



Brush-Wheel Sampler Concept  
for: Gulliver Deimos Sample Return  
*Discompro* ~~Mars Scout~~ Proposal

Presented by: Dr. Alberto Behar, Proposal Manger

Prepared by: Tom Rivellini  
Fabien Nicaise  
May 5, 2003



Reference Science and Engineering Requirements

- Sample goal: 10 kg
- Collect rocks of up to 3 cm in diam.
- Rapid collection time of ~.6 sec
- Tolerant of large (>3cm) rocks
- Single pass full sample as a goal, but with capability of multiple passes
- May use an extendable boom of up to 5 m in length



## Design Drivers

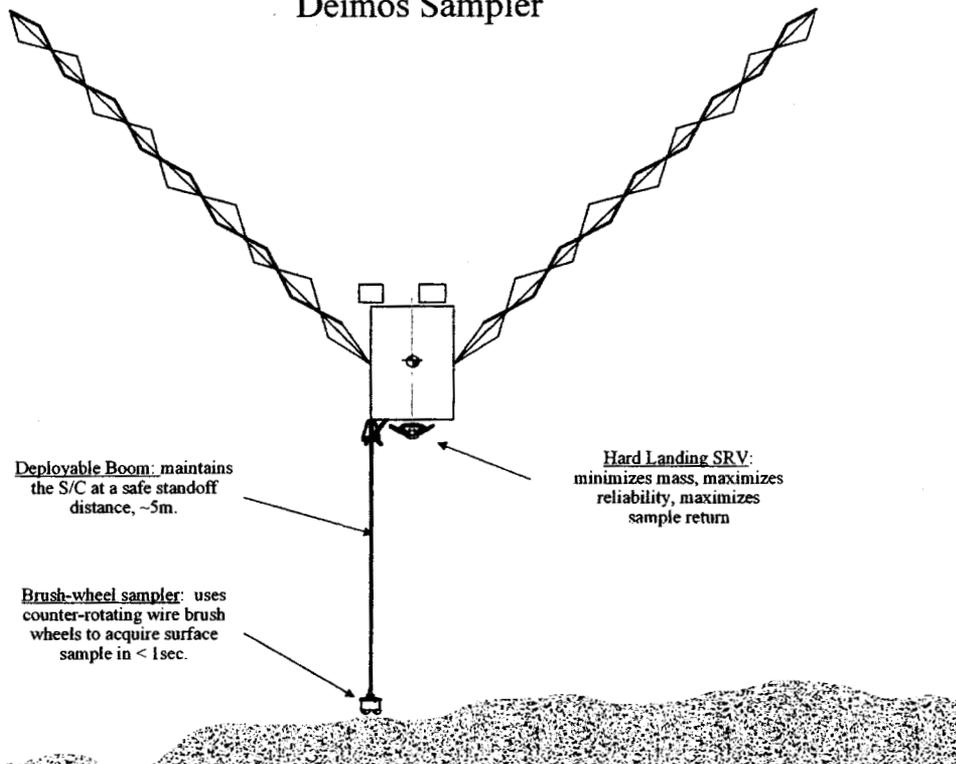
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- Minimum to no interaction with spacecraft control system
  - No net momentum vector
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- Open loop operation
- Only momentary contact with surface required
- Touch and Go velocity assumptions (worst case)
  - $V_v = 1.0$  m/s
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- Low contact force required to collect sample
- Simple and robust handoff to Entry Vehicle
- Balanced sample regardless of final sample mass

3

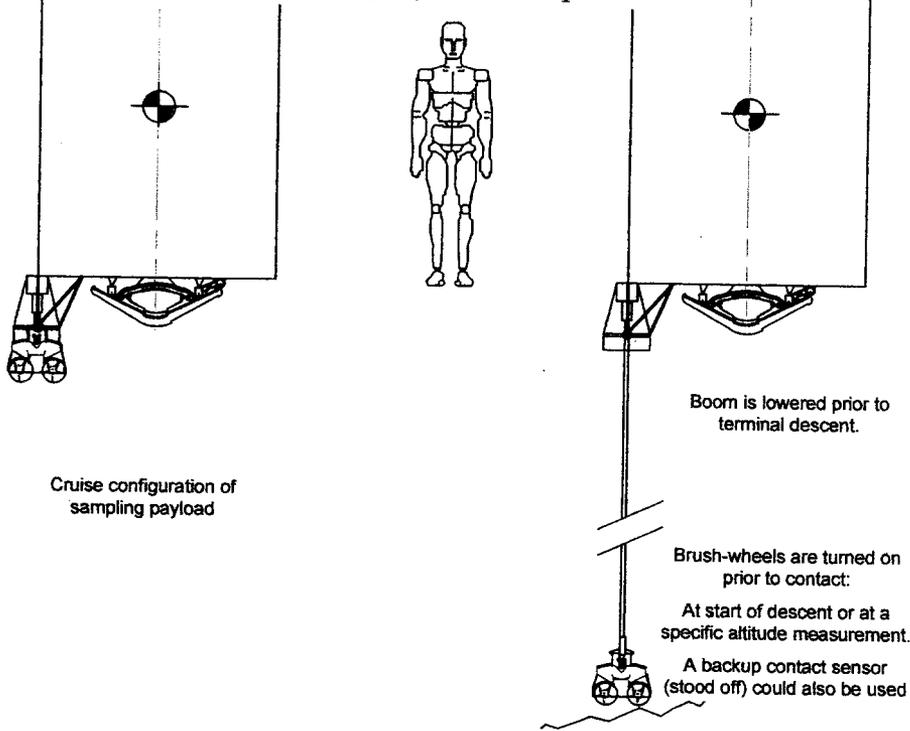


## Deimos Sampler

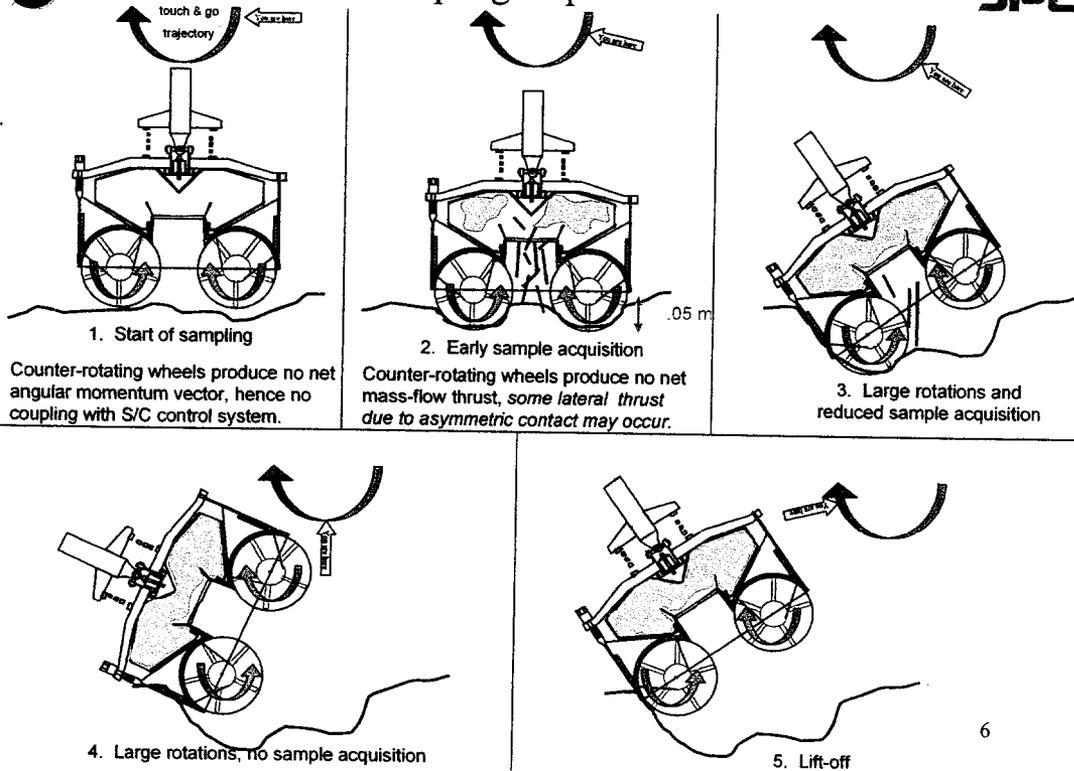




# Deployment Sequence



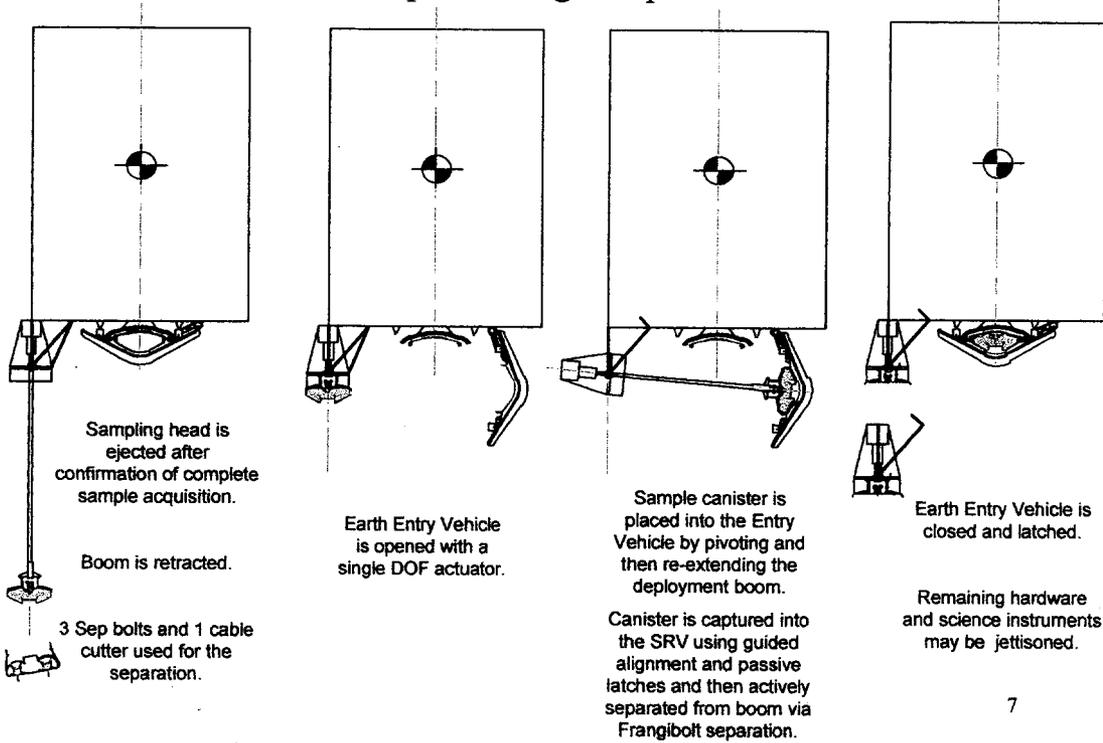
# Sampling Sequence





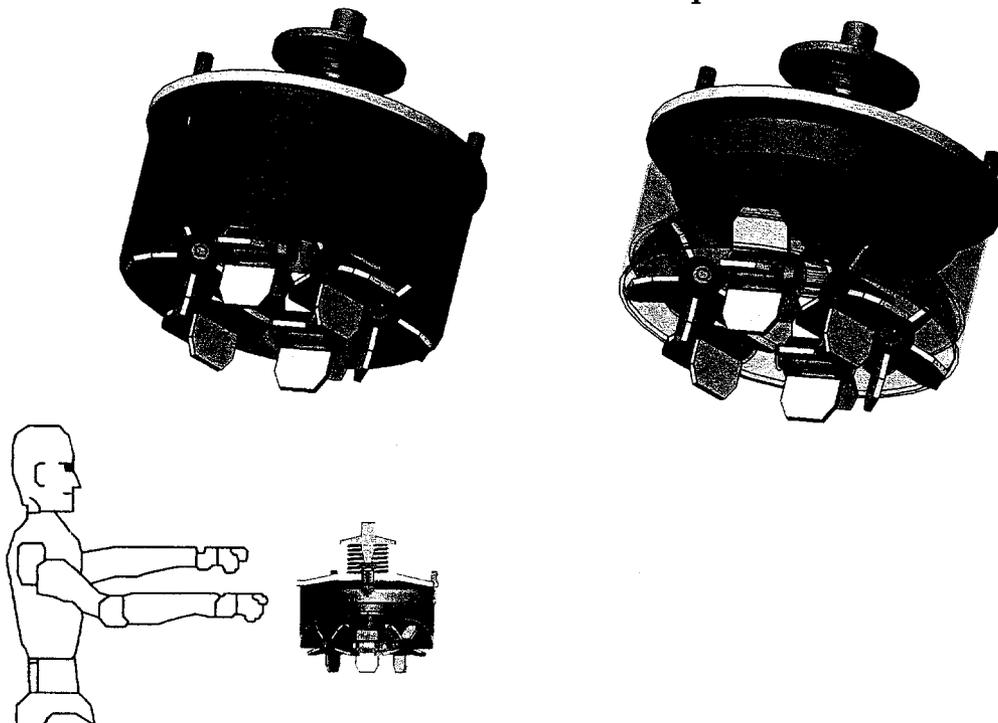
JPL

### Sample Stowage Sequence



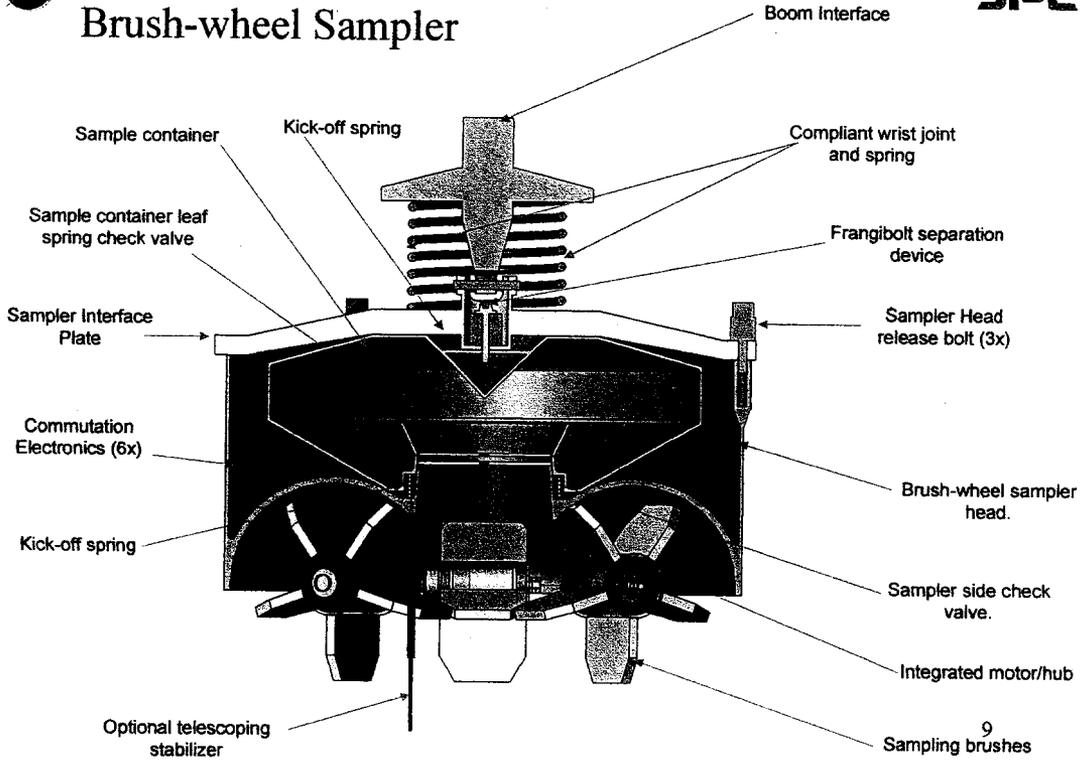
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### Brush-wheel Sampler

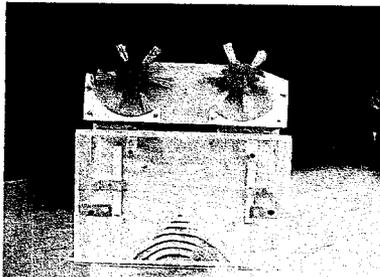
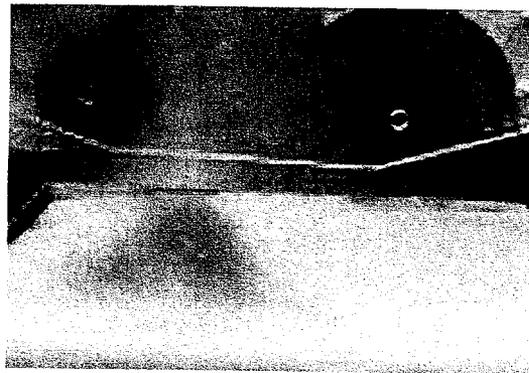
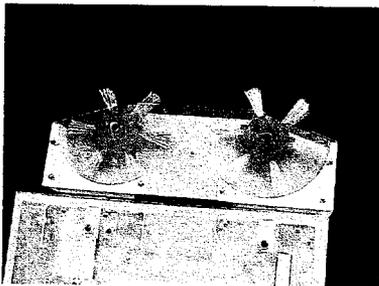




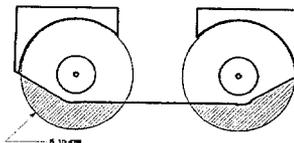
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# Brush-wheel Sampler Proof Of Concept Demo.



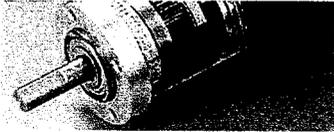
Double Click to play movie



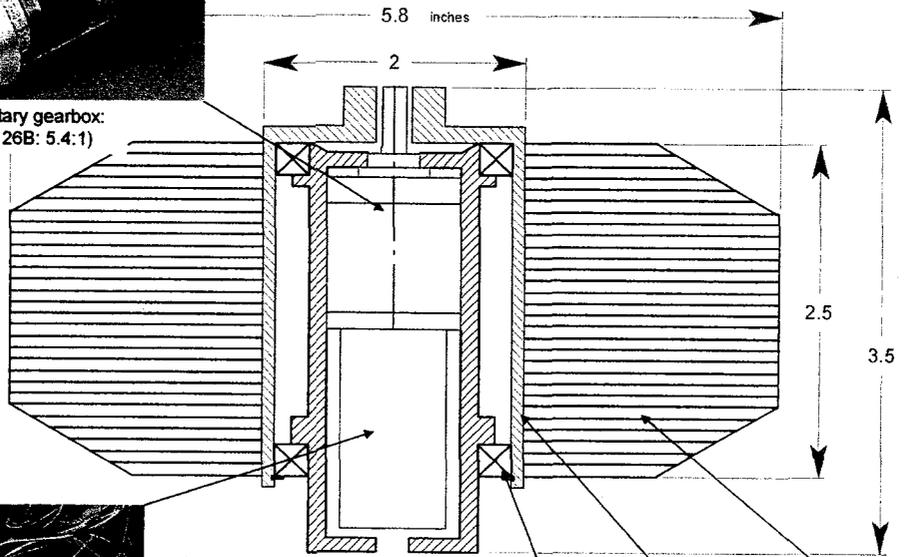
POC unit engagement volume: 130 cc
Collected sand volume: 250cc



# Rotating Brush Unit



Output planetary gearbox:  
(Maxon GP 26B: 5.4:1)

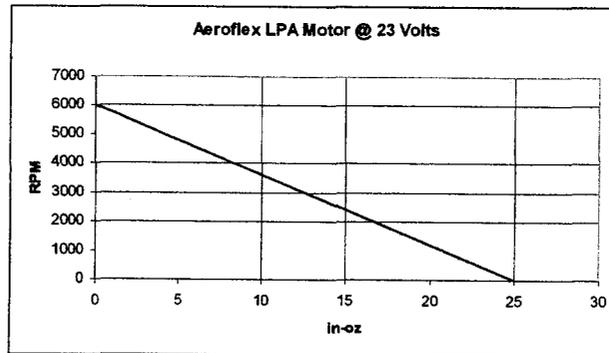


Aeroflex Brushless DC  
3 phase motor.

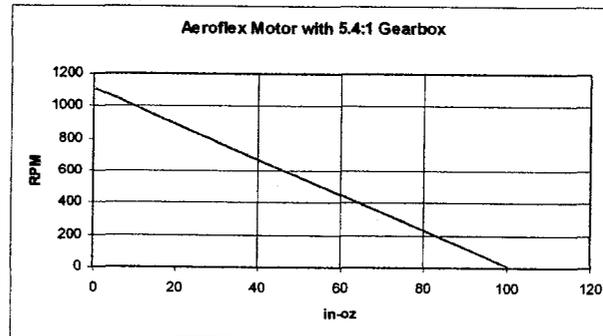
This is the MER Lander  
Petal Actuator motor  
(shown with brake)



# Approximate Motor-Gearbox Performance Range

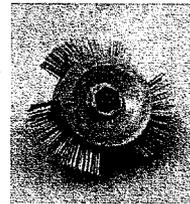
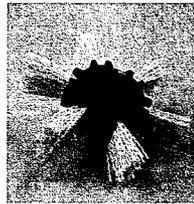
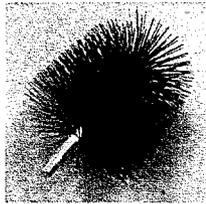
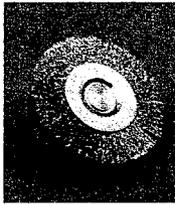
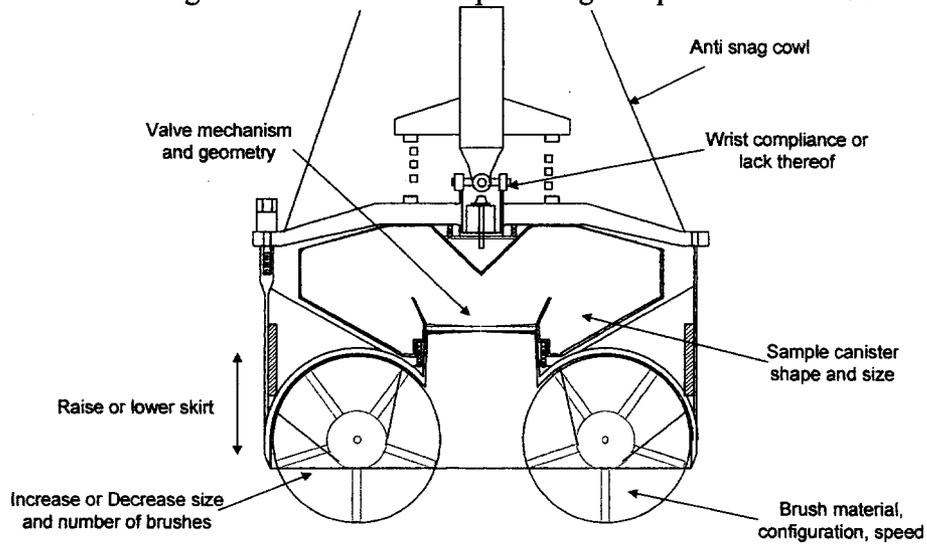


Motor can be  
operated at 35 volts  
(spec'd per MER)





# Some Degrees of Freedom for Optimizing Sampler Performance



# Pendulum Offloaded and Gimbaled Sampling

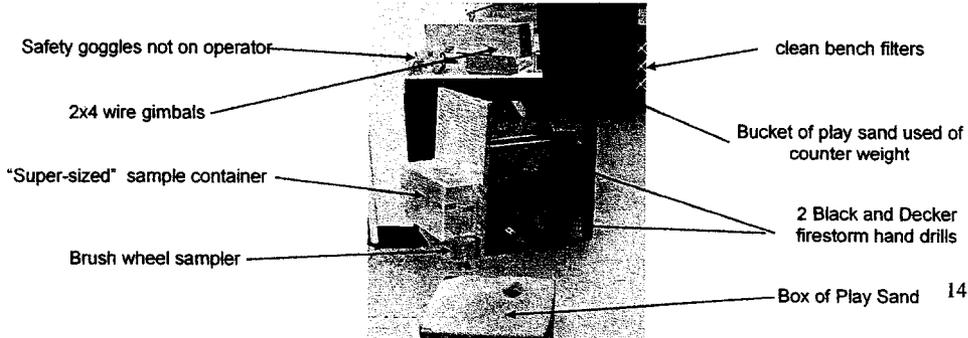
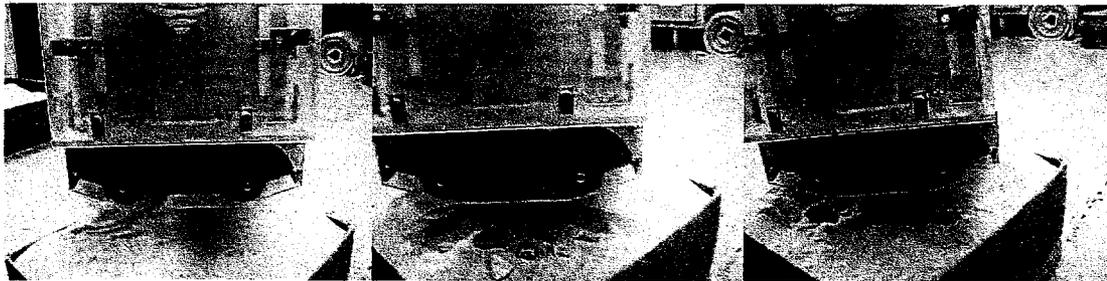


## Videos

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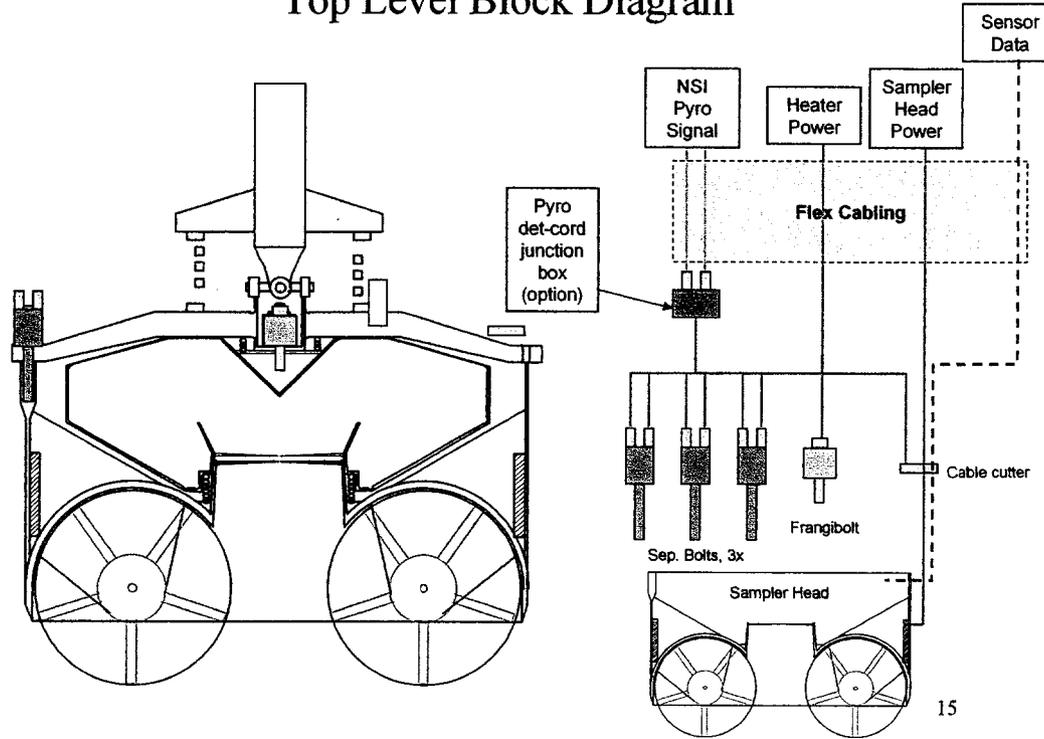
Pendulum Offloaded;  
medium rocks

Pendulum Offloaded;  
large rocks





# Top Level Block Diagram



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# Brush Wheel Sampler Ballpark Mass Estimate

Component	Mass Kg	Qty	CBE	Uncerty	CBE+Unc.
Motor	0.25	6	1.5		
gearbox	0.3	6	1.8		
housing	0.25	6	1.5		
brushwheel	0.35	6	2.1		
Bearings (set of 2)	0.1	6	0.6		
Electronics	0.1	6	0.6		
<b>Brush-unit subtotal</b>	<b>1.35</b>		<b>8.1</b>	<b>30%</b>	<b>10.53</b>
Sampler head sub-structure			1	30%	1.30
Separation Bolts	0.25	3	0.75	30%	0.98
Sampler Interface Plate			0.8	30%	1.04
Frangibolt			0.125	30%	0.16
Sampler head joint			0.25	30%	0.33
Cable cutter			0.125	30%	0.16
Boom Interface			0.5	30%	0.65
Cabling (pyro fuse cord)			0.5	30%	0.65
Sample Container			2	30%	2.60
Fasteners			0.25	30%	0.33
<b>Sampler Head Subtotal</b>			<b>14.4</b>		<b>18.72</b>
Launch plate w/ Interfaces			1.25	30%	1.63
Frangibolts	0.125	3	0.375	30%	0.49
Boom interface structure			0.5	30%	0.65
Rotation joint	0.35	2	0.7	30%	0.91
Rotation actuator			0.5	30%	0.65
Launch lock			0.35	30%	0.46
6 struts with fittings			2	30%	2.60
<b>Interface Structure Subtotal</b>			<b>5.68</b>		<b>7.38</b>
<b>Sampler System Total</b>			<b>20.08</b>	<b>30%</b>	<b>26.10</b>
(boom mass not included)					<b>16</b>

Boom mass between 3-4 kg (5m length)



# Boom and Sampler Dynamic Interactions



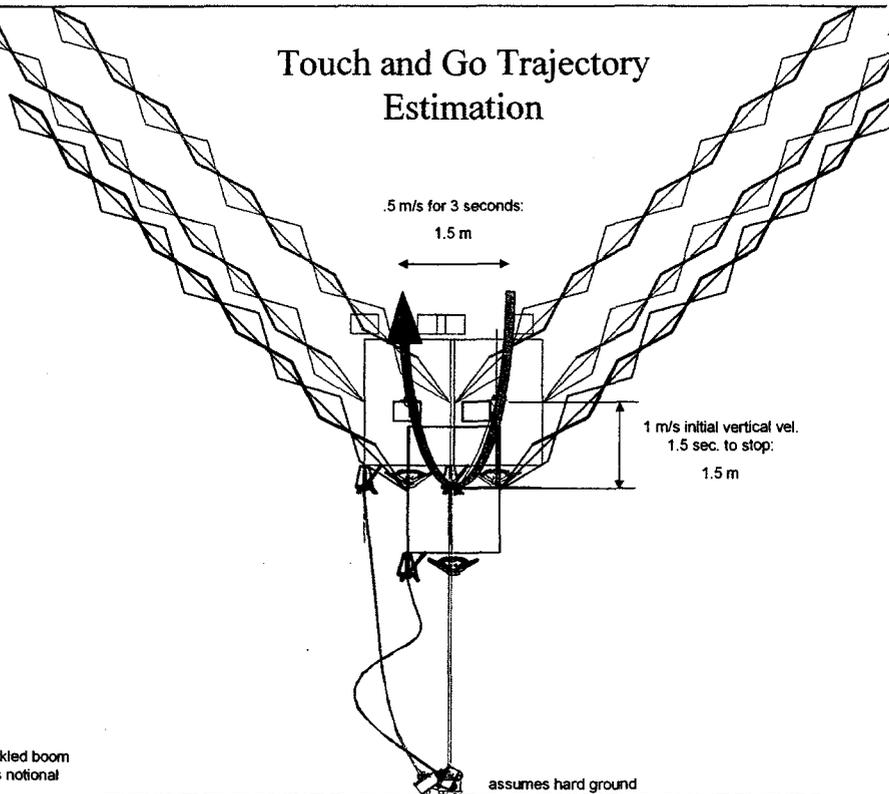
- Spacecraft dynamics will dictate that the minimum mast stiffness will be high enough to prevent large amplitude boom dynamics under nominal and worst case conditions:
  - S/C attitude control maneuvering
  - Touch and go lift-off thrust
  - Surface contact with max horizontal velocity
- Maximum mast stiffness (including buckling level) should automatically *load limit* the moments imparted to the S/C to levels lower than the S/C control authority:
  - Touch and go lift-off thrust
  - Surface contact with max horizontal velocity
- Boom system should be compliant enough to allow lateral deflection of boom under max horizontal velocity condition **X** contact time:
  - Assume .5 m/sec Vh, and 3 seconds from contact to release, 1.5m Xh
  - Assume 1.0 m/s Vv, and 1.5 seconds stopping time, 1.5 m Xv
- Bi-STEM lenticular boom is recommended.
  - Boom stiffness can be readily tailored
  - Allows for large scale buckling without damage
  - Easily stowed and deployed multiple times
  - May design a variable stiffness mast, stiff at the base more compliant at the tip.
  - { Reference info: a 22mm diam, 6m long BeCu, boom has a rated compressive load of 22N (5#)}



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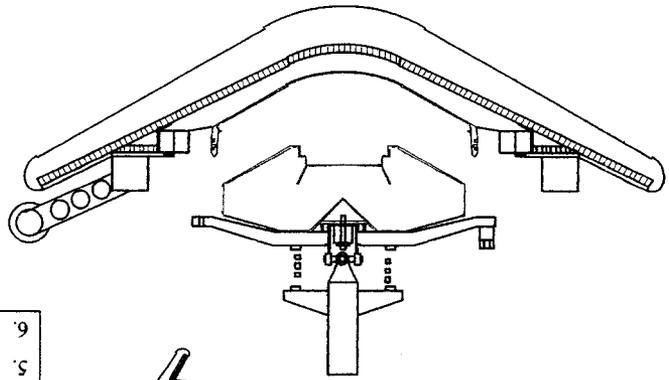
## Touch and Go Trajectory Estimation



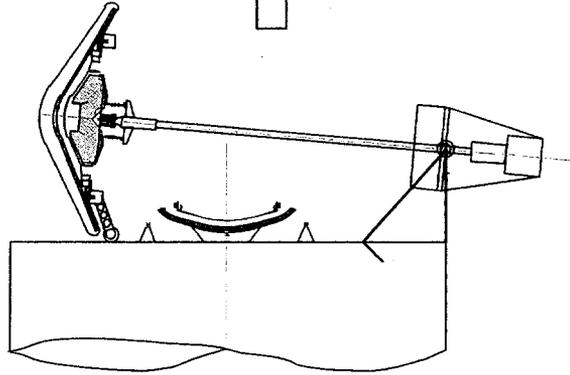
Note: buckled boom shape is notional

assumes hard ground

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- |    |  |
|----|--|
| 1. | SRV is opened, 1 DOF actuator with hard-stop   |
| 2. | Sampler mechanism is rotated into position, 1 DOF actuator with hard-stop  |
| 3. | Boom is extended; guided alignment with passive latches, contact sensor (micro-switch) verification of insertion                   |
| 4. | Sample container is released; frangibolt release mechanism, sample container held in place by passive spring loaded latch detents. |
| 5. | Boom is retracted  |
| 6. | SRV is closed  |



### Sample Handoff



Boom may also be placed so that its line of action passes as close to the S/C cg as possible to minimize torques.

### Alternate Boom Placement





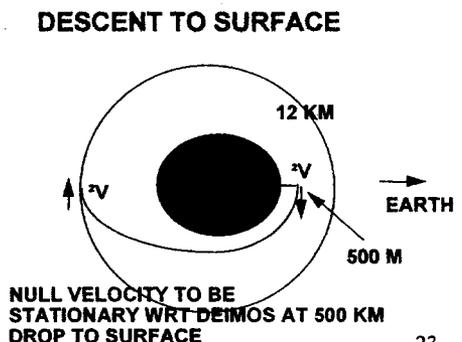
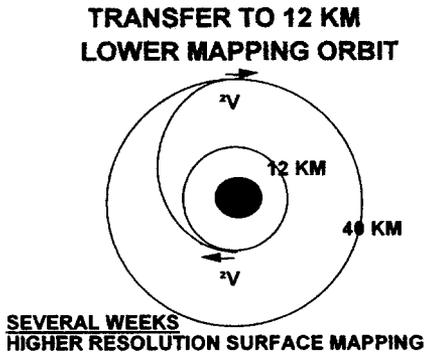
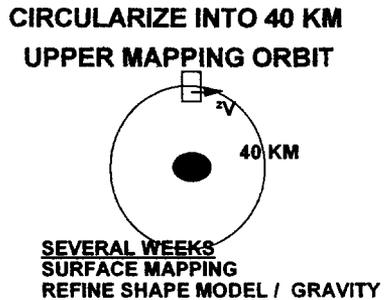
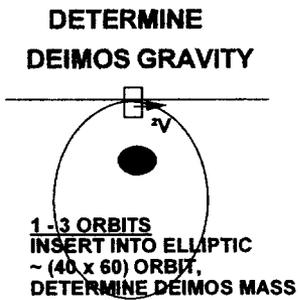
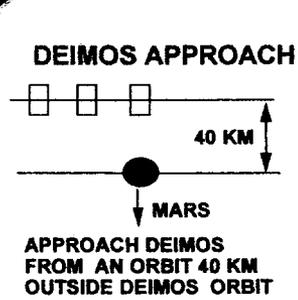
## Mass Summary

	<b>CBE</b>	<b>Unc.</b>	<b>CBE + Unc.</b>	
<b>Sampler</b>	14.5	30%	18.7	Sized for 10 kg sample
<b>Sampler Support H/W</b>	8.7	30%	11.4	5 m boom with rotation
<b>SRV</b>	18.1	30%	23.5	Sized for 10 kg sample
<b>SRV Support H/W</b>	6.0	30%	7.8	Spin eject, hinge-motor and support H/W
<b>TOTAL</b>	<b>47.3</b>	<b>30%</b>	<b>61.4</b>	



## Operations Concept

- After insertion into Mars orbit, maneuver into 40 km retrograde Deimos orbit. Map surface at 1 meter. Develop shape and gravity models. Select candidate sampling sites.
- Transfer to 12 km retrograde orbit. Map candidate sites at 30 cm resolution, refine shape and gravity models, select sampling sites.
- Descend to surface. Null out velocity at 500 meters. Extend 8 meter boom with sampler. At 50 meters, reduce vertical and horizontal velocity to < 0.3 m/s and drop toward surface.
- On contact, sampler acquires 10 kg of sample in 1 second. Spacecraft reverses course and returns to 12 km altitude. Touch-and-go sampling.
- Full telemetry during descent and sampling. Descent camera operating continuously with compressed imagery.





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*Discovery* Mars Scout Proposal

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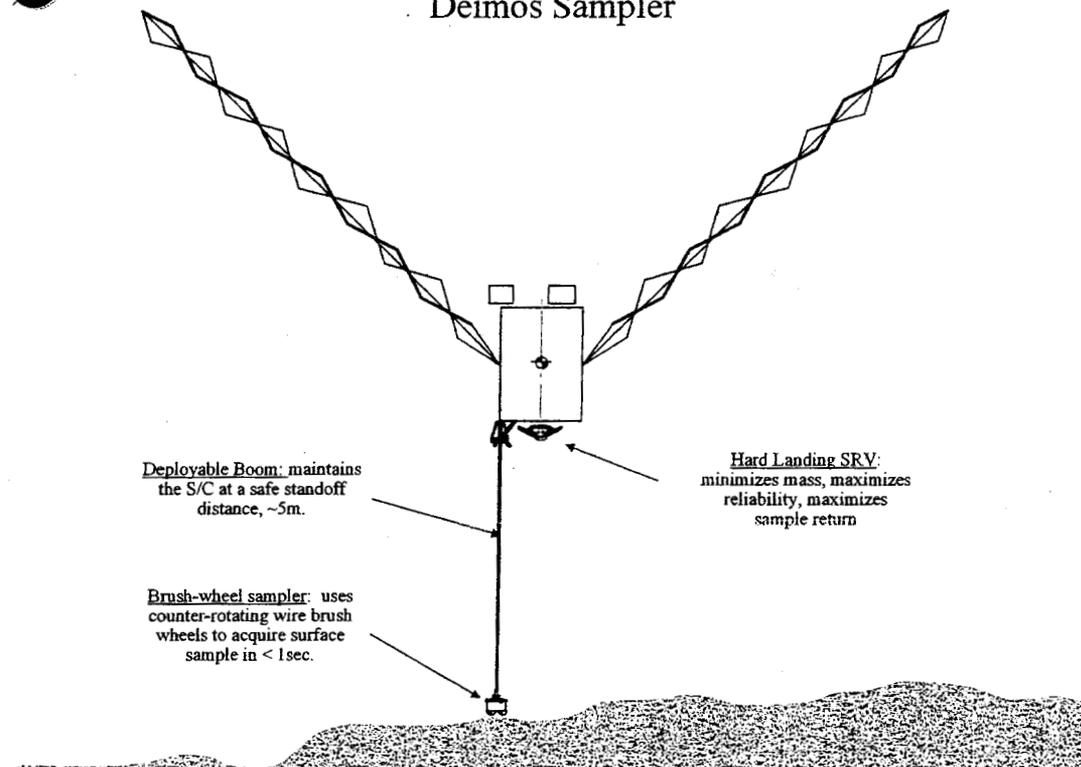
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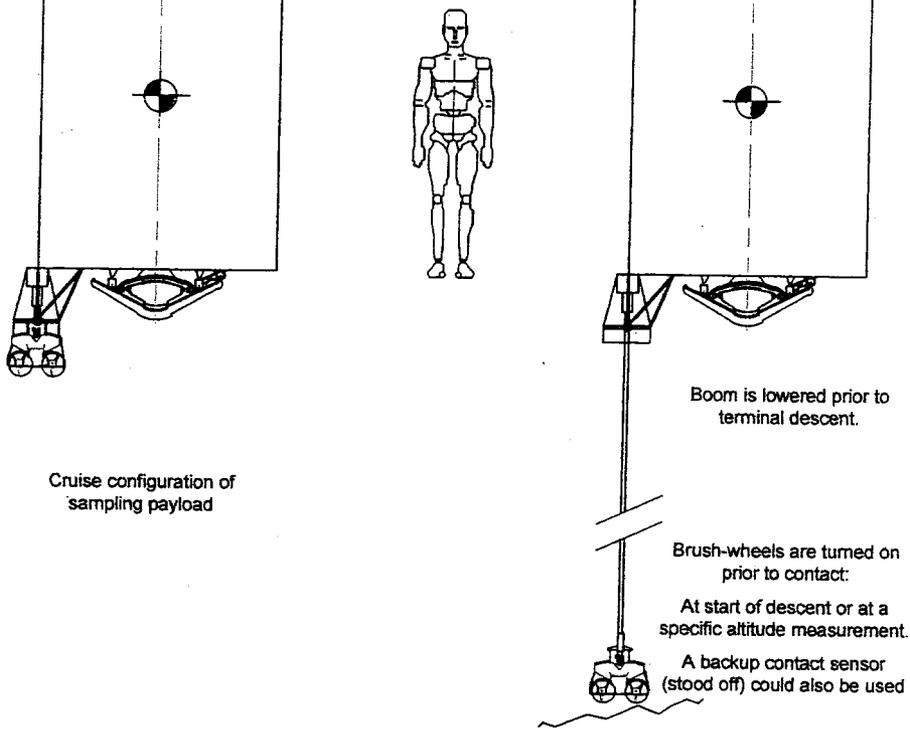


## Deimos Sampler





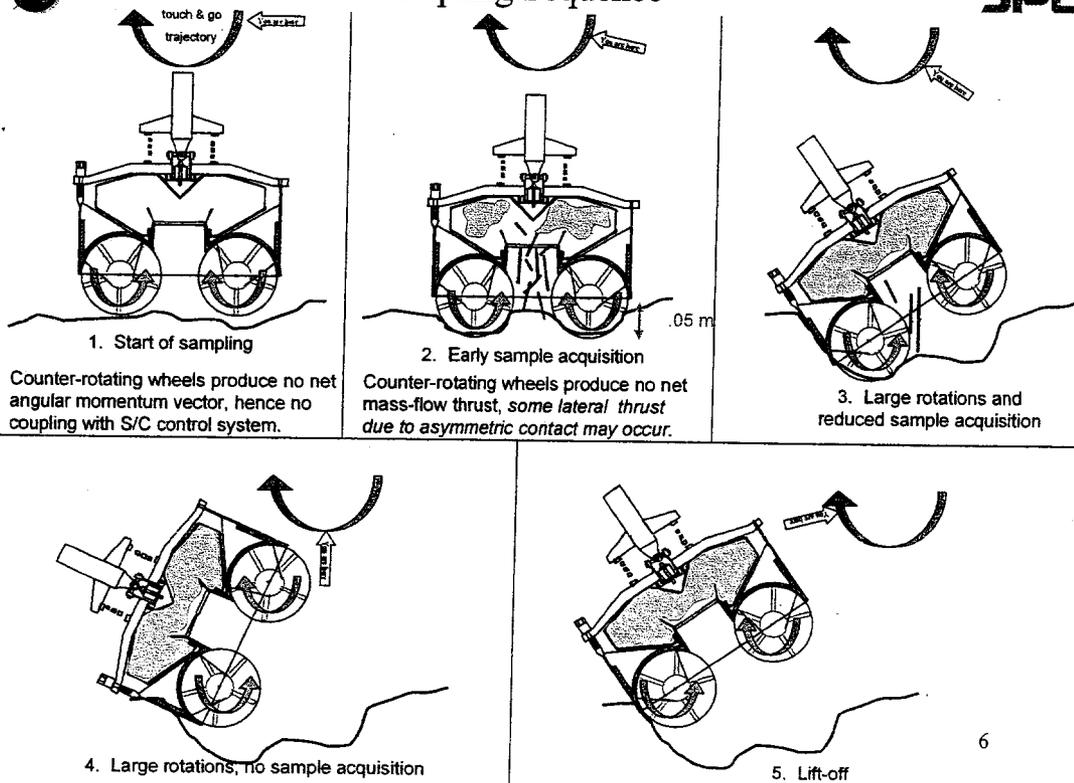
# Deployment Sequence



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# Sampling Sequence

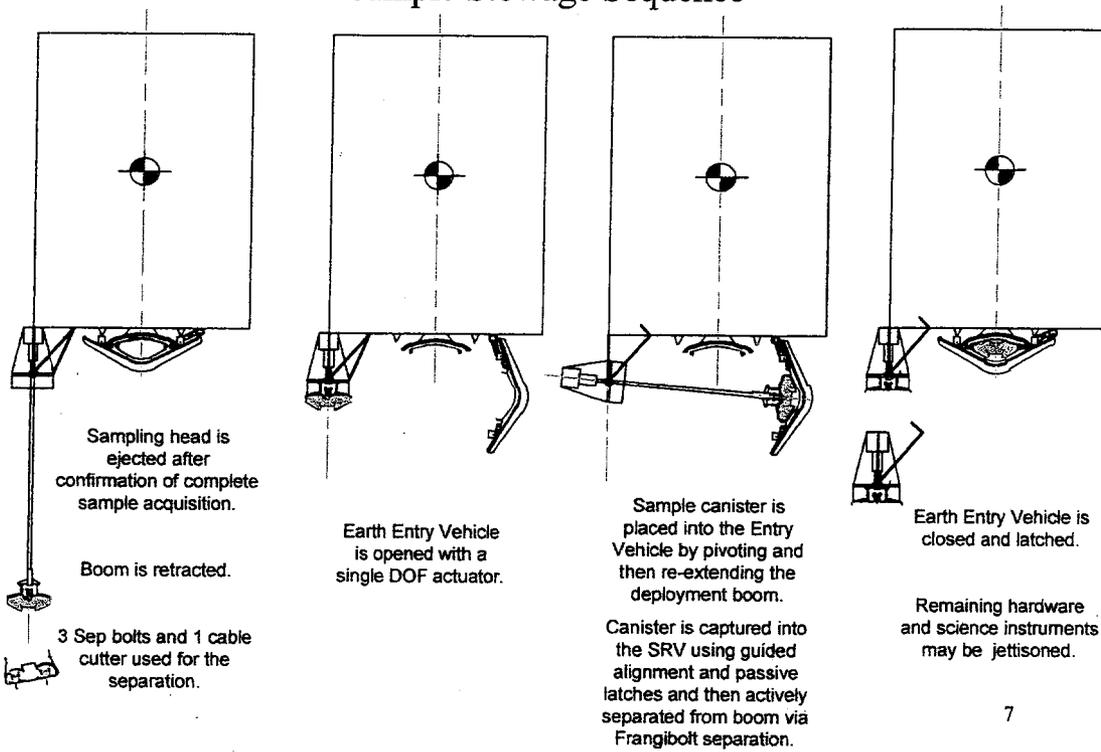


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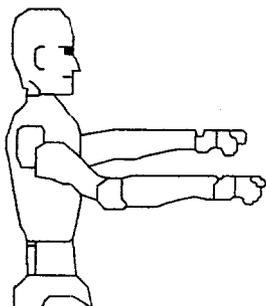
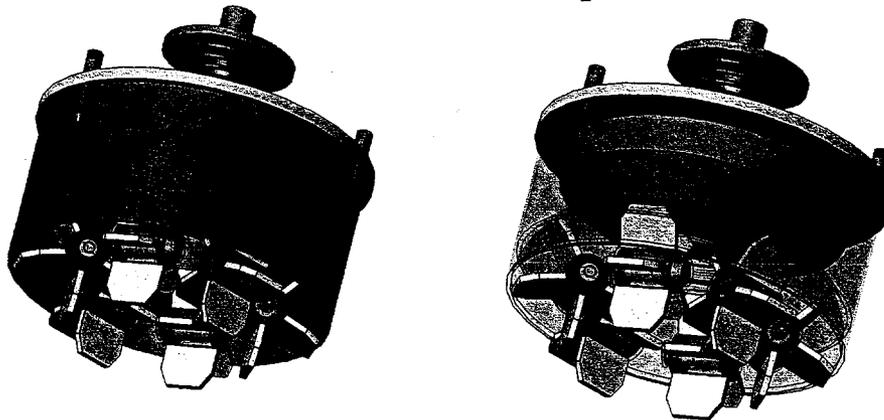
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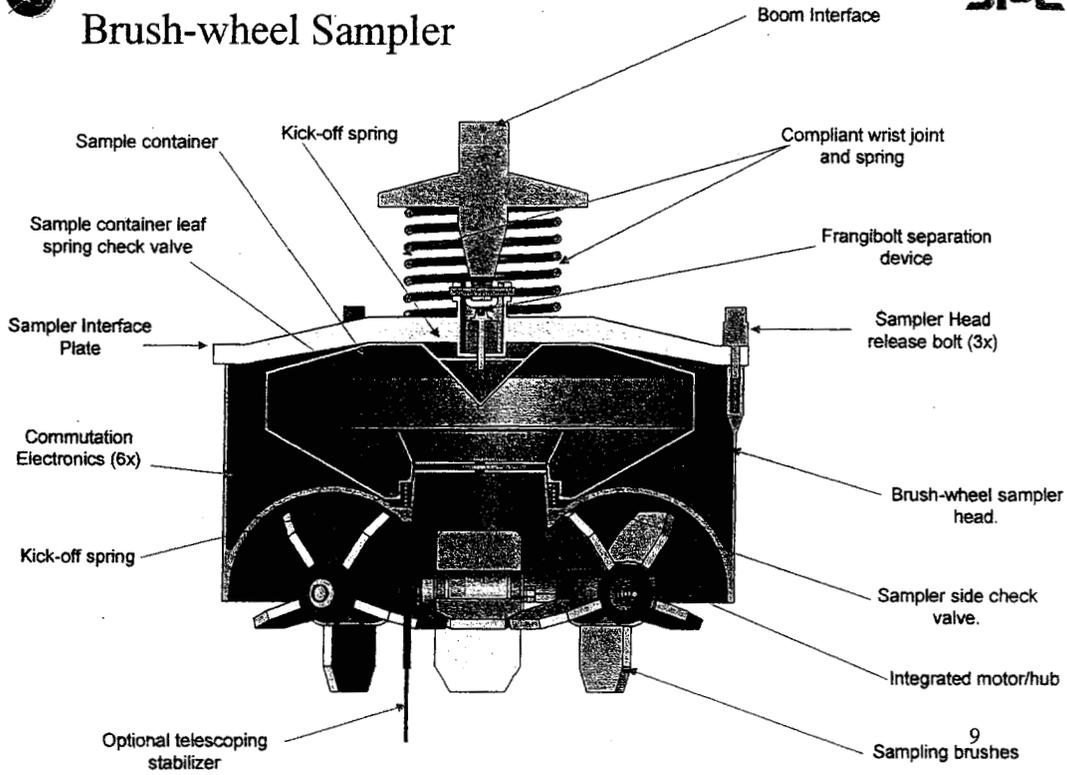
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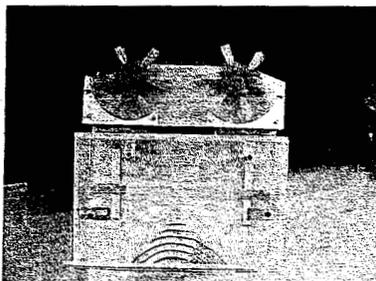
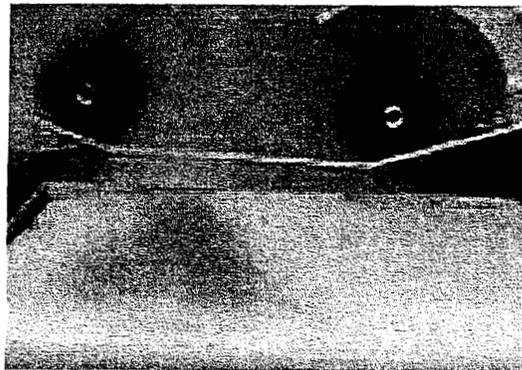
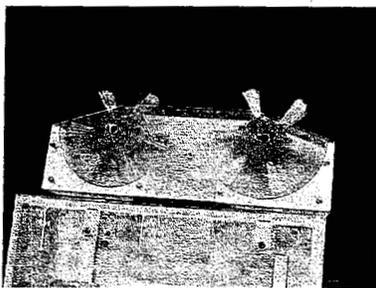




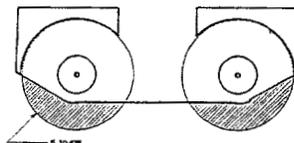
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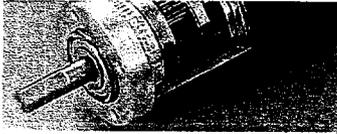
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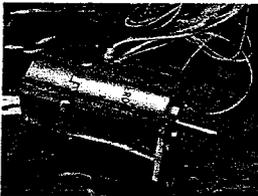
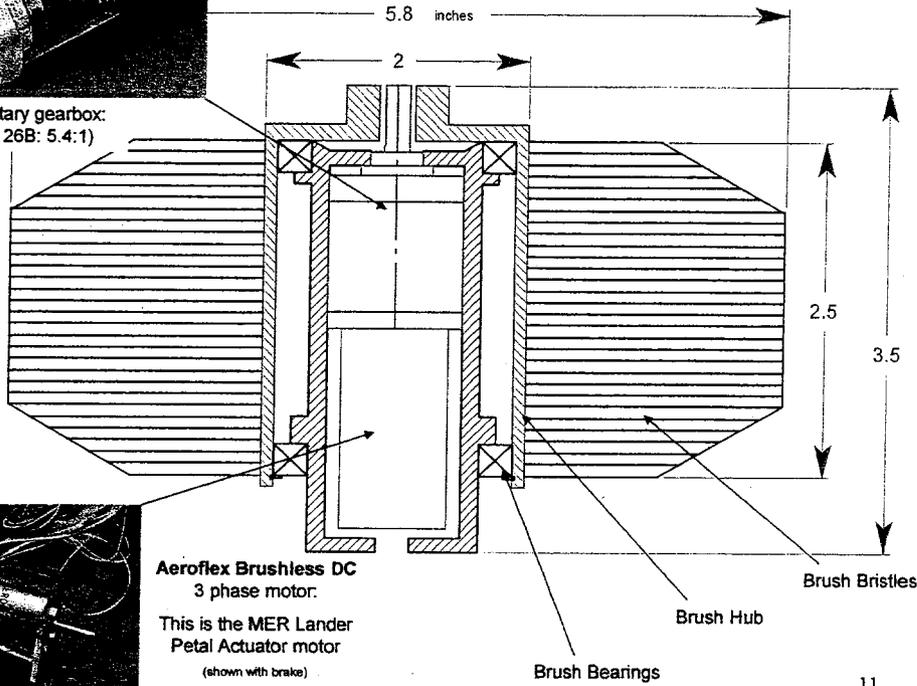
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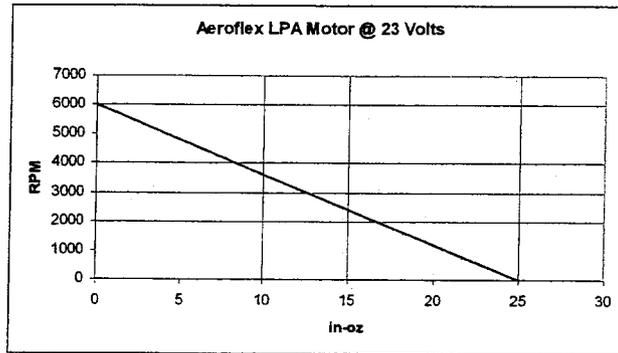
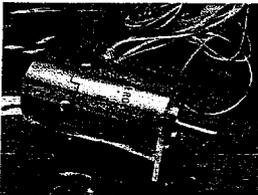
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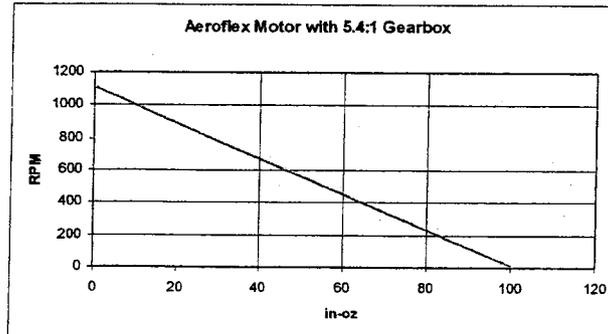
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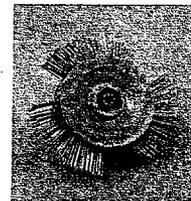
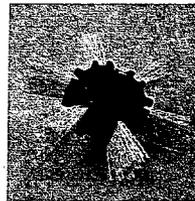
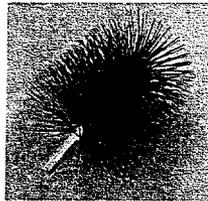
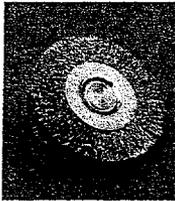
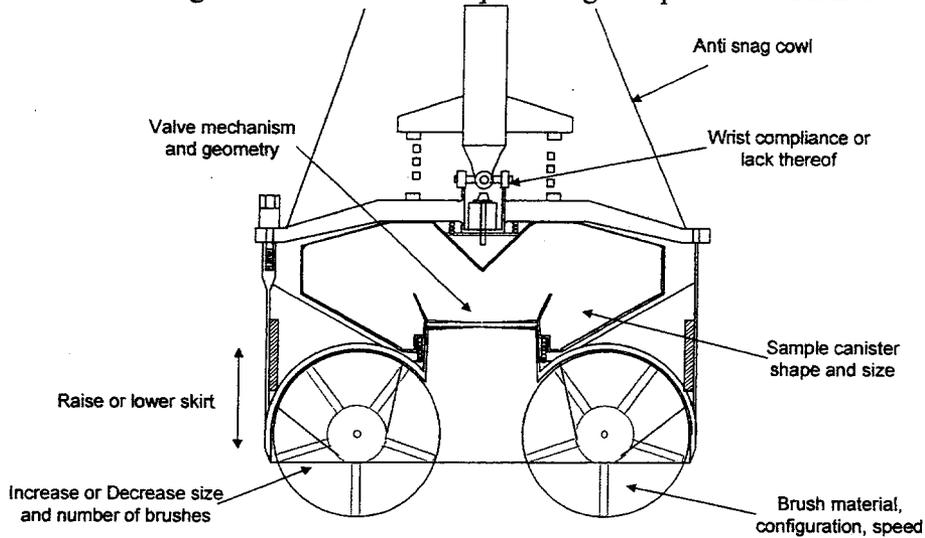


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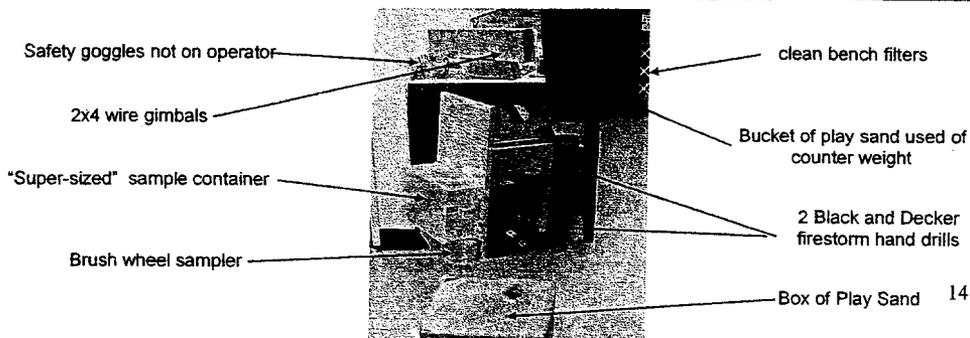
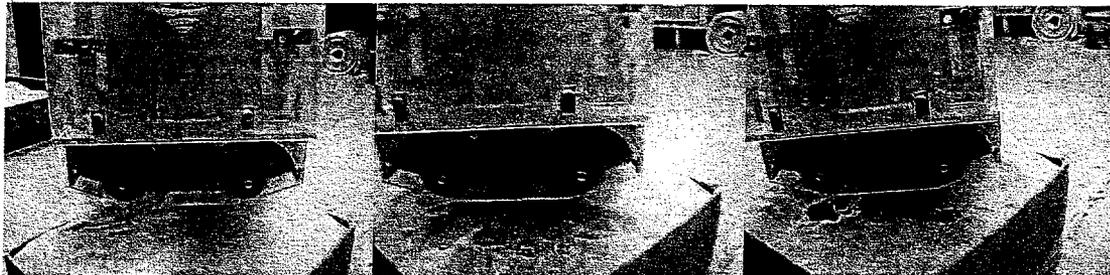


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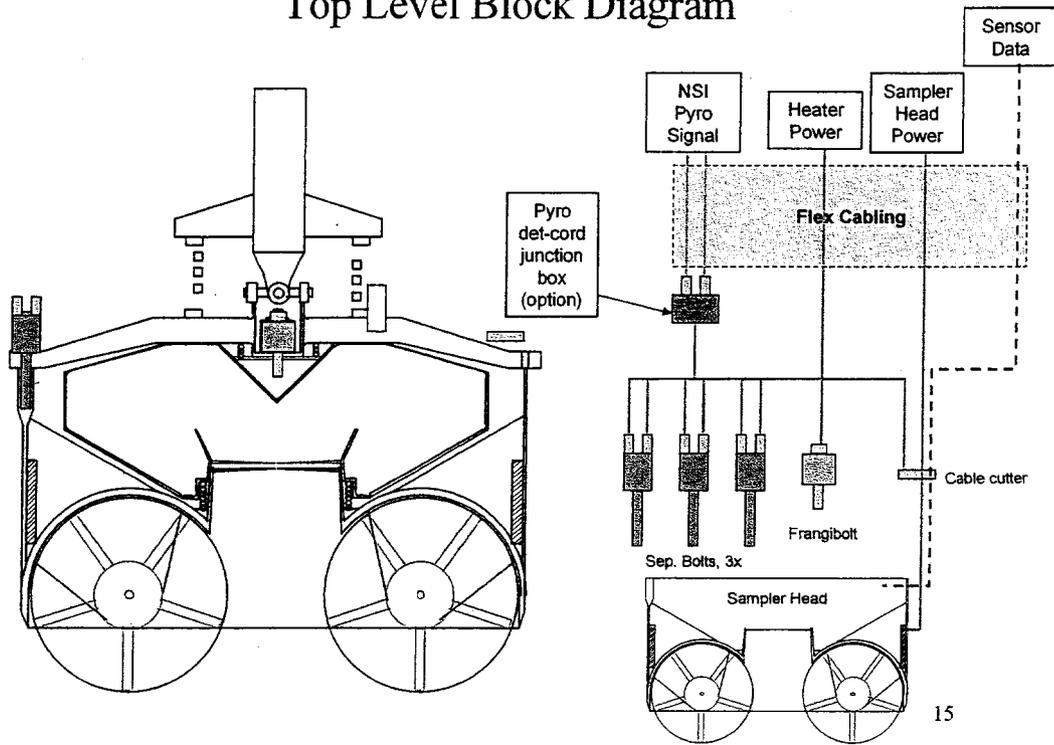
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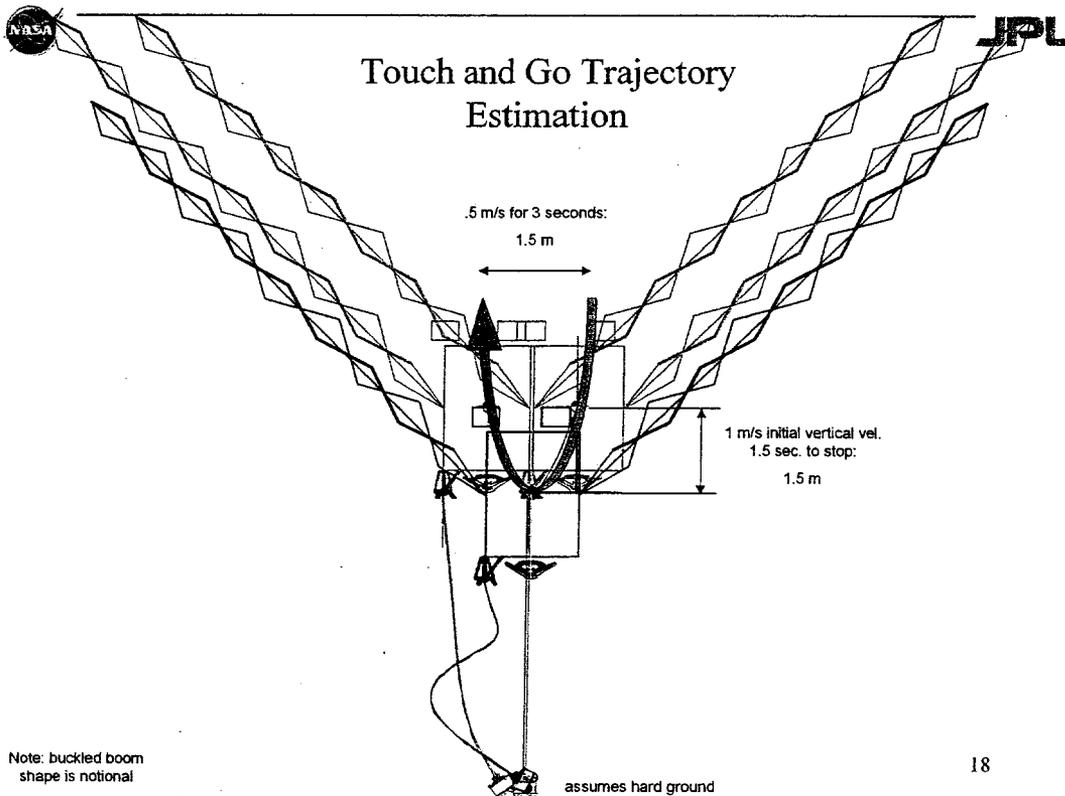
# Boom and Sampler Dynamic Interactions



- Spacecraft dynamics will dictate that the minimum mast stiffness will be high enough to prevent large amplitude boom dynamics under nominal and worst case conditions:
  - S/C attitude control maneuvering
  - Touch and go lift-off thrust
  - Surface contact with max horizontal velocity
- Maximum mast stiffness (including buckling level) should automatically *load limit* the moments imparted to the S/C to levels lower than the S/C control authority:
  - Touch and go lift-off thrust
  - Surface contact with max horizontal velocity
- Boom system should be compliant enough to allow lateral deflection of boom under max horizontal velocity condition **X** contact time:
  - Assume .5 m/sec Vh, and 3 seconds from contact to release, 1.5m Xh
  - Assume 1.0 m/s Vv, and 1.5 seconds stopping time, 1.5 m Xv
- Bi-STEM lenticular boom is recommended.
  - Boom stiffness can be readily tailored
  - Allows for large scale buckling without damage
  - Easily stowed and deployed multiple times
  - May design a variable stiffness mast, stiff at the base more compliant at the tip.
  - {Reference info: a 22mm diam, 6m long BeCu, boom has a rated compressive load of 22N (5#)}



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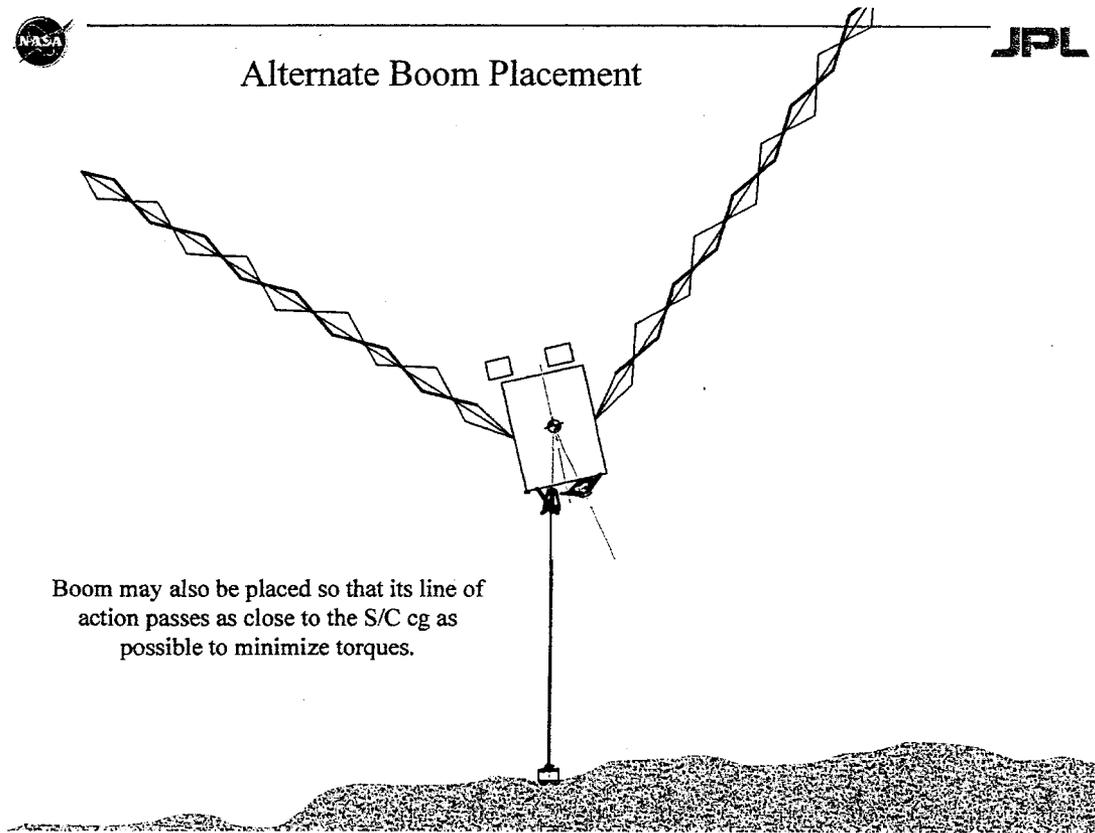
Note: buckled boom shape is notional

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## Alternate Boom Placement

JPL

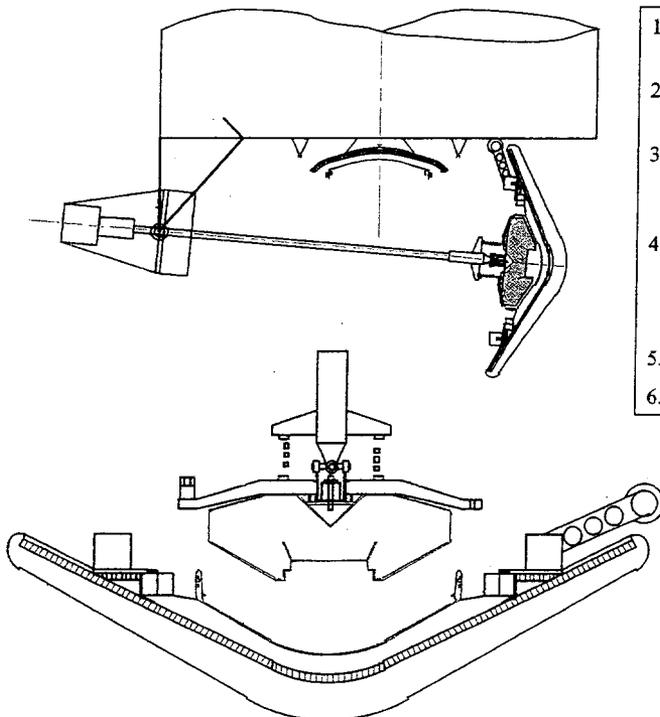


Boom may also be placed so that its line of action passes as close to the S/C cg as possible to minimize torques.



## Sample Handoff

JPL



1. SRV is opened; 1 DOF actuator with hard-stop
2. Sampler mechanism is rotated into position; 1 DOF actuator with hard-stop
3. Boom is extended; guided alignment with passive latches, contact sensor (micro-switch) verification of insertion
4. Sample container is released; frangibolt release mechanism, sample container held in place by passive spring loaded latch detents.
5. Boom is retracted
6. SRV is closed



## Mass Summary

	<b>CBE</b>	<b>Unc.</b>	<b>CBE + Unc.</b>	
<b>Sampler</b>	14.5	30%	18.7	Sized for 10 kg sample
<b>Sampler Support H/W</b>	8.7	30%	11.4	5 m boom with rotation
<b>SRV</b>	18.1	30%	23.5	Sized for 10 kg sample
<b>SRV Support H/W</b>	6.0	30%	7.8	Spin eject, hinge-motor and support H/W
<b>TOTAL</b>	<b>47.3</b>	<b>30%</b>	<b>61.4</b>	

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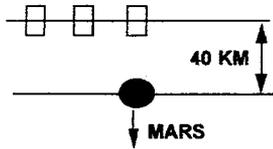
## Operations Concept

- After insertion into Mars orbit, maneuver into 40 km retrograde Deimos orbit. Map surface at 1 meter. Develop shape and gravity models. Select candidate sampling sites.
- Transfer to 12 km retrograde orbit. Map candidate sites at 30 cm resolution, refine shape and gravity models, select sampling sites.
- Descend to surface. Null out velocity at 500 meters. Extend 8 meter boom with sampler. At 50 meters, reduce vertical and horizontal velocity to < 0.3 m/s and drop toward surface.
- On contact, sampler acquires 10 kg of sample in 1 second. Spacecraft reverses course and returns to 12 km altitude. Touch-and-go sampling.
- Full telemetry during descent and sampling. Descent camera operating continuously with compressed imagery.

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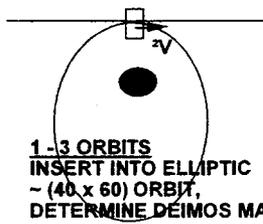


### DEIMOS APPROACH



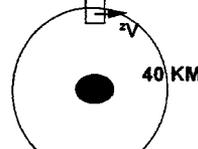
APPROACH DEIMOS  
FROM AN ORBIT 40 KM  
OUTSIDE DEIMOS ORBIT

### DETERMINE DEIMOS GRAVITY



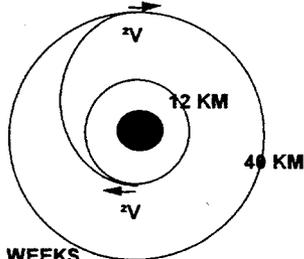
1-3 ORBITS  
INSERT INTO ELLIPTIC  
~ (40 x 60) ORBIT,  
DETERMINE DEIMOS MASS

### CIRCULARIZE INTO 40 KM UPPER MAPPING ORBIT



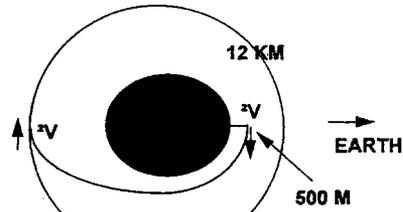
SEVERAL WEEKS  
SURFACE MAPPING  
REFINE SHAPE MODEL / GRAVITY

### TRANSFER TO 12 KM LOWER MAPPING ORBIT



SEVERAL WEEKS  
HIGHER RESOLUTION SURFACE MAPPING

### DESCENT TO SURFACE



NULL VELOCITY TO BE  
STATIONARY WRT DEIMOS AT 500 M  
DROP TO SURFACE

JPL