The budgeted cost for the rover development is $60M. Current estimates for development and fabrication of 2 flight rovers are: communication $8.4M, computing $2.7M, visualization/safeguarding $7.6M, power $13.1M, thermal $8.0M, locomotion $4.1M, structure $1.8M for a total of $45.7M. With the addition of a 15% management margin and an overhead of 15% for contingency, the total development costs are $60.4M. This number does not include software development, and the thermal/locomotion/structure numbers are quite rough at this time. Cost and potential vendor information is shown in Table 4.3.

TABLE 4.2 *Rover mass and power budget.*

Compenent (#)		Component Mass (kg)	Support Mass (kg)	Power (W)	Margin Used
Target value including system margin and efficiency losses		**251.8**		**70 loco + 352 other**	**5% system 82% ineff**
TOTAL FOR ONE ROVER		**248.8 224.4 + 24.4**		**70 loco + 363 other**	
Locomotion		**54.2**		**70W avg**	
Driving Actuators	(6)	18.5	-	variable	13%
Steering Actuators	(4)	9.5	-	variable	13%
Wheels	(6)	11.8	-	-	13%
Chassis and Fenders	(1)	14.4	-	-	13%
Communication		**15.9**	**1.8**	**101.9**	
Phased Array	(1)	12.6	12%	94.5	5%
Transponder	(1)	1.0	12%	5.3	5%
Inter-rover Link	(1)	1.0	12%	1.0	5%
Backup omni Link	(1)	1.1	12%	backup	5%
Multiplexer	(1)	0.1	-	1.0	5%
RF Switching	(3)	0.1	-	0.1	5%
Visualization/Safeguarding		**24.1**	**2.9**	**63.6**	
Pano-sphere Cameras	(4)	7.3	15%	24.0	5%
Under-body Cameras	(2)	3.2	10%	5.4	5%
Stellar Compass	(1)	1.0	10%	0.1	5%
IMU's	(2)	1.1	-	16.8	5%
Impulse Radar	(150)	10.4	12%	11.7	30%
State sensors	(??)	1.1	10%	5.6	13%
Computing		**11.3**	**1.0**	**197.6**	
VME Cage	(1)	3.5	10%	16.2	8%
MCM's	(5)	7.3	10%	181.4	8%
Cabling to Power	(??)	0.5	-	-	8%
Power		**57.3**	**12.6**		
Plutonium GPHS	(14)	29.4	30%		5%
AMTEC	(112)	14.7	20%		5%
Power Regulation	(1)	4.3	11%		8%
DC/DC Conversion	(10)	1.1	10%		8%
Cappatteries	(20)	2.3	10%		13%
Intersubsystem Cabling	(59m)	5.5	-		13%
Thermal		**34.5**	**6.1**		

TABLE 4.2 *Rover mass and power budget.*

Compenent (#)		Component Mass (kg)	Support Mass (kg)	Power (W)	Margin Used
Radiator	(3)	5.4	20%		8%
Heat Pipe	(??)	14.7	20%		13%
MLI	(100m^2)	3.4	20%		13%
Carbon Aerogel	(??)	4.2	10%		5%
Joints	(??)	6.8	10%		13%
Structure		**27.1**			
Base	(1)	7.9			13%
Ribs	(5)	10.4			13%
Gussets	(??)	3.2			13%
External Covering	(50m^2)	5.6			13%

TABLE 4.3 *Rover cost budget and vendor information*

Component (#)		Develop Cost ($M)	Unit Cost of 1 rover ($M)	Total Cost D+2*UC ($M)	Model / Vendor
TARGET COST ($60M with 15% management and 15% contingency)				**43.35**	
TOTALS		**13.4**	**15.85**	**45.1**	
Locomotion		**0.8**	**1.45**	**3.7**	
Driving Actuators	(6)	0.2	0.5	1.2	Inland RBE-01512,
Steering Actuators	(4)	0.2	0.4	1.0	HD Systems CSF-2A-GR
Wheels	(6)	0.2	0.3	0.8	CMU fabrication
Chassis	(1)	0.2	0.25	0.7	CMU fabrication
Communication		**3.3**	**2.7**	**8.7**	
Phased Array	(1)	3.2	1.6	6.4	Ball Aerospace
Transponder	(1)	0.1	0.45	1.0	Motorola
Inter-rover Link	(1)	-	0.25	0.5	E-systems
Backup Omni Link	(1)	-	0.25	0.5	E-systems
Multiplexer	(1)	-	0.05	0.1	Loral
RF Switching	(3)	-	0.1	0.2	Loral
Visualization/Safeguarding		**3.95**	**1.825**	**7.6**	
Pano-sphere Cameras	(4)	1.5	0.5	2.5	DALSA, CA-D9
Under-body Cameras	(2)	1.0	0.25	1.5	DALSA, CA-D9
Startracker	(1)	-	0.15	0.3	Lawrence Livermore, STSC
IMU's	(2)	0.1	0.75	1.6	Litton, Honeywell
Impulse Radar	(150)	1.3	0.1	1.5	Lawrence Livermore, MIR
State Sensors	(??)	0.05	0.075	0.2	-
Computing		**1.55**	**0.575**	**2.7**	
VME Cage	(1)	0.1	0.2	0.5	-
MCM's/Rad hardened C80	(5)	1.4	0.3	2.0	TI, MVP-C80; Harris, RH3000
Cabling to Power	(??)	0.05	0.075	0.2	-
Power		**2.6**	**5.2**	**13.0**	

TABLE 4.3 *Rover cost budget and vendor information*

Component (#)		Develop Cost ($M)	Unit Cost of 1 rover ($M)	Total Cost D+2*UC ($M)	Model / Vendor
Plutonium GPHS	(14)	1.0	2.0	5.0	Lavochkin Institute
Thermo-Electric Conv	(112)	1.0	2.0	5.0	AMPS,
Power Regulator	(1)	0.4	0.4	1.2	Matra Marconi, INMARSAT
DC/DC Conversion	(10)	0.1	0.35	0.8	Interpoint, MHP270
Cappatteries	(20)	0.1	0.2	0.5	Evans, Cappatery
Intersubsystem Cabling	(59m)	-	0.25	0.5	-
Thermal		**0.8**	**3.6**	**8.0**	
Radiator	(3)	0.2	0.9	2.0	????
Heat Pipe	(??)	0.2	0.8	1.8	Noren Products
MLI	($100m^2$)	0.1	0.3	0.7	Thermo Electron Technologys Corp
Carbon Aerogel	(??)	0.1	1.45	3.0	BMDO/JPL
Joints	(??)	0.2	0.15	0.5	-
Structure		**0.4**	**0.45**	**1.3**	
Base	(1)	0.1	0.15	0.4	Hexcel
Ribs	(5)	0.06	0.05	0.16	CMU Fabrication
Gussets	(??)	0.04	0.03	0.1	CMU Fabrication
External Covering	($50m^2$)	0.1	0.12	0.34	DuPont, Thermo Electron Tech. Corp
Pyrotechnic Disconnects	(6)	0.1	0.1	0.3	

locomotion

Six wheels, each independently driven, are suspended from the body using a passive linkage “rocker-bogie” chassis with the wheels equally spread along the side of the vehicle. The wheels (40 cm diameter, 30 cm width) have a mesh tread comprised of zinc coated steel wires, with 18 aluminum grousers attached for traction (2.5 cm high by 0.3 cm thick). The tread is attached to three perforated aluminum disks which are, in turn, attached to the wheel hub. The front and middle wheels on each side are connected via the short bogie (75 cm) which is attached to the rear wheel by the long bogie (115 cm). The rear wheels on both sides are connected via an averaging linkage. The bogie members are made of rectangular aluminum sections, again perforated to reduce weight. To prevent dust from being kicked onto the rover body by the wheels, the top sector of each wheel is covered by a fender. The six drive actuators contain redundant motors, a harmonic drive, brake, and Hall effect sensors for velocity feedback. Explicit steering on the corner wheels enhances the trafficability of the robot. The wheelbase of the vehicle is a 2.0 m x 2.0 m square. The locomotion system uses 58 W of power on average with 320 J available in reserve, and the total mass of the actuators, wheels, and chassis are 54.2 kg.

communication

Downlink communication from the rover to earth is achieved using a phased array antenna operating in X band, with a low-gain omnidirectional antenna for the uplink and as downlink backup. Applications have been filed for frequency licensing from bandwidth allocated for experimental space research. The 655 element antenna (0.55 m diameter) is capable of electronically steering the beam up to 60 degrees from the vertical. The steering vector is computed using a startracker and inertial measurements. The downlink transmission is modulated using Nyquist QPSK to band-limit the signal within the allocated frequency range. One rover utilizes right-hand circular polarization which the other uses left-hand to allow both rovers to communicate simultaneously while sharing the same frequency range. Error correction is accomplished via a rate 2/3 turbocode, and the anticipated bit-error-rate is 10^{-6}. Three ground stations with a 22m parabolic antenna are

The budgeted cost for the rover development is $60M. Current estimates for development and fabrication of 2 flight rovers are: communication $8.4M, computing $2.7M, visualization/safeguarding $7.6M, power $13.1M, thermal $8.0M, locomotion $4.1M, structure $1.8M for a total of $45.7M. With the addition of a 15% management margin and an overhead of 15% for contingency, the total development costs are $60.4M. This number does not include software development, and the thermal/locomotion/structure numbers are quite rough at this time. Cost and potential vendor information is shown in Table 4.3.

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Compenent (#)		Component Mass (kg)	Support Mass (kg)	Power (W)	Margin Used
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TOTAL FOR ONE ROVER		**248.8 224.4 + 24.4**		**70 loco + 363 other**	
Locomotion		**54.2**		**70W avg**	
Driving Actuators	(6)	18.5	-	variable	13%
Steering Actuators	(4)	9.5	-	variable	13%
Wheels	(6)	11.8	-	-	13%
Chassis and Fenders	(1)	14.4	-	-	13%
Communication		**15.9**	**1.8**	**101.9**	
Phased Array	(1)	12.6	12%	94.5	5%
Transponder	(1)	1.0	12%	5.3	5%
Inter-rover Link	(1)	1.0	12%	1.0	5%
Backup omni Link	(1)	1.1	12%	backup	5%
Multiplexer	(1)	0.1	-	1.0	5%
RF Switching	(3)	0.1	-	0.1	5%
Visualization/Safeguarding		**24.1**	**2.9**	**63.6**	
Pano-sphere Cameras	(4)	7.3	15%	24.0	5%
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IMU's	(2)	1.1	-	16.8	5%
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Computing		**11.3**	**1.0**	**197.6**	
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Power Regulation	(1)	4.3	11%		8%
DC/DC Conversion	(10)	1.1	10%		8%
Cappatteries	(20)	2.3	10%		13%
Intersubsystem Cabling	(59m)	5.5	-		13%
Thermal		**34.5**	**6.1**		

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Carbon Aerogel	(??)	4.2	10%		5%
Joints	(??)	6.8	10%		13%
Structure		**27.1**			
Base	(1)	7.9			13%
Ribs	(5)	10.4			13%
Gussets	(??)	3.2			13%
External Covering	($50m^2$)	5.6			13%

TABLE 4.3 *Rover cost budget and vendor information*

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Backup Omni Link	(1)	-	0.25	0.5	E-systems
Multiplexer	(1)	-	0.05	0.1	Loral
RF Switching	(3)	-	0.1	0.2	Loral
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IMU's	(2)	0.1	0.75	1.6	Litton, Honeywell
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State Sensors	(??)	0.05	0.075	0.2	-
Computing		**1.55**	**0.575**	**2.7**	
VME Cage	(1)	0.1	0.2	0.5	-
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Intersubsystem Cabling	(59m)	-	0.25	0.5	-
Thermal		**0.8**	**3.6**	**8.0**	
Radiator	(3)	0.2	0.9	2.0	????
Heat Pipe	(??)	0.2	0.8	1.8	Noren Products
MLI	($100m^2$)	0.1	0.3	0.7	Thermo Electron Technologys Corp
Carbon Aerogel	(??)	0.1	1.45	3.0	BMDO/JPL
Joints	(??)	0.2	0.15	0.5	-
Structure		**0.4**	**0.45**	**1.3**	
Base	(1)	0.1	0.15	0.4	Hexcel
Ribs	(5)	0.06	0.05	0.16	CMU Fabrication
Gussets	(??)	0.04	0.03	0.1	CMU Fabrication
External Covering	($50m^2$)	0.1	0.12	0.34	DuPont, Thermo Electron Tech. Corp
Pyrotechnic Disconnects	(6)	0.1	0.1	0.3	

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