MARS 2007 SMART LANDER

Reference Science Scenario for SDT Report

9/17/01

Jennifer Mindock

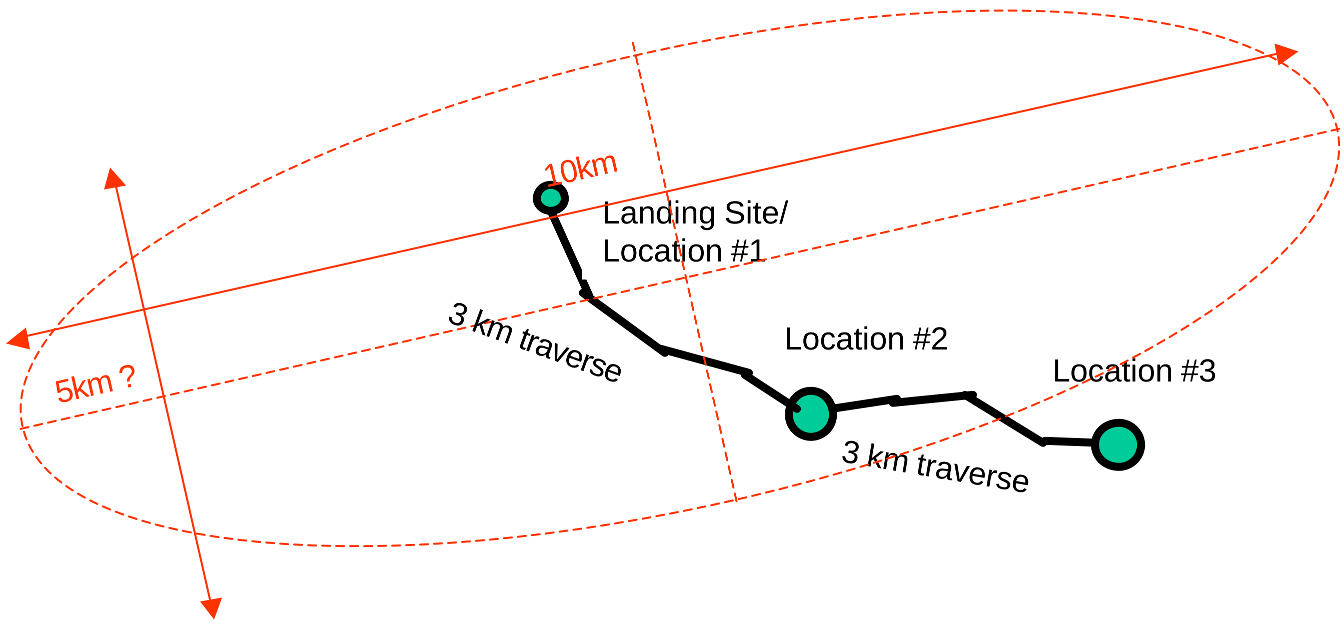
Leslie Tamppari

Daniel Limonadi

Sue Smrekar

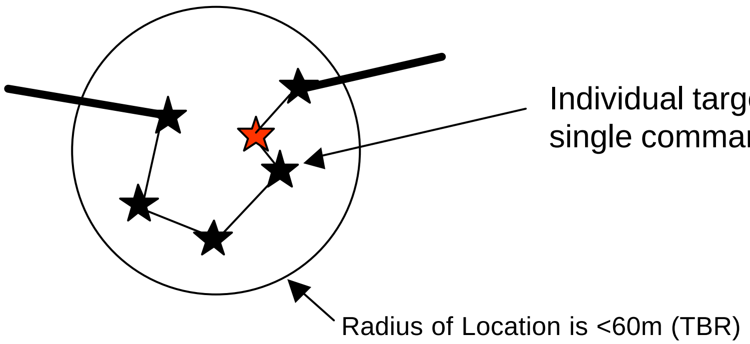
Reference Mission – Big Picture

- **Total duration of mission = 180 sols**
  - 33% margin held on mission duration, so available # of sols = 120
- **Ls = 110 to 200 (must start later if Lat is below 45S)**
- **Total distance traversed = 6 km**
- **3 locations total including landing site**
  - 3 km traverse between locations



Reference Mission – At A Location

- **Science at each location:**
  - Once at the location, the rover performs remote science first to choose the rock and soil targets
  - 4 rock targets including coring
  - 1 soil target which includes initial soil analysis and one 1 m drill hole



Drilling Scenarios

Min =minutes to carry out operation; Com- Command cycles to Earth to enable activity; Day –when activity occurs, e.g. 8 am is on the morning of the 8th day since the start of drilling; "|" with a "v" below are arrows, indicating a series of activities grouped together. Light shading indicates the start of a new step. Dark shading indicates steps that may or may not be needed.

<table>
<tr><td></td><td>Autonomy level</td><td>A1</td><td>A1</td><td>A1</td><td>A3</td><td>A3</td><td>A3</td></tr>
<tr><td></td><td>Steps</td><td>Min</td><td>Com</td><td>Day</td><td>Min</td><td>Com</td><td>Day</td></tr>
<tr><td>1</td><td>0. Command received from Earth to start scenario</td><td></td><td>E-1</td><td>1 am</td><td></td><td>E-1</td><td>1 am</td></tr>
<tr><td>2</td><td>1. Deploy the drill</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>a. Unstrap the drill and its components</td><td>1</td><td>E-1</td><td>1 pm</td><td>v</td><td></td><td></td></tr>
<tr><td>4</td><td>b. Move drill into position</td><td>5</td><td>E-1</td><td>1 pm</td><td>6</td><td>E-1</td><td>1 pm</td></tr>
<tr><td>5</td><td>2. Drill to 1st sampling point: 20 cm</td><td></td><td></td><td>2 am</td><td></td><td></td><td>2 am</td></tr>
<tr><td>6</td><td>a. Rotate drill bit</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>7</td><td>b. Adjust drilling controls as needed</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>8</td><td>c. Advance the bit</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>9</td><td>d. Record and transmit data from any downhole instruments</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>10</td><td>e. Validate target depth reached</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>11</td><td>f. Remove cuttings</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>12</td><td>g. Unstick drill (if needed)</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>13</td><td>h. Take action if drill won't cut</td><td>|</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>14</td><td>3. Collect sample</td><td>v</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>15</td><td>a. Get sample into sample acquisition device</td><td>75</td><td>E-1</td><td>2 pm</td><td>|</td><td></td><td></td></tr>
<tr><td>16</td><td>b. Raise sample to surface, including time for snags</td><td>5</td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>17</td><td>c. Raise sample from surface to deck level</td><td>10</td><td></td><td></td><td>|</td><td></td><td></td></tr>
</table>

Drilling Scenario cont.

	Autonomy level	A1	A1	A1	A3	A3	A3
19	4. Deliver sample to sample transfer system				|		
20	a. Move sample to interface w/ sample transfer system	0.5	E-1	3 am	v		
21	b. Transfer sample to sample transfer system	0.5	E-1	3 am	91	E-1	2 pm
22	5. Prepare for next drill session			3 am			3 am
23	a. "Clean" sample acquisition device	1	E-1	3 am	|		
24	b. Return sample acquisition device downhole	v			|		
25	c. Reposition drill if needed	14	E-1	3 pm	|		
26	6-1. Repeat 2-5 for 2nd sample at 40 cm			4 am	|		
27	Repeat 2a-3a	75	E-1		v		
28	Repeat 3b -4	21	E-2		111	E-1	3 pm
29	Repeat 5	20	E-2	5 pm	|		4 am
30	6-2. Repeat 2-5 for 3rd sample at 60 cm			6 am	|		
31	Repeat 2a-3a	75	E-1		v		
32	Repeat 3b -4	26	E-2		121	E-1	4 pm
33	Repeat 5	25	E-2	7 pm	|		5 am
34	6-3. Repeat 2-5 for 4th sample at 80 cm			8 am	|		
35	Repeat 2a-3a	75	E-1		v		
36	Repeat 3b -4	31	E-2		131	E-1	5 pm
37	Repeat 5	30	E-2	9 pm	|		6 am
38	6-4. Repeat 2-5 for 5th sample at 100 cm			10 am	|		
39	Repeat 2a-3a	75	E-1		v		
40	Repeat 3b -4	36	E-2	10 pm	141	E-1	6 pm
41	(Step 5 is not needed after last sample)						
45	12. Stow drill for next rover traverse (and finish remaining analyses)	30	E-2	12 pm	30		8 pm
	Margin			4			3
	Total Days per hole			16			11

Assumptions in Drilling Scenarios

1)This scenario is for a rover-based 1 m hole drilled into regolith or soft rock, with 5 samples obtained, 1 every 20 cm. No addition of drill rods or extra time to case the hole is included.

2) Two days are left at the end of drilling to clean the drill if needed, stow the drill,and finish analysis. Additionally, time should be allocated up front to position the drill.

3) A 33% time margin was added to drilling as it is a relatively poorly understood activity.

4) The sample transfer mechanism, contamination issues, and the form of the sample (cuttings or chips) have not been studied.

Example Science Scenario (Reconnaissance)

	Autonomy Level	A1: MER-like			A3: Desired		
	Rock/Soil Analysis with Reconnaissance Science	**Min**	**Com**	**Day**	**Min**	**Com**	**Day**
	1. Command received from Earth to start scenario			1 am			1 am
Recon	2. Reconnaissance science						
	a. Take Pancam data	30			30		
	b. Take first 1/2 of mini-TES data	360	E-1	1 pm	360	E-1	1 pm
	c. Take second 1/2 of mini-TES data	360	E-1	2 pm	360	E-1	2 pm
	d. Take LIBS measurements	4	E-1	3 am	4	E-1	3 am
	e. Take LIBS measurements (A1)	4	E-1	4 am			
Recon Summary	*1 location site (4 rocks and 1 soils [1-m drill hole] to be done)*	*754*	*E-4*		*754*	*E-3*	

A1 and A3 are autonomy levels , see section 5.0 for descriptions. Min = minutes; Com = command cycle to Earth; Day= days since start of activity, am or pm.

Example Science Scenario (Rock Analysis)

Mars 2007 Smart Lander

	Autonomy Level	A1: MER-like			A3: Desired		
		Min	Com	Day	Min	Com	Day
Rock	3. Drive to rock target and perform initial analysis						
	a. Command to start approach		E-1	5 am		E-1	4 am
	b. Approach from 10-20 m to < 2 m (A1), 0 m (A3); receive data	60 *	E-1	5 pm	60		
	c. Command to start short approach		E-1	6 am	N/A	N/A	
	d. Approach from <2 m to <20 cm; receive data	30 *	E-1	6 pm	N/A	N/A	
	e. Deploy arm	10 *	E-1	7 am	10 *		
	f. Verify arm placement via imaging	2	E-1	7 pm	2	E-1	4 pm
	g. Preliminary rock science analysis						
	i. Pancam data on target rock	5			5		
	ii. Mini-TES data on target rock	120			120		
	iii. Return data to Earth		E-1	7 pm		E-1	4 pm
	4. Rock coring and initial core analysis						
	a. Acquire rock core	60			60		
	b. Raman	2			2		
	e. Microscopic imaging	1			1		
	d. APXS	600			600		
	e. Moessbauer	720	E-1	8 pm	720	E-1	5 pm
	5. Deliver rock core to sample transfer system						
	a. Move sample next to interface with sample transfer system	0.5	E-1	9 am	0.5		
	b. Transfer sample to sample transfer system	0.5	E-1	9 am	0.5	E-1	6 am
	6. Prepare sample						
	a. Cut sample into 5 segments	60 *		9 am	60 *		
	b. Crush sample segments	120 *			120 *		
	c. Deliver samples to instruments (or vice versa)	5 *			5 *		
	7. Science analysis on crushed core segments						
	a. Mars organics detection	60			60		
	b. Mass spectrometry	3			3		
	c. Mars oxidant detection	3			3		
	d. Microscopic imaging	1	E-1	9 pm	1	E-1	6 pm
	8. Repeat steps 3-7 on second rock target						
	Steps 3-7 summary	1863	E-11		1863	E-6	
	9. Repeat steps 3-7 on third rock target						
	Steps 3-7 summary	1863	E-11		1863	E-6	
	10. Repeat steps 3-7 on fourth rock target						
	Steps 3-7 summary	1863	E-11		1863	E-6	
Rock Summary	*4 rock targets total*	*7452*	*E-44*		*7452*	*E-24*	
Soil Summary	*1 soil targets with 1-m drill hole and analysis*			*11 pm*			*7 am*

* To Be Resolved

Example Science Scenario (Soil Analysis)

	Autonomy Level	A1: MER-like			A3: Desired		
		Min	**Com**	**Day**	**Min**	**Com**	**Day**
Soil	11. Drive to soil target						
	a. Approach from 10-20 m distance to < 2 m (A1), 0 m (A3)	60 *	E-1	1 am	60		1 am
	b. Preliminary soil science analysis	125			125		
	i. Pancam data on soil target	5			5		
	ii. Mini-TES data on target rock	120			120		
	12. Deliver soil sample to sample transfer system						
	13. Initial soil analysis						
	(or place sample in view)	60 *			60 *		
	b. Raman	2			2		
	c. Microscopic imaging	1			1		
	d. APXS	600			600		
	e. Moessbauer	720	E-1		720	E-1	
	14. Prepare sample in analysis chamber						
	a. Crush sample	120 *			120 *		
	b. Deliver samples to instruments (or vice versa)	5 *			5 *		
	15. Science analysis on crushed soil sample						
	a. Mars organics detection	60			60		
	b. Mass spectrometry	3			3		
	c. Mars oxidant detection	3			3		
	d. Microscopic imaging	1	E-1		1	E-1	
	16. Repeat steps 12 - 16d on next 4 samples (every 20 cm depth)			11 pm			7 pm
Soil Summary	*1 soil targets with 1-m drill hole and analysis*			*11 pm*			*7 am*

* To Be Resolved

Summary of Activity Durations

Function	Duration (days)		Notes:
	A1	A3	
Remote Science	**4**	**3**	**1 per location/3 locations**
PanCam and Mini-TES 360 panoramas	2	2	
LIBS Targets	2	1	
Rock Analysis	**4.5**	**2.5**	**4 per location/3 locations**
Approach rock, coring & initial analysis	3.5	1.5	
Sample transfer, prep, and analysis	1	1	
Soil Analysis/Drill	**17**	**12**	**1 per location/3 locations**
Soil analysis at drill site	1	1	for future analysis, should be 2.5 for A1, 1.5 for A3
Drill 1m, sample transfer, and analysis	10	6	
Stow drill/finish analyses	2	2	
Margin	4	3	
Traverse	**60**	**12 to 31**	**For entire 6 km traverse**
			A3 depends on power available (varies for RPS or with latitude for solar)
MISSION TOTAL without margin	**177**	**87 to 106**	
MISSION TOTAL with margin	**265.5**	**131 to 159**	

Example Traverse Calculation for a Given Average Day

INPUT	**unit**	**value**
Vehicle Characteristics		
Wheel Diameter	m	0.5
Solar Array Area	m^2	6.00
Constants		
uflat	none	1.1
Rock Climb Energy/m	W-hr/m	6
Environment		
Latitude	deg	-30
Ls	deg	185
Gravity	m/s^2	3.8
Slope	deg	10
Rock Coverage	%	20%
Energy from sun	W-hr/m^2	716
Mission		
Drive Duration	hrs	2.64
DTE Duration	hrs	2
UHF Duration	hrs	0.7
Charge Duration	hrs	3
Sleep Duration	hrs	16.26
Total Day Duration (as a check)	hrs	24.6
Driving Support Power	W	159
DTE Power	W	216
UHF Power	W	199
Charge Power	W	24
Sleep Power	W	42

DERIVED	**unit**	**value**
Vehicle Characteristics		
Mass	kg	600.0
uslope	none	1.26
Average Velocity	m/s	0.06
Traverse Distance	m/sol	**572.4**
DTE Energy	W-hrs	432
UHF Energy	W-hrs	139.3
Charge Energy	W-hrs	72
Sleep Energy	W-hrs	682.92
Driving Support Energy	W-hrs	419.76
Sum of all support energy	W-hrs	1745.98
Mobility Power-no rock climb	Watts	171.95
Mobility Energy-no rock climb	W-hrs	453.95
Climb Energy	W-hrs	686.87
TOTAL ENERGY REQUIRED	W-hrs	2887
TOTAL ENERGY AVAILABLE	W-hrs	4124
Energy Avail w/ 30% margin		**2886.8**
Drive duration (should match C18)	hrs	2.650
(press cntrl+l to iterate after changing C18)		
Total distance between locations	m	3000
Odometry multiplier		1.5
Total odometry/traverse	m	4500
Total sols/traverse	**sols**	**7.86**
Thermal penalty	W-hrs	172

Explanation of Traverse Calculations

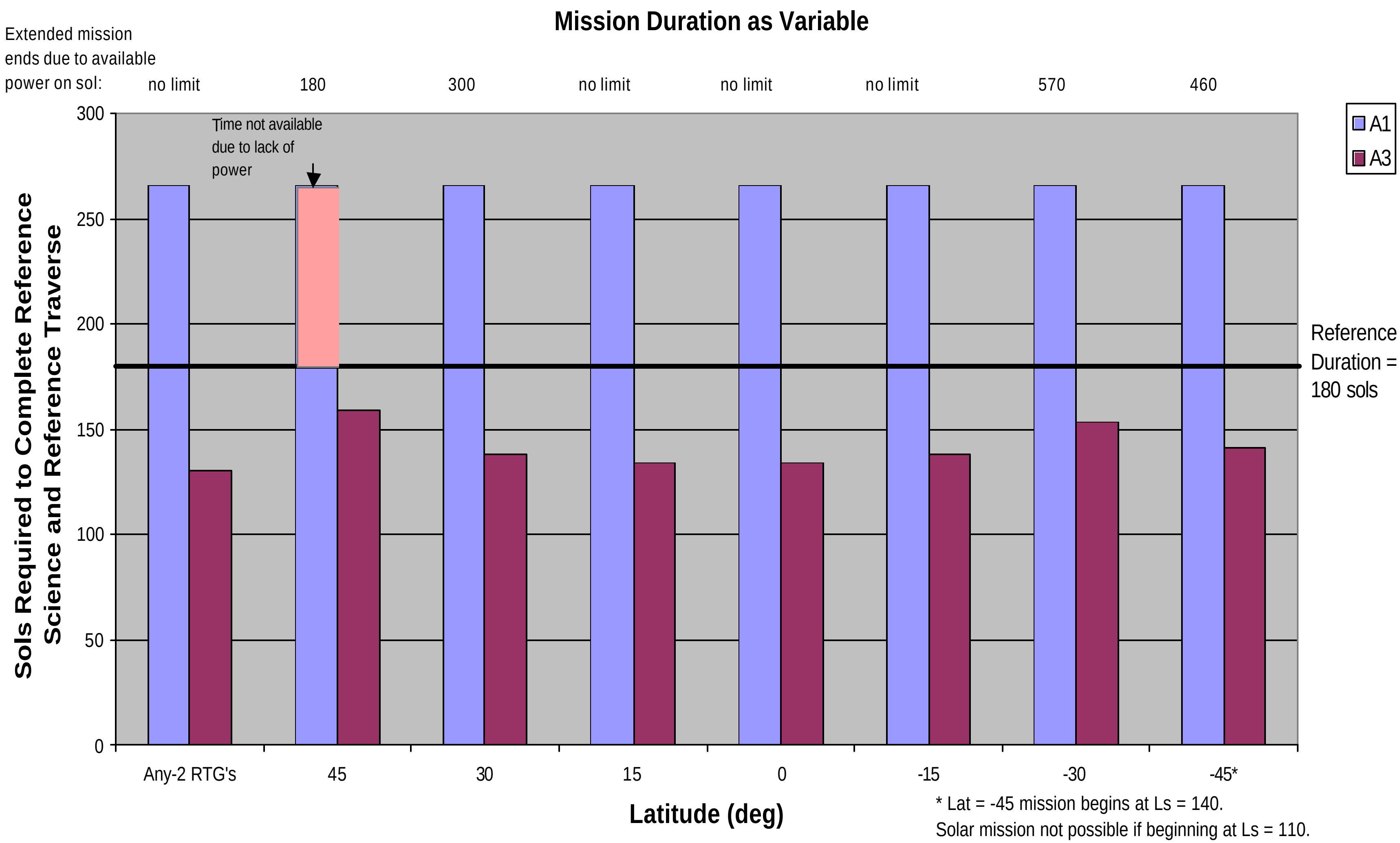
- **Vehicle Characteristics (Input and Derived)**
  - Wheel diameter, mass, and solar array area are from reference vehicle assumptions
  - Power required for mobility of the rover: P = u * Mass * Gravity * Velocity of rover
    - Uflat is the loss coefficient, u, on flat terrain
    - 1.1 value is derived from large rover test data
    - Uslope is the loss coefficient, u, increased due to driving on a slope
  - Rock Climb Energy/m is the amount of energy required by the rover to climb over a rock per meter of ground that is covered by rocks
  - Average Velocity is based on test rover data and traverse requirements
- **Environment**
  - Latitude and Ls are not used in any calculations, but must be known to find energy from sun at that average day
  - Gravity, Slope, and Rock Coverage are inputs for calculating mobility power required
  - Energy from sun is found from the model of energy available based on latitude and Ls
- **Mission**
  - DTE, UHF, and Charge Durations are held constant based on the average day assumed
  - Drive Duration is based on how much energy is available
  - Sleep Duration is remaining time
  - Driving Support, DTE, UHF, Charge, and Sleep Power values are based on design team work assuming the level of component operations for each of these modes

Explanation of Traverse Calculations cont.

- **Support Energy**
  - DTE, UHF, Charge, Sleep, and Driving Support energy values are the time duration of each mode times the power required in each mode
- **Mobility Energy – no rock climb**
  - Is the power required for mobility without climbing (P=uMgV) times the drive duration
- **Climb Energy**
  - Is the Rock Climb Energy/m times the Traverse Distance
- **Total Energy Required = Support Energy + Mobility Energy + Climb Energy**
- **Total Energy Available = Energy from sun * Solar Array Area**
- **Energy Available with 30% Margin = 70% of Total Energy Available**
- **Calculation**
  - Spreadsheet changes Traverse Distance so Energy Required matches Energy Available with 30% Margin
  - Calculates drive duration by dividing traverse distance by average velocity
  - Then iterate Drive Duration under Mission description until everything agrees
- **Total sols/Traverse is how many sols it takes to complete a 3 km traverse based on the Traverse Distance found for this average day**
- **Thermal penalty varies depending on latitude (input from thermal analysis)**

Mission Duration as Variable

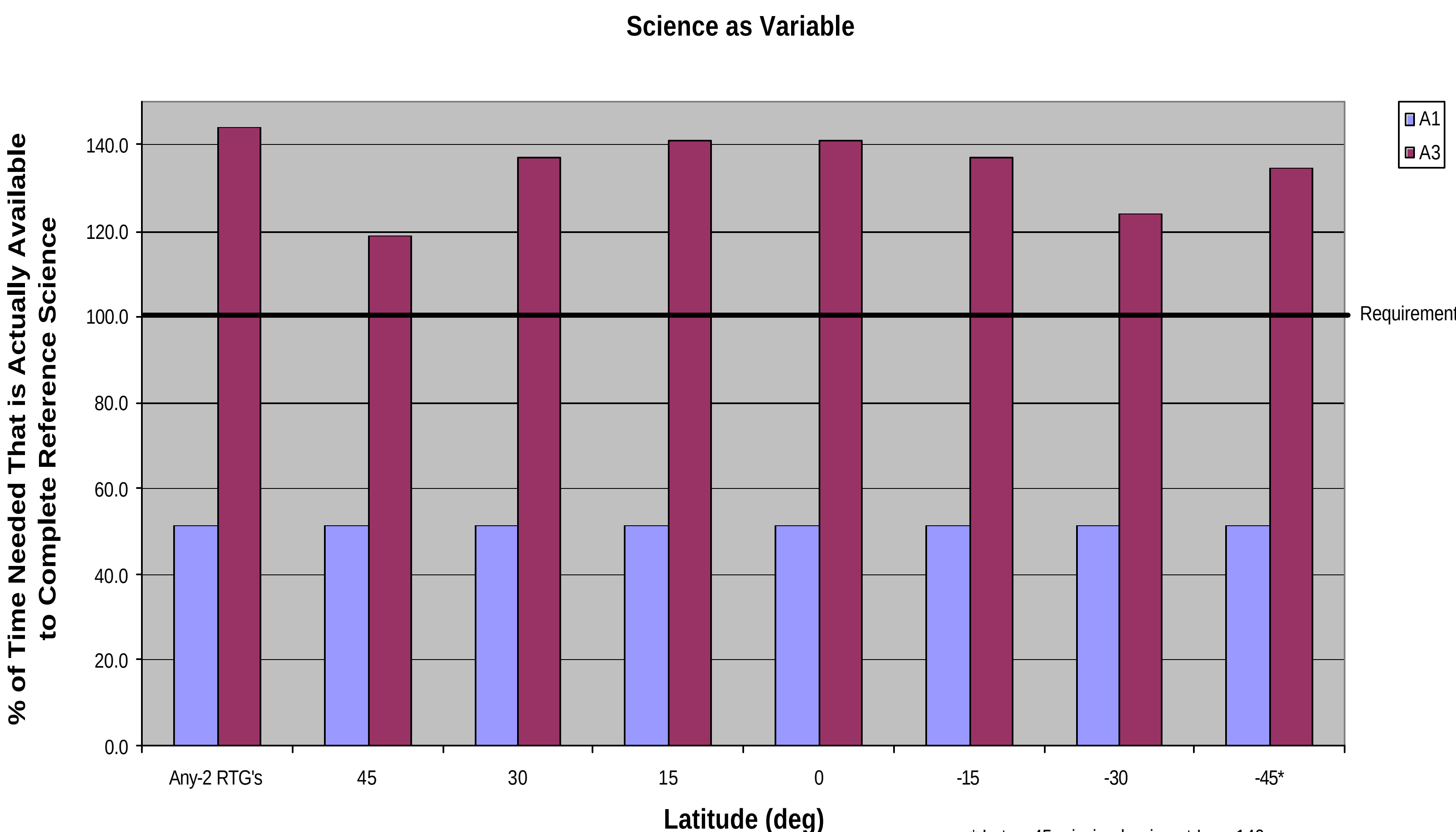
Mars 2007 Smart Lander



Comments on Mission Duration Graph

- **The 180 sol mission is divided into 3 segments of 60 sols each. 20 sols in each of the 3 segments are held as margin. For each segment, the available power used is the average for those 60 sols.**
- **Because of the average segment approach, quantization error, in our estimate on the order of days, is introduced into the mission duration results. Therefore it is important to focus on the relative relationships between the A1 and A3 results and not the absolute values of the results.**
  - The first segment is for science activity at the landing site. No driving takes place at this average power level.
  - The remaining two segments include science activities and traverse at their respective average power levels.
- **A1 is not limited by power during its traverse, but by how far can be seen in the Navcam images. Thus the traverse duration, and therefore required mission duration, does not change with latitude.**

Science Accomplished as Variable

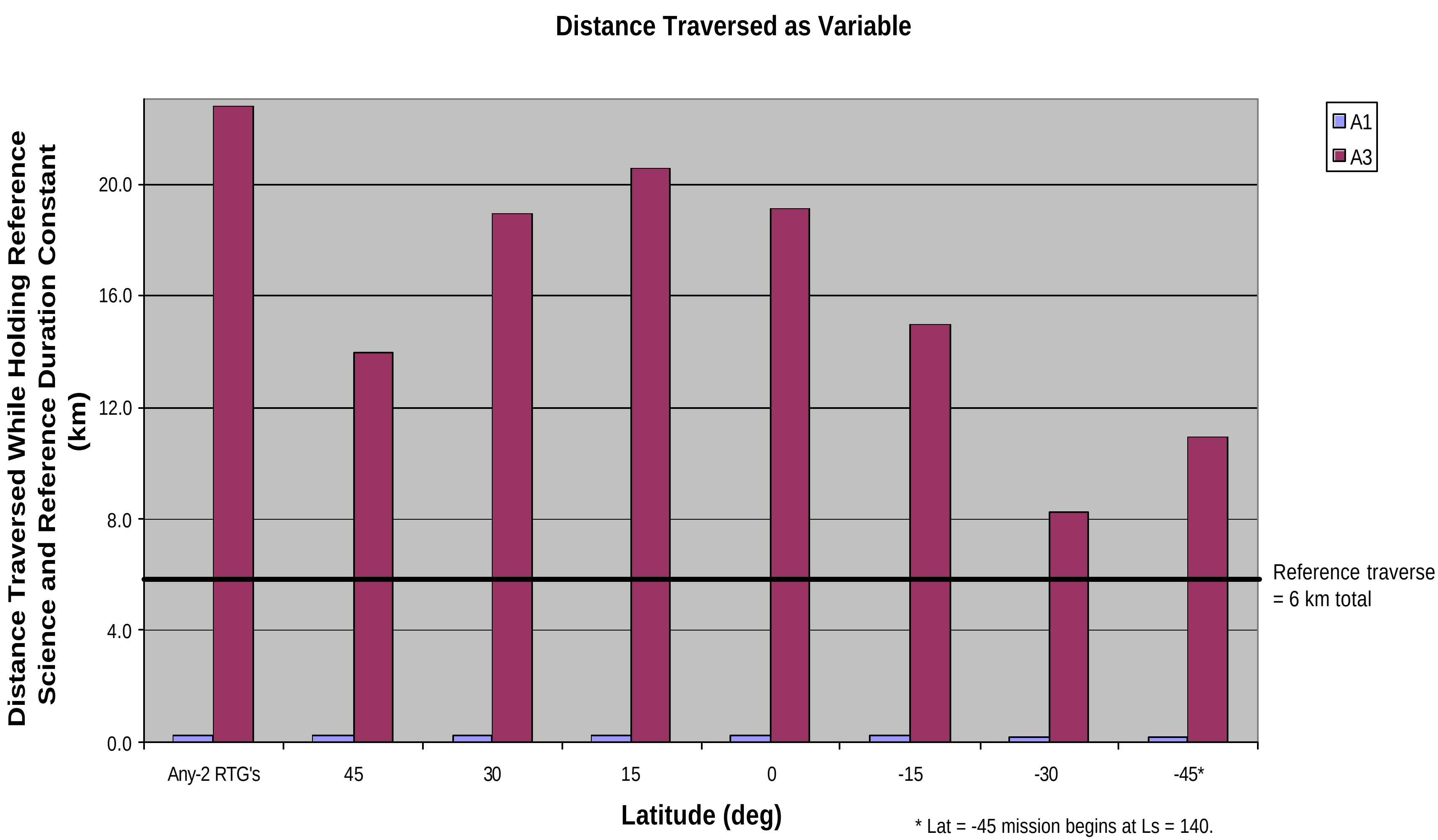


* Lat = -45 mission begins at Ls = 140.
Solar mission not possible if beginning at Ls = 110.

Comments on Science Return Graph

- **This graph is also based on time, and therefore the same flat trend across latitudes for A1 occurs because the traverse duration does not change with latitude.**
- **The same approach is applied in which the 180 sol mission is divided into 3 segments of 60 sols each, with 20 sols of margin in each segment. For each segment, the available power used is the average for those 60 sols.**
  - The first segment is again at the landing site and only science activities, the reference and additional ones if time permits, are performed.
  - The remaining segments require the reference science activities and reference traverse to be performed. The remaining time during the segment after 1 reference science location and 1 reference traverse is left to additional science activities.

Distance Traversed as Variable



* Lat = -45 mission begins at Ls = 140.
Solar mission not possible if beginning at Ls = 110.

Comments on Distance Graph

- **The same approach is applied in which the 180 sol mission is divided into 3 segments of 60 sols each, with 20 sols for margin in each. For each segment, the available power used is the average for those 60 sols.**
  - The first segment is again at the landing site. In this case, the reference science is completed and the remaining time is left to traverse at that average power level.
  - The remaining segments require the reference science activities to be completed as well. The time remaining in each segment is left to traverse at the respective segment's power level.
- **A1 has a slight decrease in the lower latitudes (-30 and –45) because traverse during the first average segment was allowed. The available power levels during these first segments does not allow the 100m/sol traverse for A1. For these latitudes A1 and A3 are both power limited during the first segment.**

Days Saved by A3 compared to A1