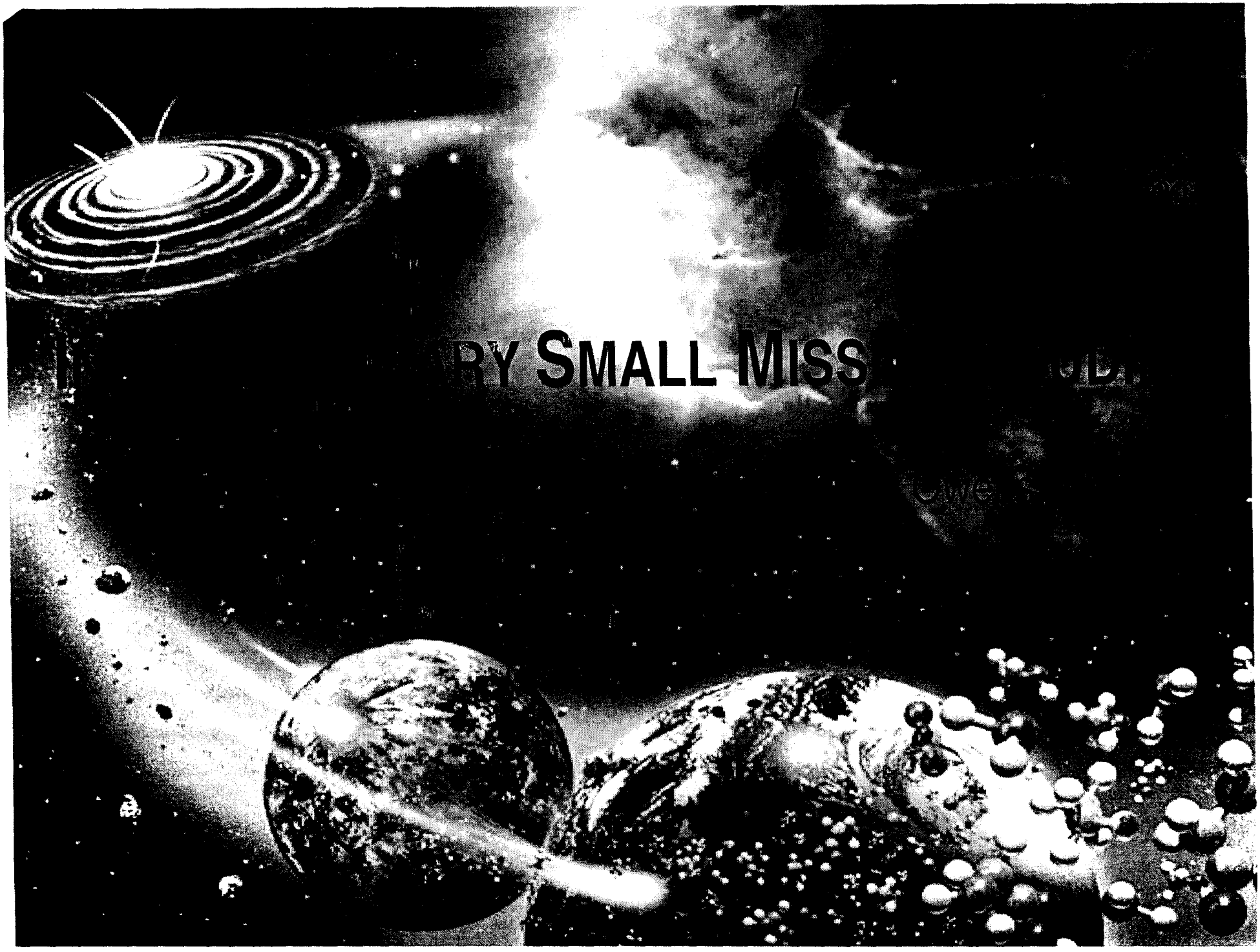
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PRESENTATION OUTLINE

- Study Goals
- Design Envelope
- Description of Concurrent Design Process
- Candidate Missions
  - Lunar Science Orbiter
  - Venus Balloon
  - Mars Balloon
  - Mars Science Orbiter
- Study Results/Conclusions
- Q&A

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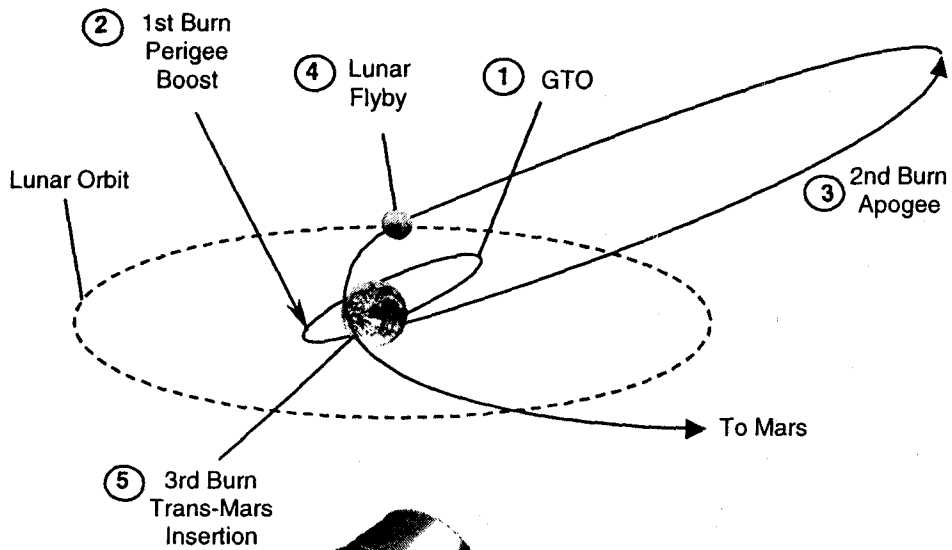
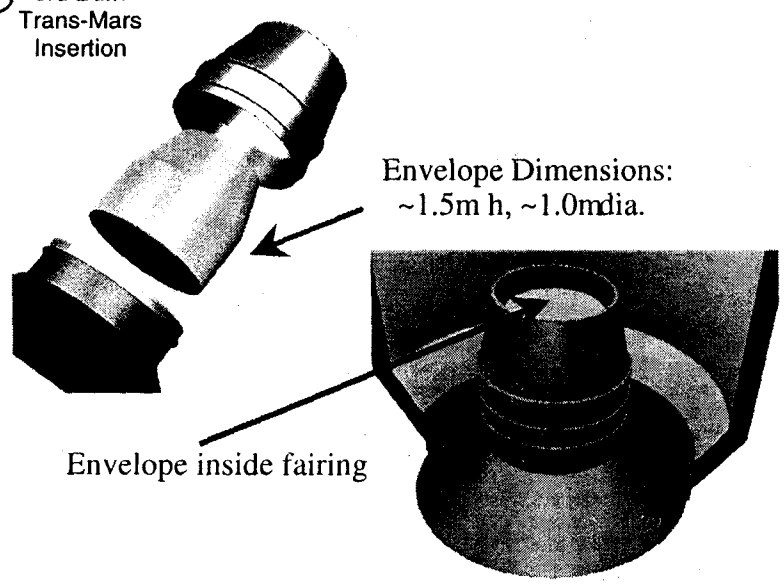
STUDY GOALS

- Show *feasible* small interplanetary mission concepts, launched on a secondary payload platform, that reduce total mission cost by *at least* a factor of 2.
- Preserve scientifically significant payloads, despite the limited design envelope, to show viability of the interplanetary mission concept.
- Investigate mission concepts considering a range of interplanetary targets including Earth's Moon, Mars, and Venus.
- Document specific metrics to weigh the value of these small mission concepts against (1) other small mission concepts, and (2) traditional interplanetary mission concepts.

DESIGN ENVELOPE





- Mission Design
  - Micromission Trajectory
- Launch Vehicle Envelope
  - 500 kg Total Mass
  - 1.5m x 1.0m Ø Cylindrical Volume
  - Secondary Payload Classification
- Potential Launch Vehicles
  - Ariane V
  - Atlas
  - Delta
- Cost Cap Considerations
  - "Micro-Discovery" Class
  - 50% reduction when compared with "traditional" missions

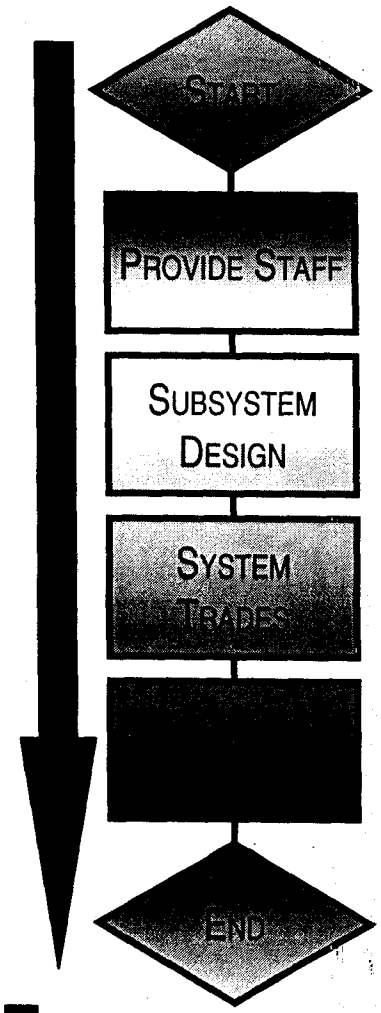
ADVANCED PROJECTS DESIGN TEAM

What is Team X?

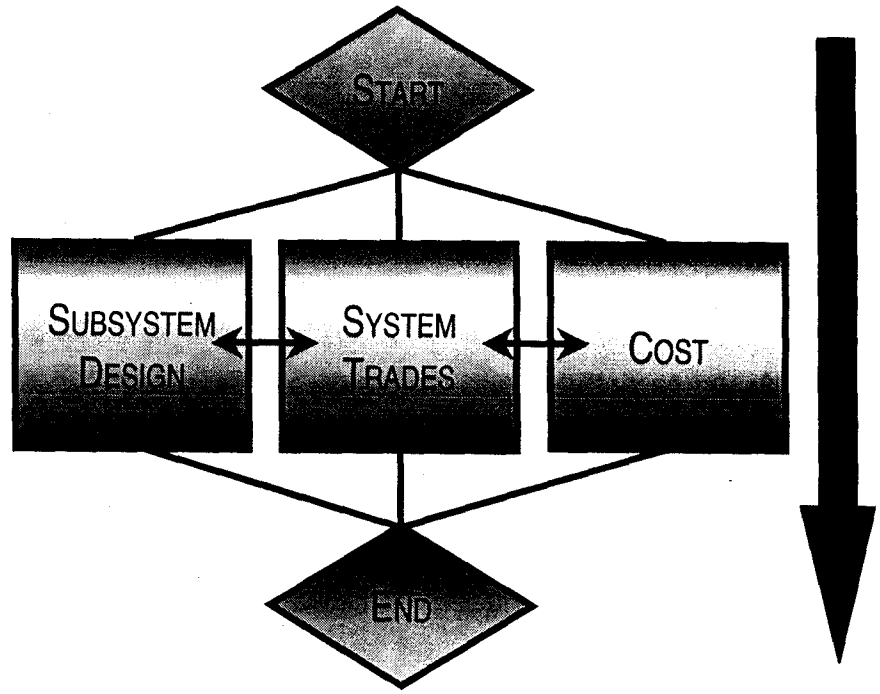
- JPL's concurrent engineering team
- Rapid spacecraft conceptual design/analysis
- Chartered to:
  - Improve the speed and quality of JPL's mission concepts,
  - Create a continuing study process with dedicated facilities, equipment, procedures, and tools to produce the best possible proposals,
  - Develop an initial mission requirements database to be continually updated and tapped for future project phases, and
  - Develop experienced engineers into mission generalists.

CONCURRENT DESIGN PROCESS

Old Process: Sequential Design



New Process: Concurrent Design



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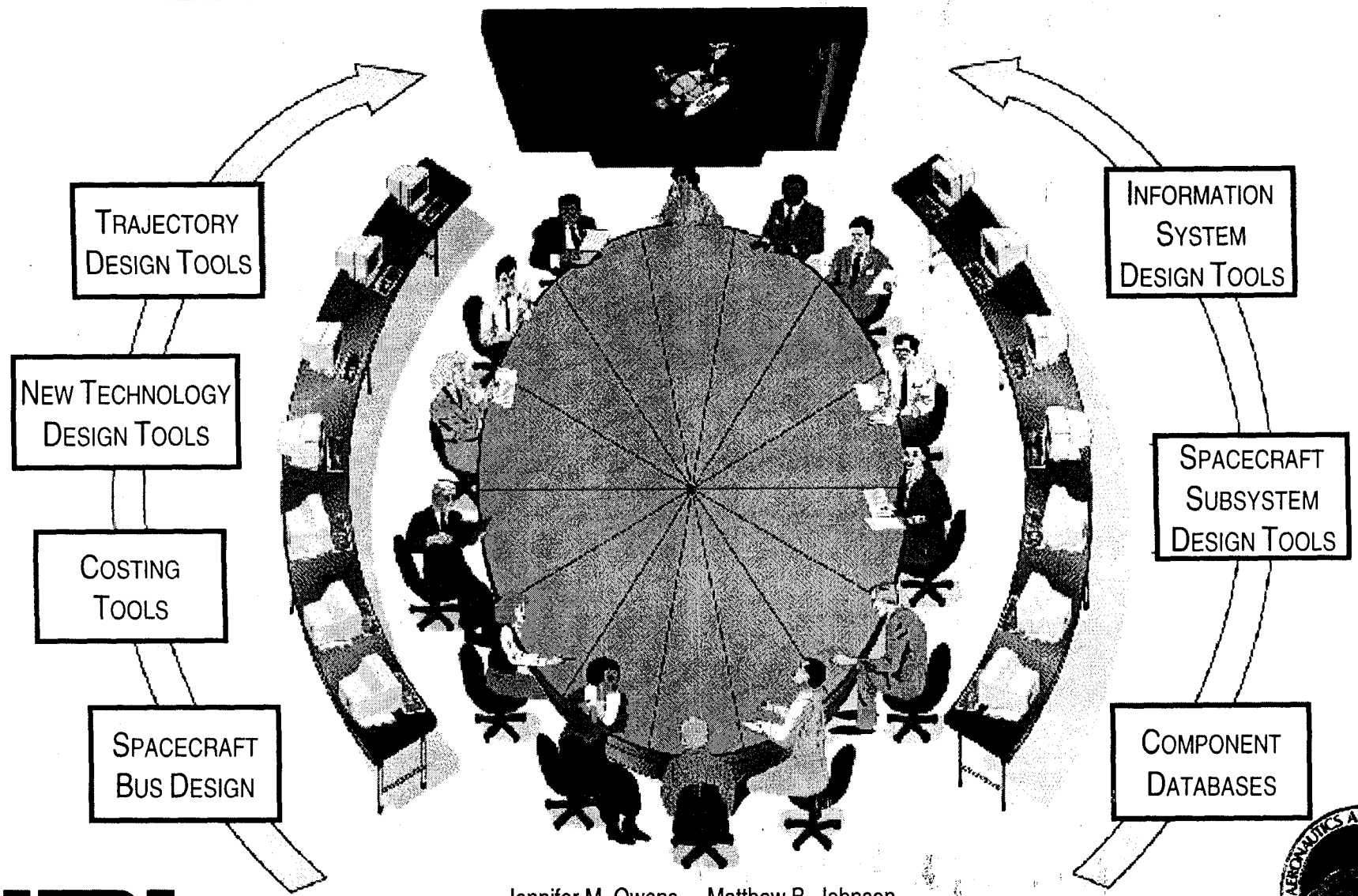
TEAM X ORGANIZATION



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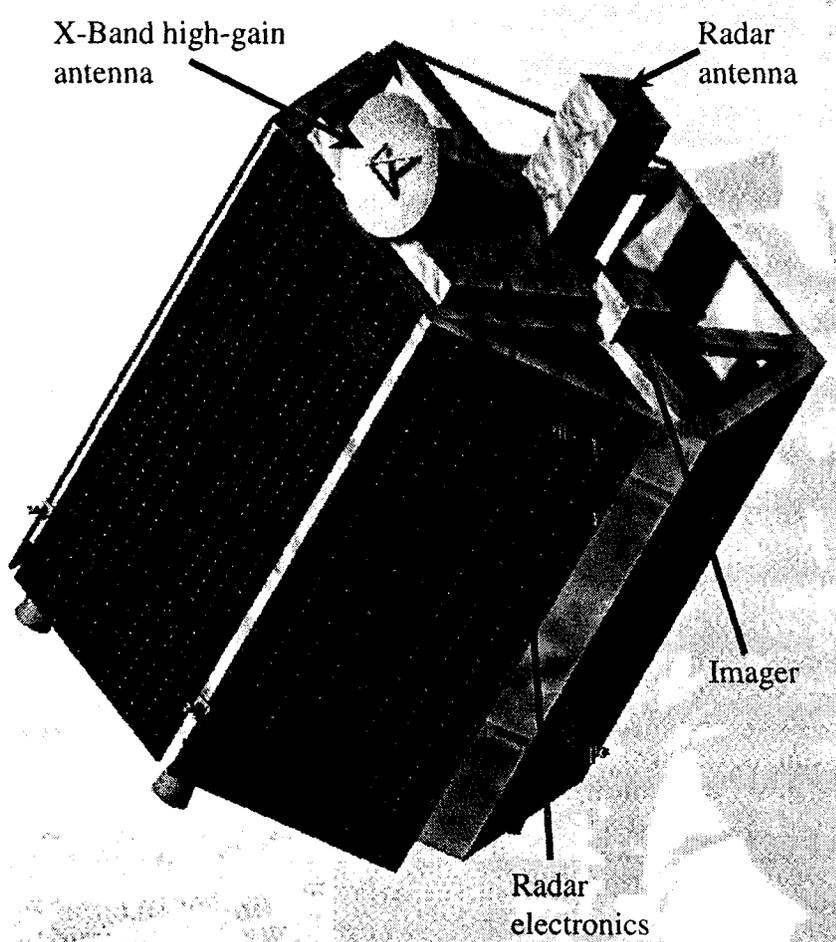
LUNAR SCIENCE ORBITER



- Mission Design
  - Micromission Trajectory
  - 15km x 200km Lunar Orbit
  - Polar Periapsis
  - One Month at Each Pole
- Science Mission
  - Water Detection/Mapping
  - Ice-Penetrating Radar
  - Imager for Correlation (10m res.)
- Major Design Trades
  - Instrument Selection, **Radar** vs. Imager
  - Propulsion, Bi-Prop vs. **Mono-Prop**
  - Telecom Frequency, **X-band** vs. S-band

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LUNAR SCIENCE ORBITER

Lunar Science Orbiter Mission Design Summary	
Mission Target:	Earth's Moon
Mission Duration:	8 months cruise, 2 months on orbit
Mission Elements:	Lunar Science Orbiter
Redundancy Scheme:	Single String
Return Data Rate:	100 kbps
Data Storage:	8 Gb
Maximum Link Distance:	400,000 km
Telecom Band:	X Band
Radiation Total Dose:	10 krad
Technology Cutoff Date:	2003 (assumes a 2005 launch date)
Launch Vehicle, Capability:	500 kg
Delta V Required:	2150 m/s
Launch Mass:	494 kg, includes 29 kg LV adapter
Launch Margin:	1.1%

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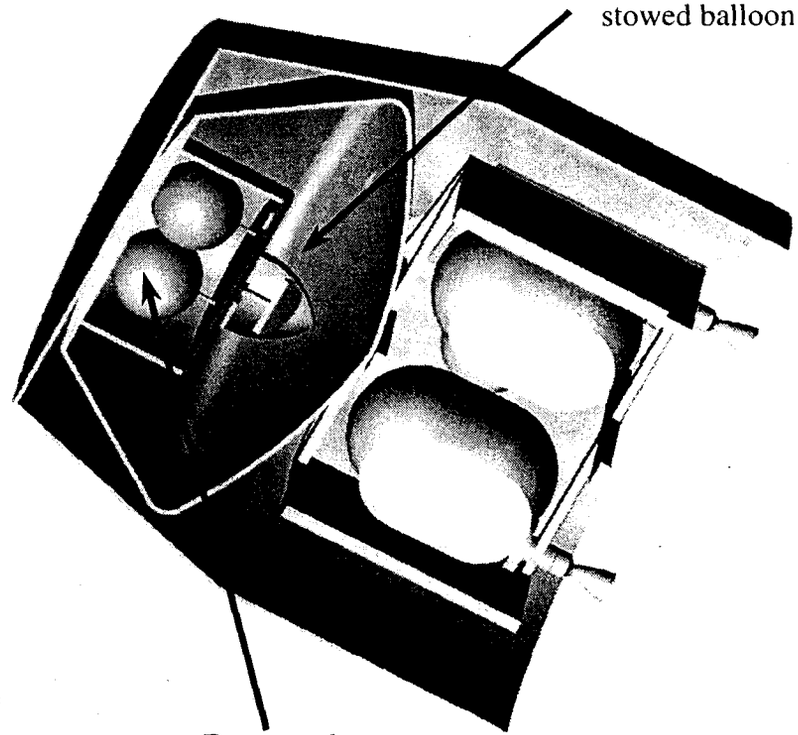
LUNAR SCIENCE ORBITER

Lunar Science Orbiter Element Summary Table

Subsystem	Mass (kg)	Power (W) *Science Mode*	Power (W) *Telecom Mode*
Payload			
Instruments	12.3	26.0	0.0
Payload Total	**12.3**	**26.0**	**0.0**
Bus			
ACS	3.1	18.3	15.2
CDH	7.7	35.1	35.1
Power	15.7	15.7	13.9
Propulsion	29.4	9.5	9.5
Structure	36.8	0.0	0.0
S/C Adapter	7.5	0.0	0.0
Cabling	9.1	0.0	0.0
Telecom	3.7	13.6	28.6
Thermal	4.1	19.0	19.0
Bus Total	**117.0**	**111.1**	**121.2**
Spacecraft Total	**129.3**	**137.1**	**121.2**
Contingency, 30%	38.8	41.1	36.4
Spacecraft Total w/ Contingency	**168.1**	**178.2**	**157.6**
Propellant	297.2		
Total Wet Mass	**465.3**		

VENUS BALLOON

- Mission Design
  - Micromission Trajectory, Moon/Earth Flybys
  - 54km Altitude, 4 Day Balloon Lifetime
- Science Mission
  - Venutian Atmospheric Science
  - Instrument Suite:
    - Temp/Press Sensors, Airspeed Indicato
    - Mass Spectrometer
    - CCD Camera
- Major Design Trades
  - Communications, **Data Relay** vs. Direct
  - Number of Drop Sondes, **2**
  - Spin-Stabilized S/C vs. **Spin Platform**
  - Pressurization Gas Selection, **Helium**



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VENUS BALLOON

Venus Balloon Mission Design Summary

Mission Target:	Venus
Mission Duration:	12 months cruise, 4 days science
Mission Elements:	Drop Sondes (2), Balloon, Probe Carrier
Redundancy Scheme:	Single String
Return Data Rate:	16 kbps
Data Storage:	1 Gb
Maximum Link Distance:	1.3 AU
Telecom Band:	X Band
Radiation Total Dose:	25 krad
Technology Cutoff Date:	2003 (assumes a 2005 launch date)
Launch Vehicle, Capability:	500 kg
Delta V Required:	1440 m/s
Launch Mass:	506.2 kg, includes 29 kg LV adapter
Launch Margin:	-1.2%

VENUS BALLOON

Venus Drop Sonde Element Summary Table

Subsystem	Mass (kg)	Power (Whr) *Descent Mode*
Payload		
Instruments	2.8	8.2
Payload Total	**2.8**	**8.2**
Bus		
CDH	0.5	3.0
Power	0.2	1.4
Structure	0.8	0.0
S/C Adapter	0.1	0.0
Cabling	0.1	0.0
Telecom	0.1	10.0
Thermal	0.8	0.0
Bus Total	**2.6**	**14.4**
Spacecraft Total	**5.4**	**22.6**
Contingency, 30%	1.6	6.8
Spacecraft Total w/ Contingency	**7.0**	**29.4**
Total Wet Mass	**7.0**	

VENUS BALLOON

Venus Balloon Element Summary Table

Subsystem	Mass (kg)	Power (Whr) *Science Mode*	Power (Whr) *Telecom Mode*
Payload			
Drop Sonde (2)	14.0	0.0	0.0
Payload Total	**14.0**	**0.0**	**0.0**
Bus			
CDH	0.5	9.6	57.6
Power	11.2	8.8	177.2
Structure	5.7	0.0	0.0
Gondola Heat Shield Interface	0.8	0.0	0.0
Cabling	0.7	0.0	0.0
Telecom	6.2	58.3	1305.1
Thermal	0.1	0.0	0.0
Bus Total	**25.1**	**76.7**	**1539.9**
Spacecraft Total	**39.1**	**76.7**	**1539.9**
Bus Contingency, 30%	7.5	23.0	462.0
Balloon & Inflation System	40.0	0.0	0.0
Total Delivered Balloon Mass	**86.6**	**99.7**	**2001.9**
Entry System	39.9		
Total Entry Mass	**126.5**		

VENUS BALLOON

Venus Probe Carrier Element Summary Table

Subsystem	Mass (kg)	Power (W) *Cruise*
Payload		
Entry System	126.5	12.0
Release Mechanism	5.8	0.0
Payload Total	**132.3**	**12.0**
Bus		
ACS	4.1	12.1
CDH	2.1	2.5
Power	10.7	13.7
Propulsion	23.0	23.2
Structure	54.9	0.0
S/C Adapter	4.6	0.0
Cabling	11.9	0.0
Telecom	6.7	33.8
Thermal	9.0	22.2
Bus Total	**126.8**	**107.5**
Spacecraft Total	**259.1**	**119.5**
Bus Contingency, 30%	38.0	32.2
Spacecraft Total w/ Contingency	**297.1**	**151.7**
Propellant	180.1	
Total Wet Mass	**477.2**	

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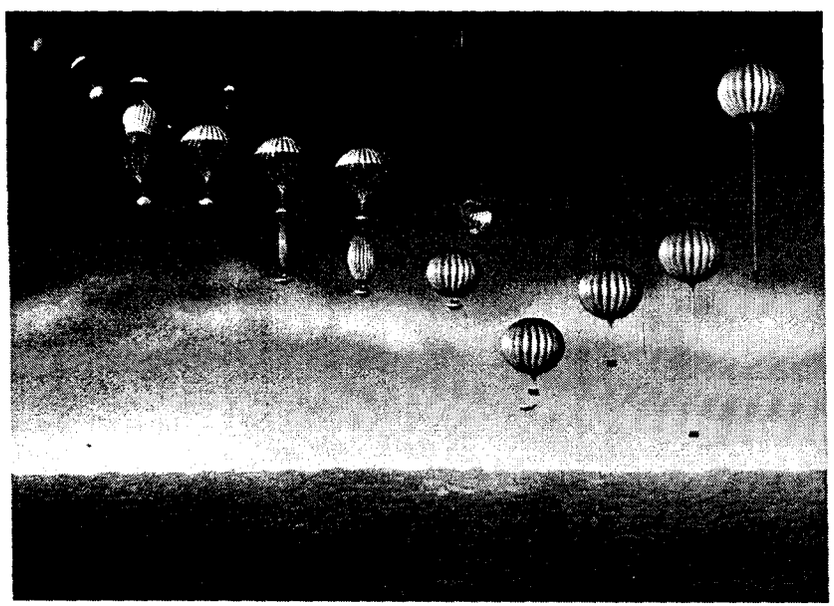
MARS BALLOON



- Mission Design
  - Micromission Trajectory, Moon/Earth Flybys
  - Carrier Dies at Probe Delivery
  - 2km, 5 Day Minimum Mission
- Science Mission
  - Water Detection/Topography Mapping
  - Instrument Suite:
    - 3-head Imager
    - Neutron Spectrometer
    - Temp/Press Sensors
- Major Design Trades
  - Gondola Mass
  - Communications, **Data Relay** vs. Direct
  - Orbit Orientation

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MARS BALLOON

Mars Balloon Mission Design Summary	
Mission Target:	Mars
Mission Duration:	12 months cruise, 10 days science
Mission Elements:	Mars Balloon, Probe Carrier
Redundancy Scheme:	Single String
Return Data Rate:	16 kbps
Data Storage:	1 Gb
Maximum Link Distance:	2.6 AU
Telecom Band:	UHF, using orbital relay
Radiation Total Dose:	22 krad
Technology Cutoff Date:	2003 (assumes a 2005 launch date)
Launch Vehicle, Capability:	500 kg
Delta V Required:	2100 m/s
Launch Mass:	483.6 kg, includes 29 kg LV adapter
Launch Margin:	3.2%

MARS BALLOON

Mars Balloon Element Summary Table

Subsystem	Mass (kg)	Power (W) *Science Mode*	Power (W) *Telecom Mode*
Payload			
Instruments	1.2	1.6	1.6
Payload Total	**1.2**	**1.6**	**1.6**
Bus			
ACS	0.2	0.0	0.0
CDH	0.6	1.4	1.4
Power	0.9	0.3	0.4
Structure	1.4	0.0	0.0
Gondola Heat Shield Interface	0.3	0.0	0.0
Cabling	0.6	0.0	0.0
Telecom	0.9	0.1	0.4
Thermal	0.7	0.0	0.0
Bus Total	**5.6**	**1.8**	**2.1**
Spacecraft Total	**6.8**	**3.4**	**3.7**
Contingency, 30%	2.0	1.0	1.1
Balloon & Inflation System	21.4	0.0	0.0
Total Delivered Balloon Mass	**30.2**	**4.4**	**4.8**
Entry System	15.2		
Total Entry Mass	**45.4**		

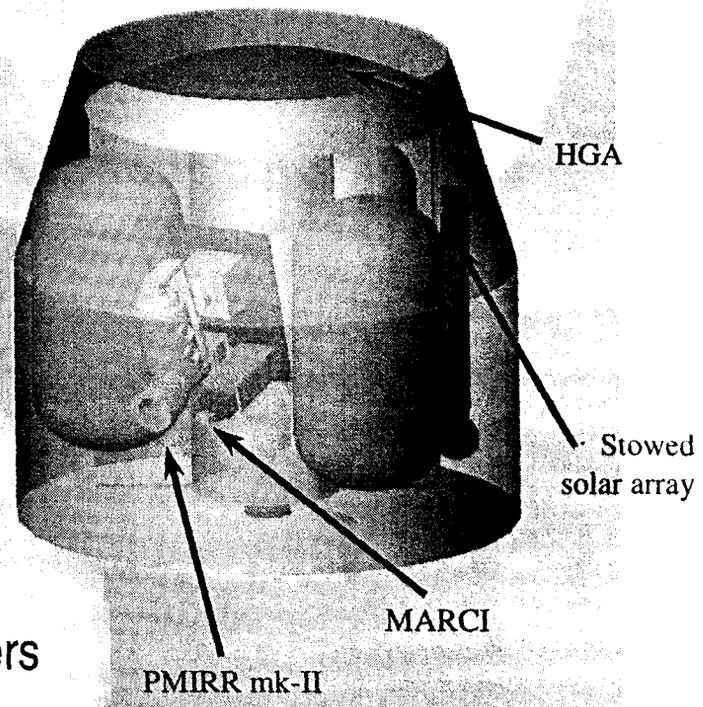
MARS BALLOON

Mars Probe Carrier Element Summary Table

Subsystem	Mass (kg)	Power (W) *Cruise*
Payload		
Entry System	45.4	12.0
Release Hardware	6.9	0.0
Payload Total	**52.3**	**12.0**
Bus		
ACS	3.2	19.0
CDH	3.2	9.5
Power	15.3	14.0
Propulsion	21.3	43.2
Structure	52.1	0.0
S/C Adapter	5.5	0.0
Cabling	10.9	0.0
Telecom	6.7	33.8
Thermal	8.5	13.3
Bus Total	**126.7**	**132.8**
Spacecraft Total	**179.0**	**144.8**
Bus Contingency, 30%	38.0	39.8
Spacecraft Total w/ Contingency	**217.0**	**184.6**
Propellant	237.6	
Total Wet Mass	**454.6**	

MARS SCIENCE ORBITER

- Mission Design
  - Micromission Trajectory, Moon/Earth Flybys
  - Chemical Orbit Insertion, 24 Hour Orbit
  - Aerobraking to 400km Parking Orbit, i = 90°
- Science Mission
  - Martian Climate/Weather Mission
  - Re-flight of MCO Science Suite
    - MARCI, med- and wide-angle imager
    - PMIR mk-II, atmospheric sounder
- Major Design Trades
  - Attitude Control, **Reaction Wheels** vs. Thrusters
  - Communications Frequency, **X-** vs. Ka-band
  - Battery Selection, NiH vs. **Li-Ion**



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MARS SCIENCE ORBITER

Mars Science Orbiter Mission Design Summary

Mission Target:	Mars
Mission Duration:	18 months cruise, 6 months aerobraking, 2 years on orbit
Mission Elements:	Mars Science Orbiter
Redundancy Scheme:	Single String
Return Data Rate:	5 kbps
Data Storage:	1 Gb
Maximum Link Distance:	2.7 AU
Telecom Band:	X Band
Radiation Total Dose:	24 krad
Technology Cutoff Date:	2005 (assumes a 2007 launch date)
Launch Vehicle, Capability:	500 kg
Delta V Required:	2850 m/s
Launch Mass:	502.7 kg, includes 29 kg LV adapter
Launch Margin:	-0.5%

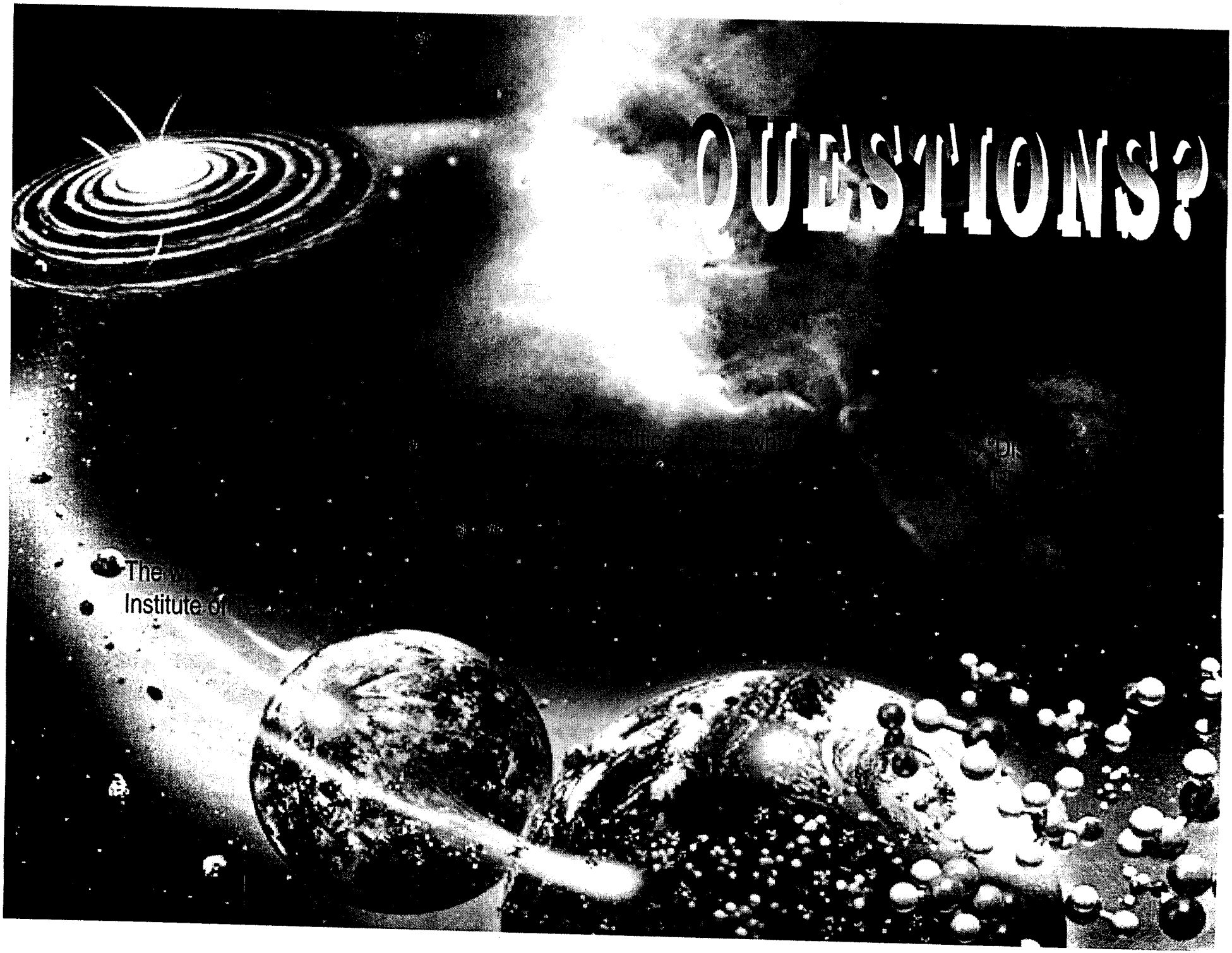
MARS SCIENCE ORBITER

Mars Science Orbiter Element Summary Table

Subsystem	Mass (kg)	Power (W) *Science Mode*	Power (W) *Eclipse Mode*
Payload			
Instruments	7.4	16.0	9.0
Payload Total	**7.4**	**16.0**	**9.0**
Bus			
ACS	10.3	34.7	34.7
CDH	6.1	15.6	11.6
Power	16.9	21.5	14.1
Propulsion	23.8	18.7	18.7
Structure	45.6	0.0	0.0
S/C Adapter	6.5	0.0	0.0
Cabling	9.9	0.0	0.0
Telecom	7.6	73.2	27.4
Thermal	8.5	6.9	6.9
Bus Total	**135.3**	**170.6**	**113.4**
Spacecraft Total	**142.7**	**186.6**	**122.4**
Contingency, 30%	42.8	56.0	36.7
Spacecraft Total w/ Contingency	**185.5**	**242.6**	**159.1**
Propellant	288.2		
Total Wet Mass	**473.7**		

STUDY RESULTS & CONCLUSIONS

- Costs are reduced by roughly 1/3.
- Missions are viable near-Earth. The secondary payload option is not viable for outer planet missions as presently defined.
- Preliminary design of Delta IV and Atlas V contain a sufficient amount of space for interplanetary secondary missions.
- The secondary payload option is valuable for the next generation of mission planners—this option enables significant scientific investigations that are overlooked (or deemed too small) by larger missions.



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