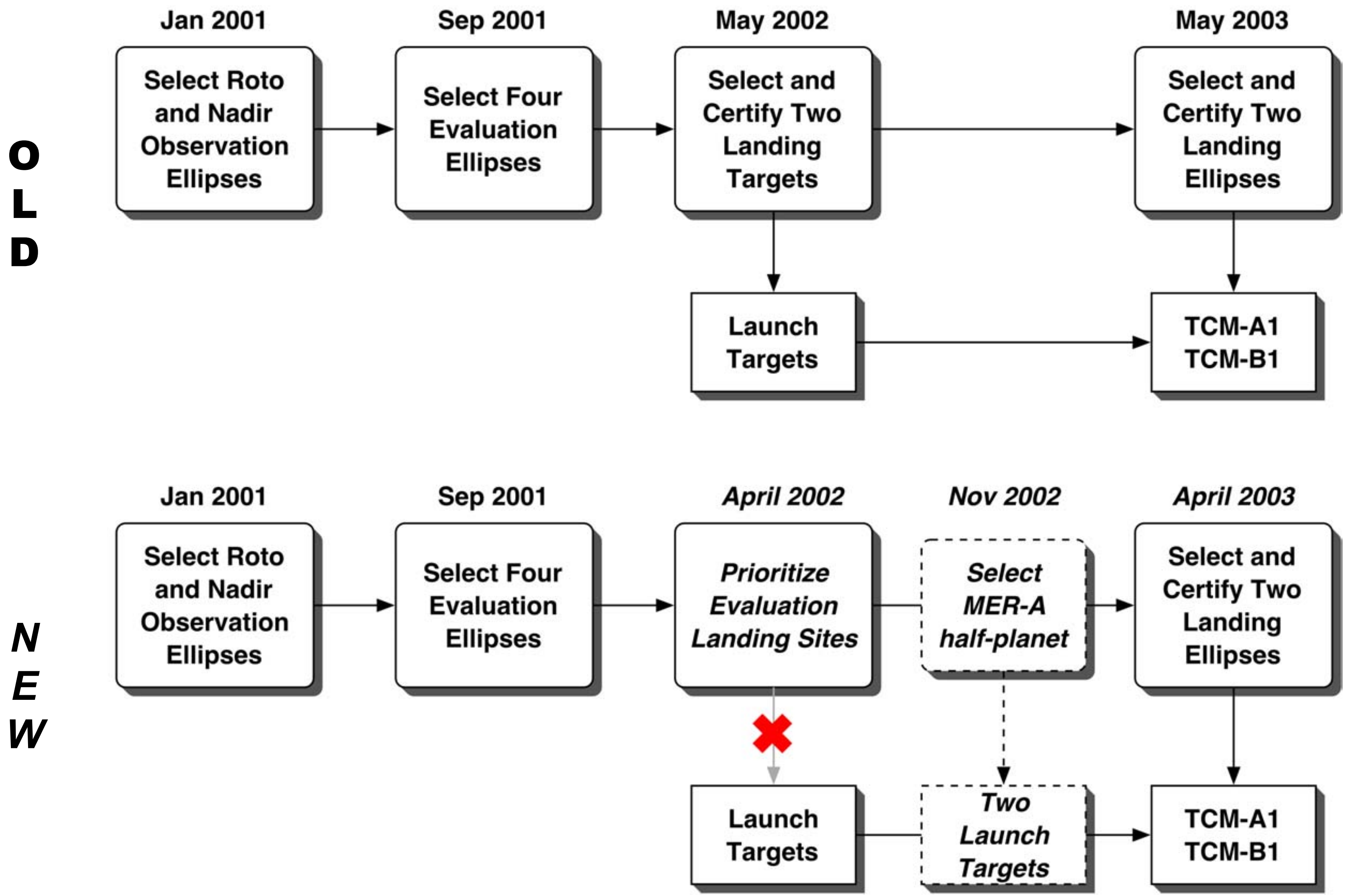
Surface Mission Constraints

- **Adequate reliability of deployment and rover egress off of lander**
  - **Affected by immediate slopes and rock abundance**
  - **Controlled by EDL rock abundance and 5 m scale slope requirements**
  - **Current baseline is three egress aids—*good system performance in test, so not a factor in site selection***
- **Surface mission lifetime and adequate energy for mission success**
  - **Solar latitude needs to be close to landing latitude over surface mission**
  - ***The center of the MER-A landing ellipse shall be within 15°S to 5°N latitude***
  - ***The center of the MER-B landing ellipse shall be within 10°S to 10°N latitude***
  - **Limit energy needed to maintain thermal control overnight**
  - ***The minimum atmospheric temperature at one meter above the surface of a landing site as determined by the measured albedo and thermal inertia shall be greater than –97C***
- **Adequate UHF data return**
  - **Avoid MER-A and MER-B seeing the same orbiter at the same time**
  - ***The centers of the MER-A and MER-B landing site ellipses shall be separated by a central angle of at least 37°***

Landing Site Selection Strategy

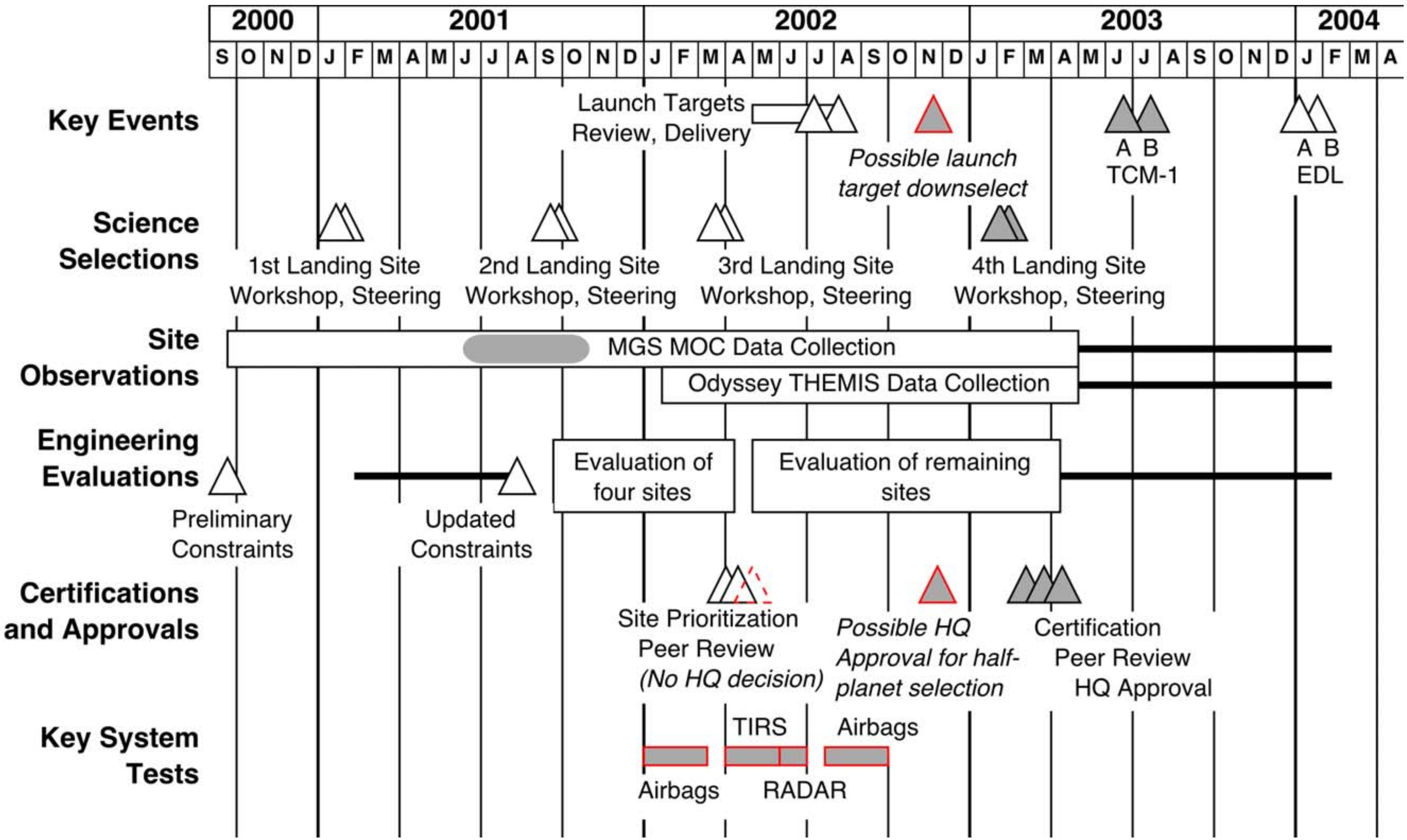
- **Old Plan:**
  - This workshop and subsequent meetings selects two landing site target regions to define the respective launch vehicle target specifications
  - Each region is 15° longitude by 10° latitude in size
  - The fourth and final workshop and subsequent meetings selects the final ellipses in each region for targeting by TCM-A1 and TCM-B1
- **New Plan:**
  - This workshop provides recommendations for the prioritization of observations and analyses of potential landing sites through Feb 2003
  - Select sites in April 2003 using TCM-A1, TCM-B1 for targeting
    - Possible half-planet down-select for MER-A in November 2002
- **Why the Change?**
  - New data on the environment brings safety of all sites into question
  - Airbag performance testing in August and September 2002
  - Other system developments and analyses over Summer 2002
  - Possibility of new discoveries from Odyssey affecting landing sites
  - New opportunities to delay site selection decisions

Old and New Selection Strategies



New Landing Site Selection Schedule

Mars Exploration Rover



New Data on Landing Sites

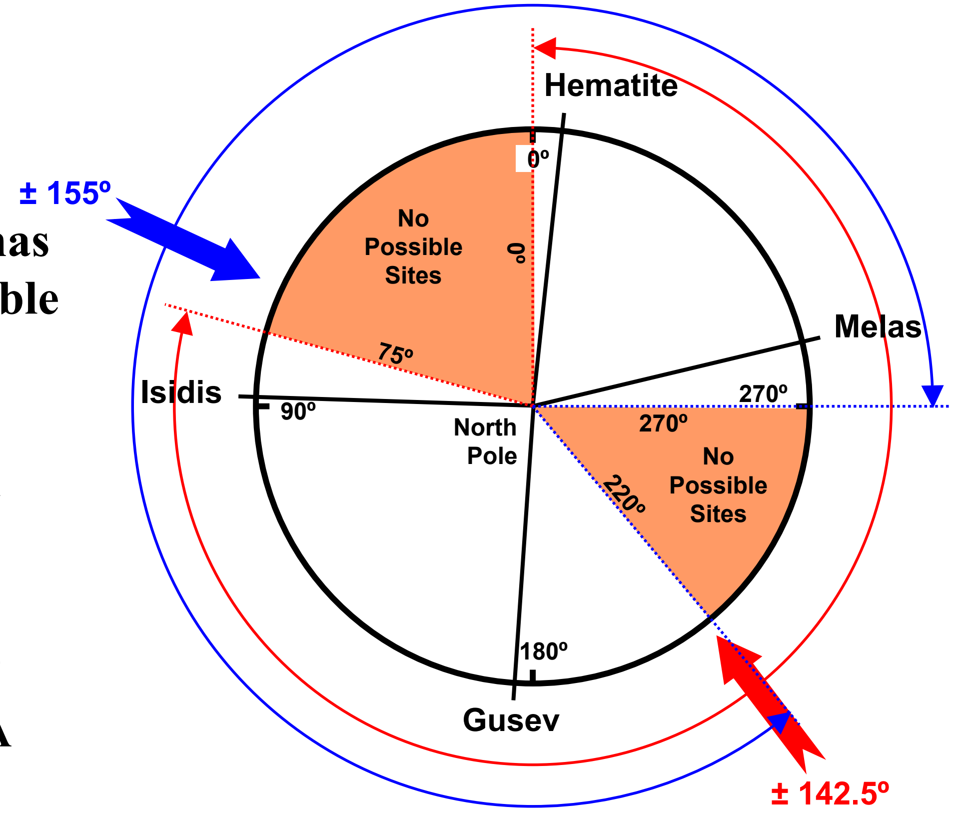
- **Mesoscale Wind Models**
  - **High winds at Melas**
  - **Wind shear at Gusev**
  - **Vertical winds at Hematite (impact not yet modeled)**
  - **Isidis not yet modeled**
- **Slopes**
  - **Significant mesas in Melas "fried egg" terrain**
    - **Breakfast food in contention—"pancake" terrain? "Grand Slam" terrain?**
  - **Some portions of Melas ellipse may have high slopes at 1 km scale**
- **Thermal**
  - **Some portions of Hematite violate thermal constraints for lifetime**
- **There are no perfect landing sites**
  - **Ok, we knew that**
  - **Continuing environmental and system analyses tend to make it look worse**
  - **Some concern that other candidates are needed to result in two safe sites at the end of all this**

New Developments on System Performance

- **Airbags**
  - **Testing and design work improving airbag capability incrementally**
  - **Tests of final airbag configuration scheduled for Aug/Sep this year**
- **Wind**
  - **Simulations showing greater sensitivity to sustained winds, especially in combination with wind shear**
    - **Previous modeling using zero-mean sustained winds shown to be optimistic**
  - **Baseline Transverse Impulse Rocket System (TIRS) mitigates wind shear**
    - **Inertial sensing of attitude combined with three horizontal rockets**
  - **Development of a ground velocity sensor may mitigate sustained winds**
    - **Descent Image Motion Estimation System (DIMES) can provide low accuracy ground velocity estimates adequate to feed into TIRS**
- **EDL Performance Assessments**
  - **Monte Carlo simulation combining driving effects still in development**
  - **Excessive conservatisms in multiple-impact models remain to be exorcised**
  - **Some conclusions can be reached from first-impact simulations**

New Decision Deferral Opportunities

- Previously TCM-1 had limited capability to change the landing target
  - Limited by 99% propellant for maneuvers and spacecraft margin
- Various improvements in the maturity of analyses and designs has resulted in more propellant available for TCM-1
  - 2 kg on MER-A, 7 kg+ on MER-B
  - Permits half-planet targeting on A
  - Permits full-planet targeting on B
- Option to develop a third launch target or more MER-A propellant
  - Two half-planet targets on MER-A
  - Pick which target in Nov 2002
  - Avoid with more MER-A propellant
    - TBD amount and source



Summary

- **Winds are now more of a concern than rocks and slope**
  - **But they all conspire together in Monte Carlo failure cases**
- **All of the high priority sites have difficulties**
  - **Hematite appears ok so far, but may have shorter surface lifetime**
- **Other candidate landing sites may need to be identified to reduce the risk of ending up with only one safe site**
  - **But do we have enough time to get the requisite MOC coverage?**
- **May be able to extend latitude band North and elevation limit up**
  - **To open up option space for other candidates**
  - **Further North results in less integrated mission energy and larger ellipses**
  - **Higher up may require shallower entry angle and thus larger ellipses**
- **Fortunately, other developments are providing us with more time**
  - **A rarity on this project**
  - **More propellant allocated for site targeting can defer any irreversible landing site decisions by six months to a year**

How You Can Help

- **We are asking the science community to comment on:**
  - **The science merits of the proposed landing sites**
  - **The veracity of the environmental models that have been developed**
  - **The application of the environmental models in the engineering analyses**
- **We'd like to come out of this workshop with:**
  - **An annotated prioritization of the sites taking into account our knowledge to date of the science and safety of the sites in order to best focus our limited observational and analysis resources over the next year**
  - **Recommendations on how to improve existing environmental analyses or perform new environmental analyses to best determine the safety of the sites**
  - **Recommendations on new observations to improve our safety and science assessments of the sites**
- **After the workshop we'd like:**
  - **A search for other candidate landing sites in possibly expanded latitude and altitude ranges that have potentially good safety and science properties**