Space Infrared Telescope Facility

Mars Exploration Rovers

Jupiter Icy Moons Orbiter

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Jet Propulsion Laboratory
California Institute of Technology

Goddard Symposium Briefing

March 26, 2003

The SIRTF Observatory

- Multi-purpose observatory cooled passively and with liquid-helium for astronomical observations in the infrared
- Launch in April 2003 for a 2.5 to 5 year mission in solar orbit
- Provides a >100 fold increase in infrared capabilities over all previous space missions
- Completes NASA's Great Observatories
- Major scientific and technical contributor to NASA's Origins Theme

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Wavele[redacted]
Telesc[redacted]
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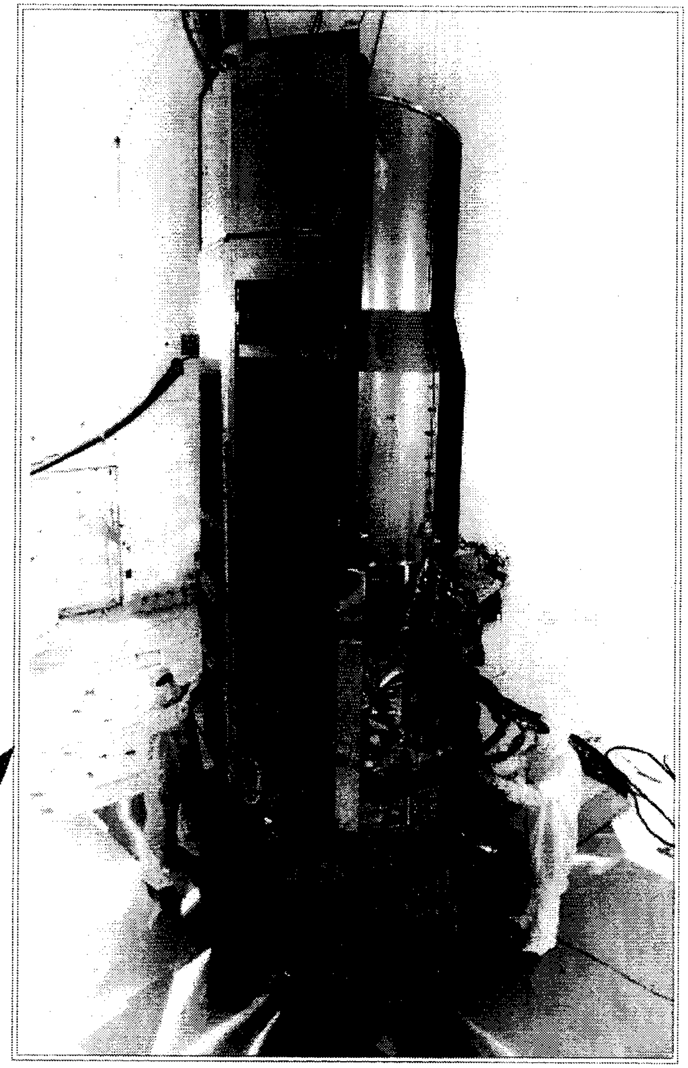
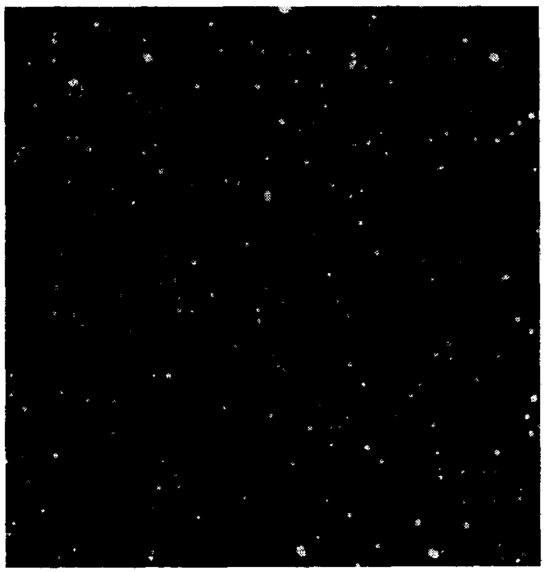
Height – 4m



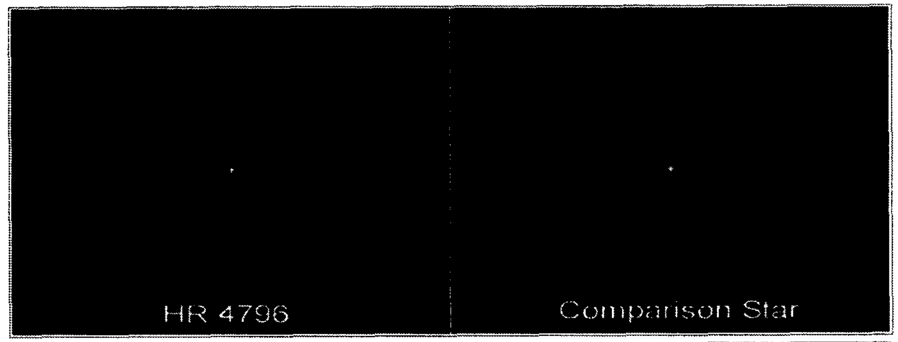
Why Infrared Astronomy?

Infrared Observations Probe:

The OLD....



The Distant Universe
Most of the light that comes to us from distant galaxies is in the infrared.



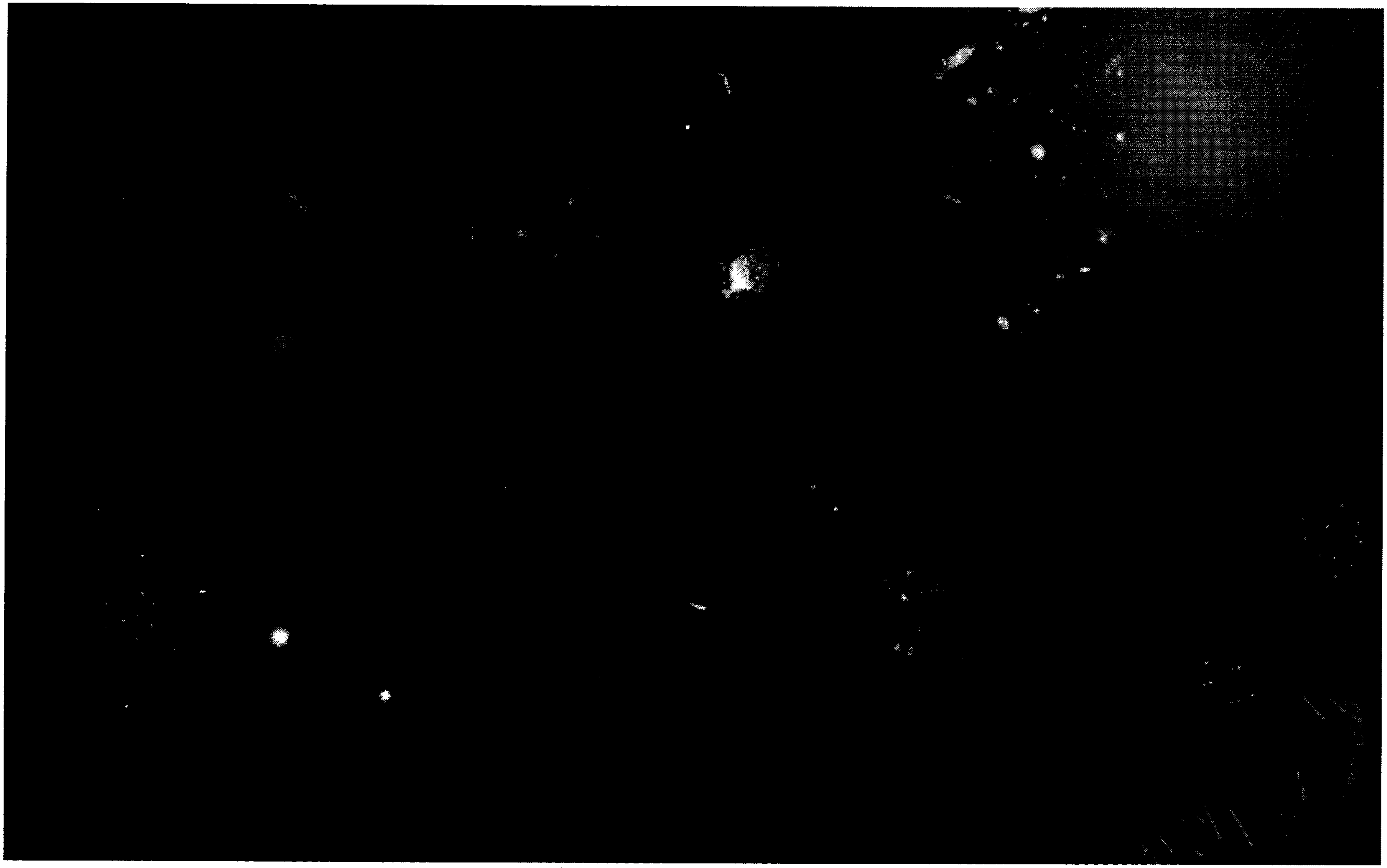
...The COLD...

The Cold Universe
Cold clouds of interstellar and circumstellar gas and dust can be best studied only in the infrared.

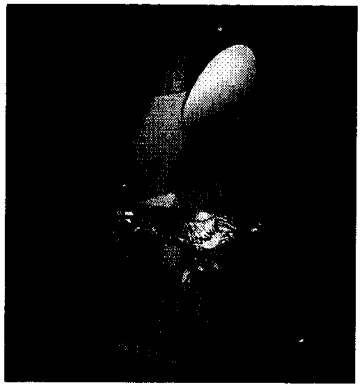
The Dusty Universe
Much infrared light comes from diffuse clouds of inter-stellar dust and gas that are opaque to visible light.

...and The DIRTY

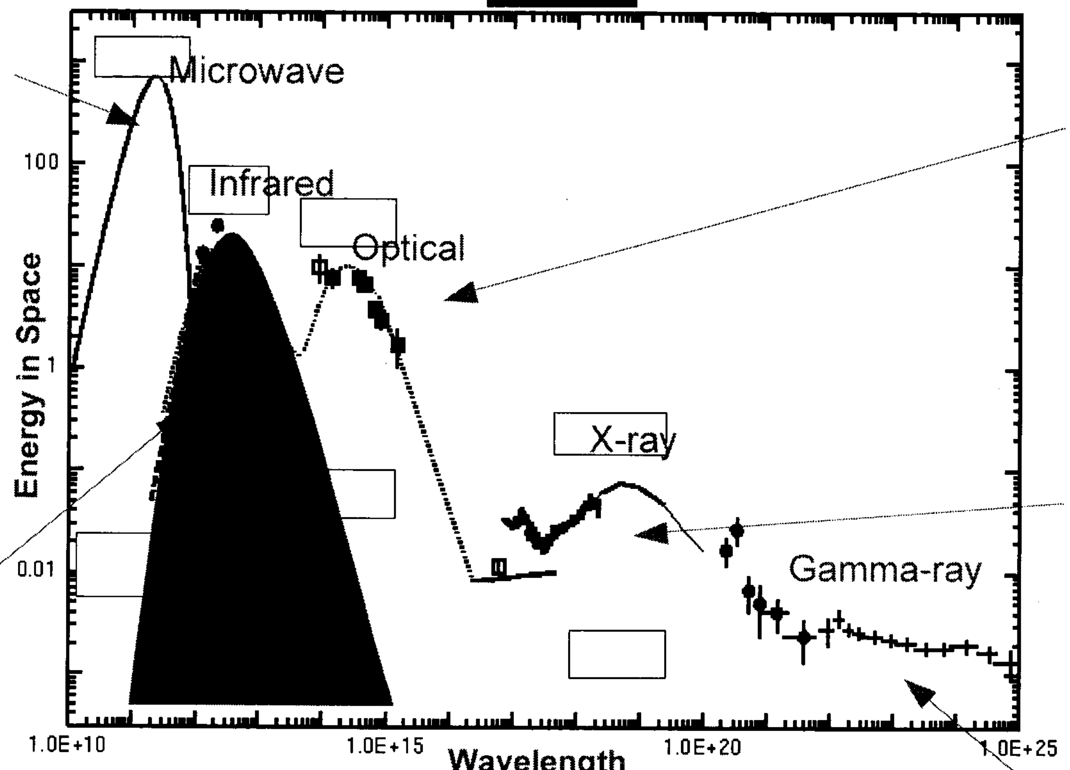
Two Key Science Questions for SIRTF



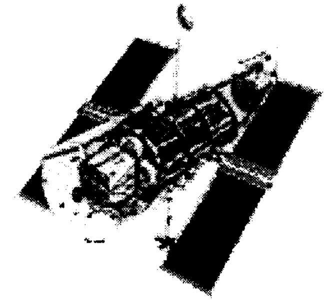
What Did the Early Universe Look Like?



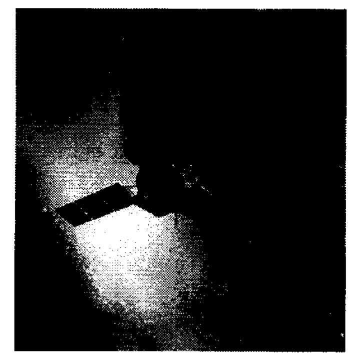
WMAP



Almost half of the energy emitted in the Universe after the Big Bang is in the infrared. SIRTF will search for its origin.



Hubble

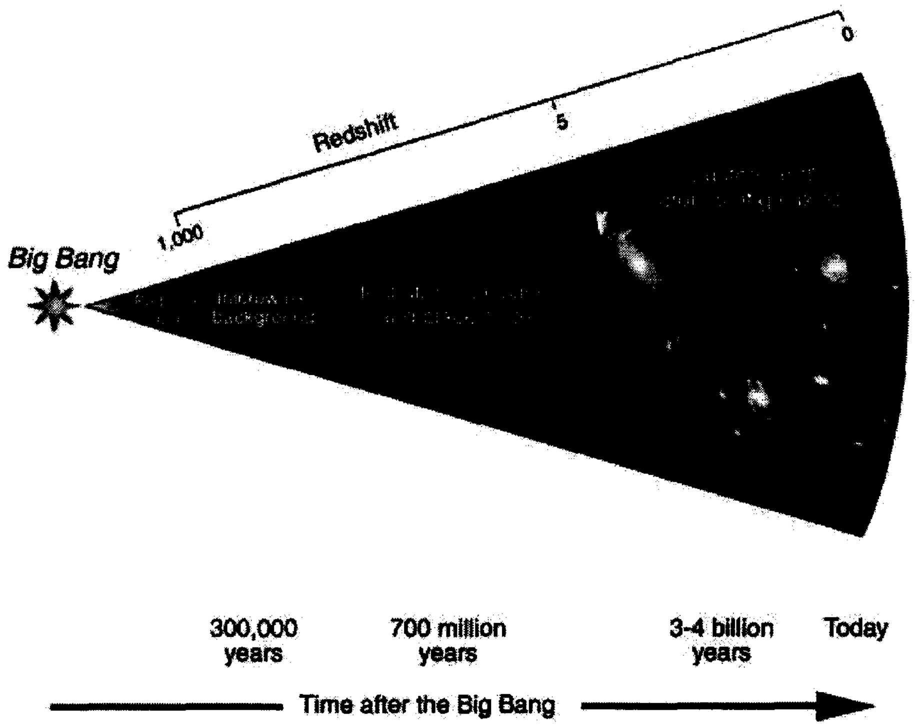


Chandra

Compton

The Power of the Great Observatories

The Journey Through Cosmic Time

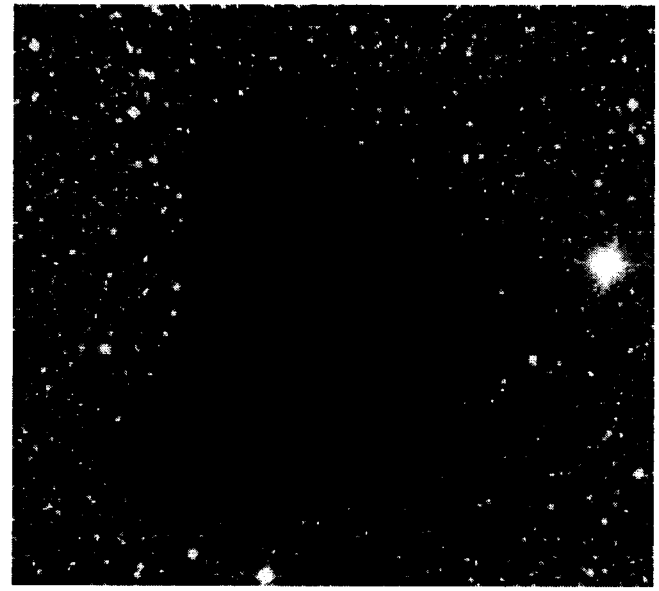


The deepest images taken by the Hubble Space Telescope, Chandra X-Ray Observatory, and SIRTF will be in the same patch of sky. Together, these coordinated panchromatic images will show us what galaxies looked like when they were first forming when the Universe was <10% its current age.

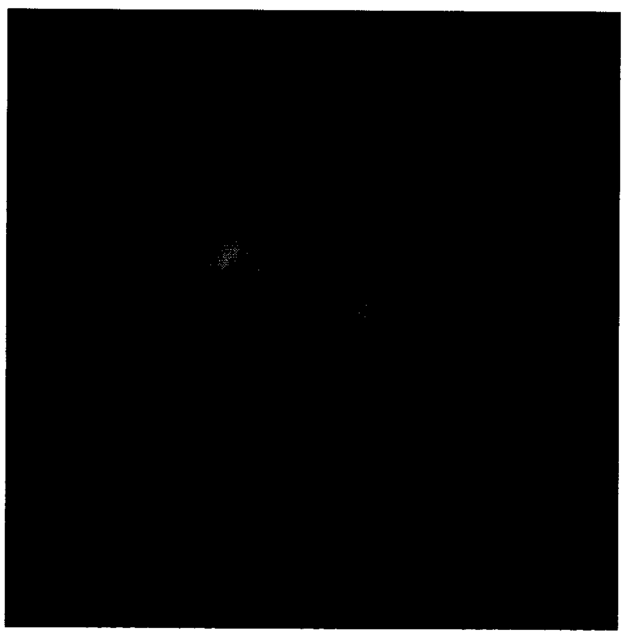
CDF-S HDF-N

How Do Stars and Planets Form and Evolve Now ?

- New stars are still forming today from the dust and gas in dark interstellar clouds
- Planets form in large disk-shaped clouds circling newborn stars.



Visible light image of dark globule B68



HST/NICMOS image of an edge-on disk in Taurus

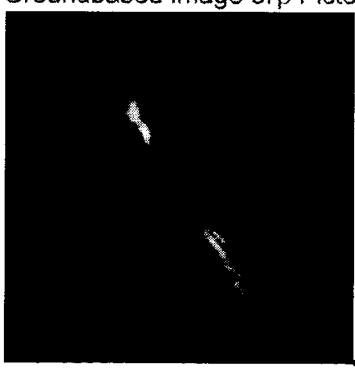
- These "circumstellar" disks are best seen in infrared light
- SIRTF can study the evolution of disks in the key phase of Earthlike planet formation

What is the Raw Material for Planet Formation ?

JPL

- The dust particles which form planets glow brightest at the infrared wavelengths where SIRTF will be observing
- Comets in our own solar system also give off dust particles. SIRTF will show how the composition of our solar system relates to that of other planetary systems.

Groundbased image of β Pictoris



Planet-forming Disk

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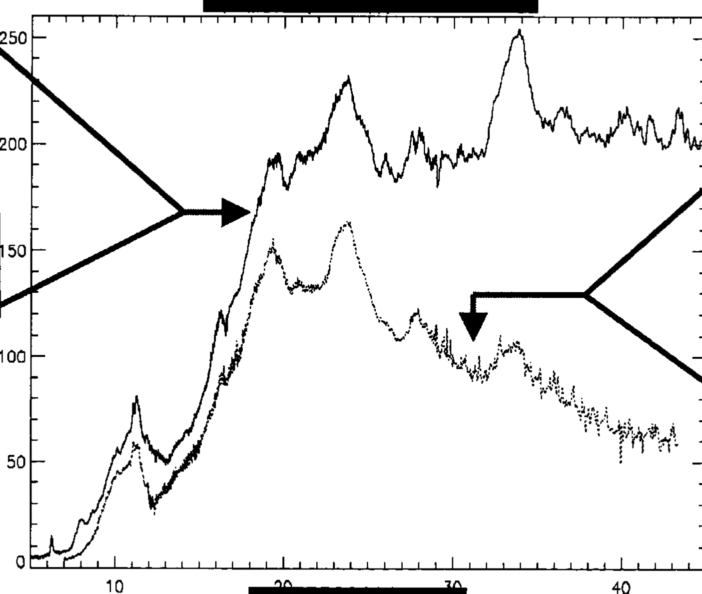

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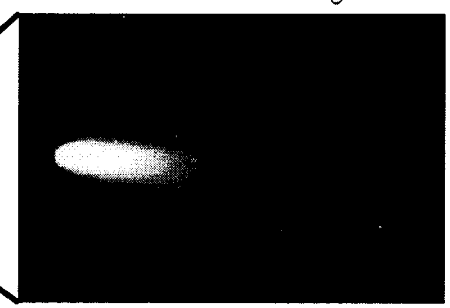
Groundbased visible image



Comet Hale-Bopp

How Can SIRTF Sense Planets Around Other Stars?

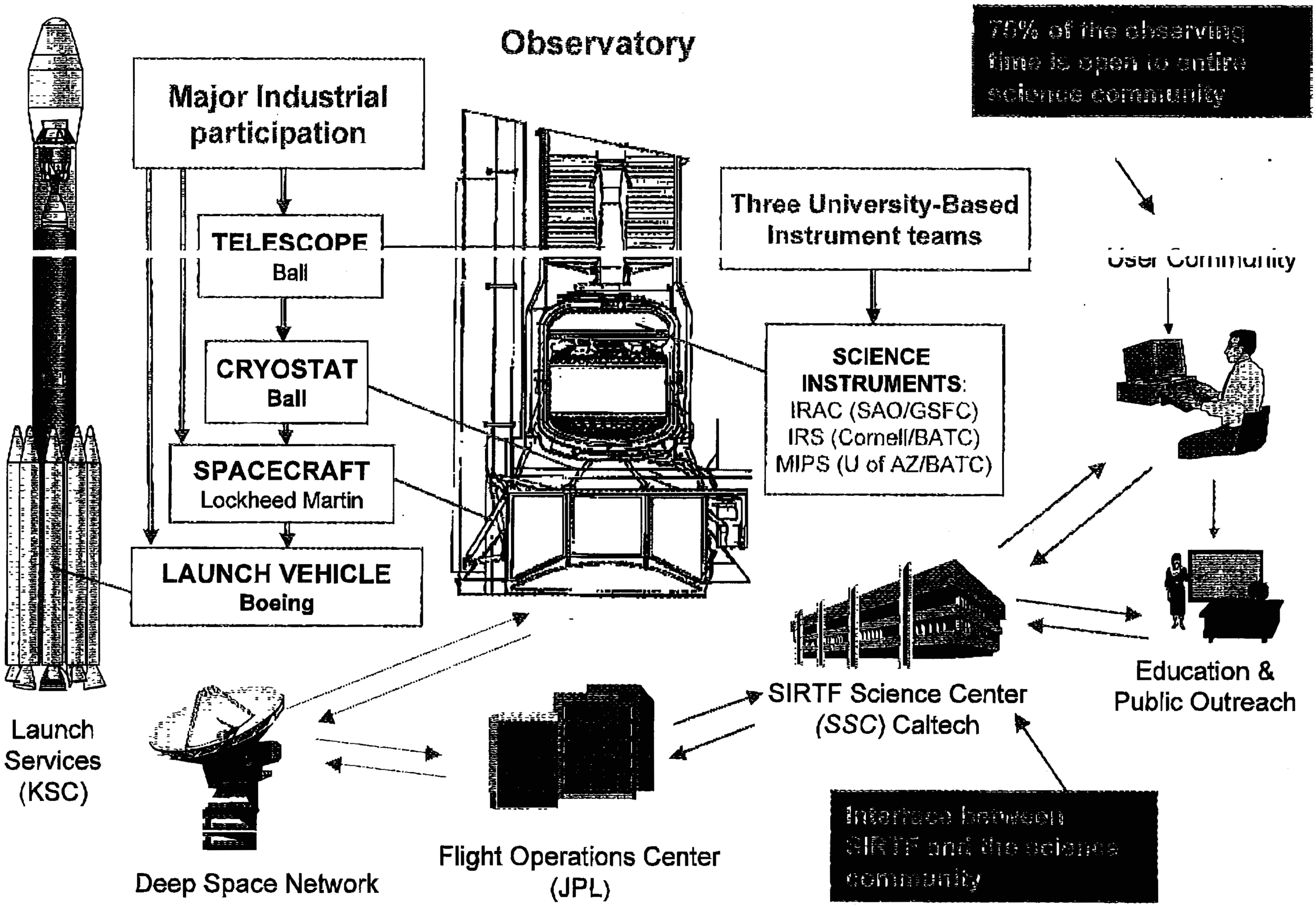
- Even when a planet itself is too faint to see directly, its gravitational influence on its star's dust disk can still be visible, just as small moons sculpt Saturn's rings.

Voyager image of Saturn's rings

HST/ACS visible light image of a debris disk HD141569

- SIRTF will provide the first images of many nearby circum-stellar disks. Holes, clumps, or sharp edges in these disks may betray the presence of planets.

The SIRTF Team & The User Community



SIRTF's Three Instruments Use State-of-the-Art Detectors

SIRTF technologies available to be used in future missions include:

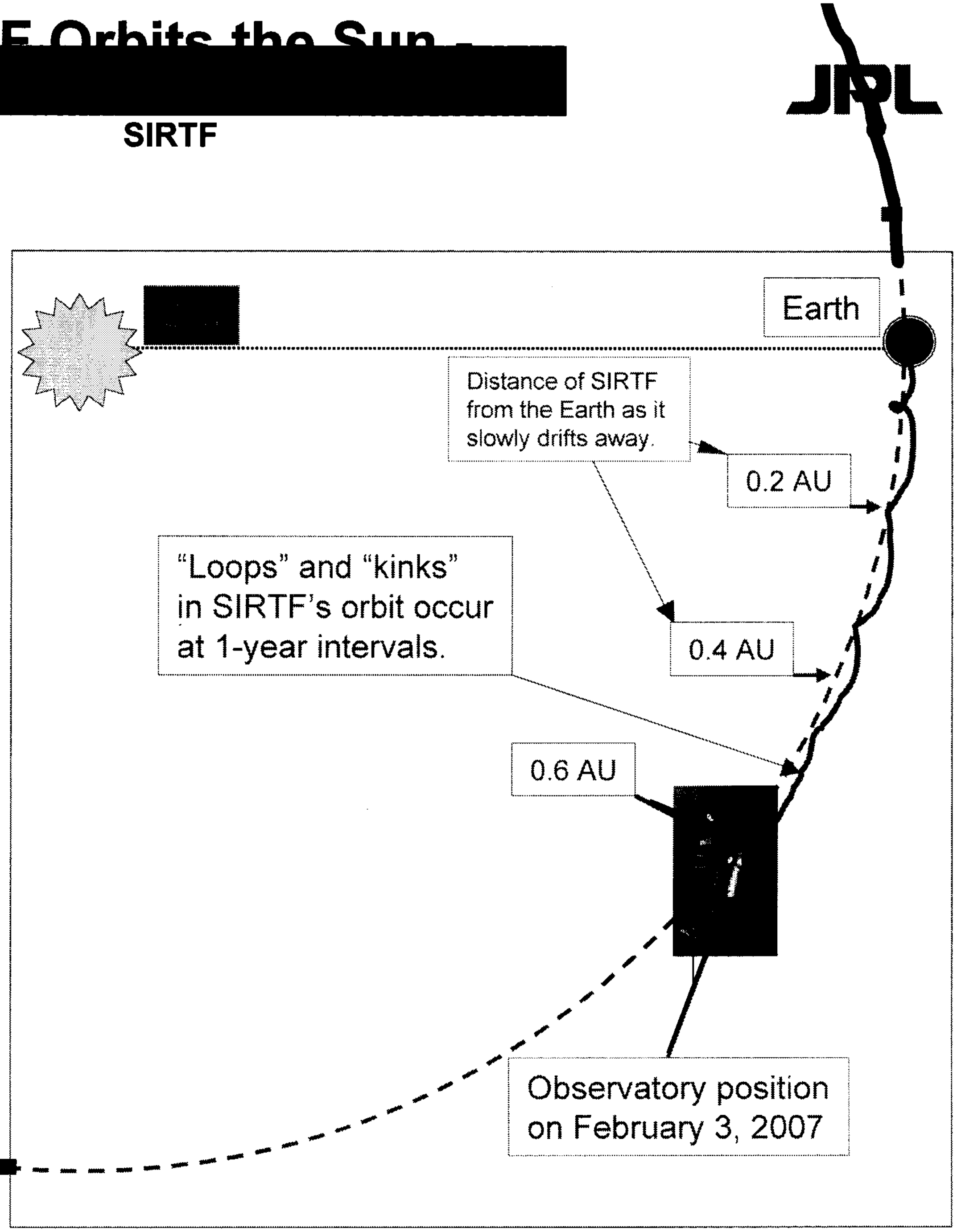
- High Performance IR Detector Arrays *(JWST, possible use in TPF)*
- Lightweight all-Beryllium Telescope Optics at Low T *(possible use in JWST)*
- Efficient cooling system combining stored cryogens and passive cooling *(JWST, possible use in TPF)*
- Observatory operations in distant orbit *(JWST, SIM, TPF)*

Instrument integration into flight cryostat at Ball Aerospace

[redacted]

SIRTF

[redacted]



SIRTF Science: Year One

First year science plans in place: *Launch date April 15, 2003*

EROs

6 mo

12 mo

Launch

In-Orbit Checkout

60(66days60 d)

Science Verification (30d)

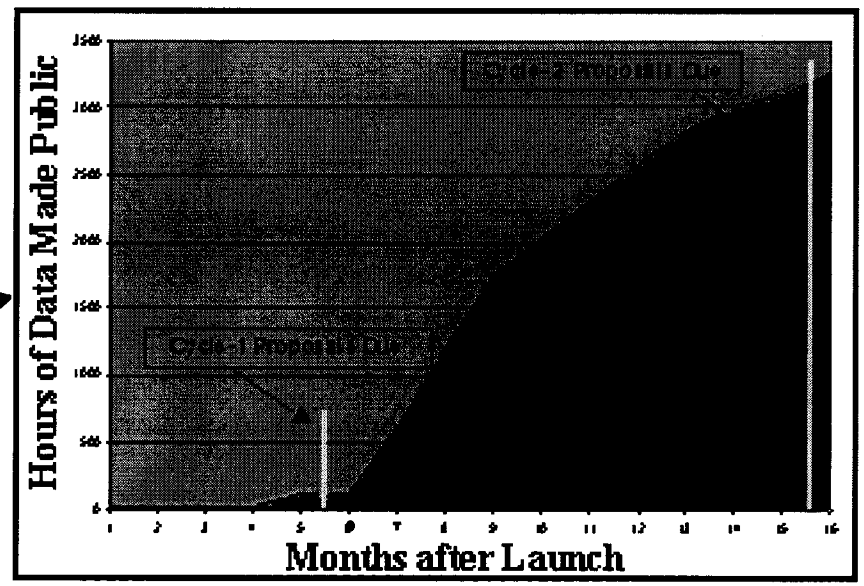
First-Look Survey (100h)

Guaranteed Time Observations (GTOs)

Legacy Science Program

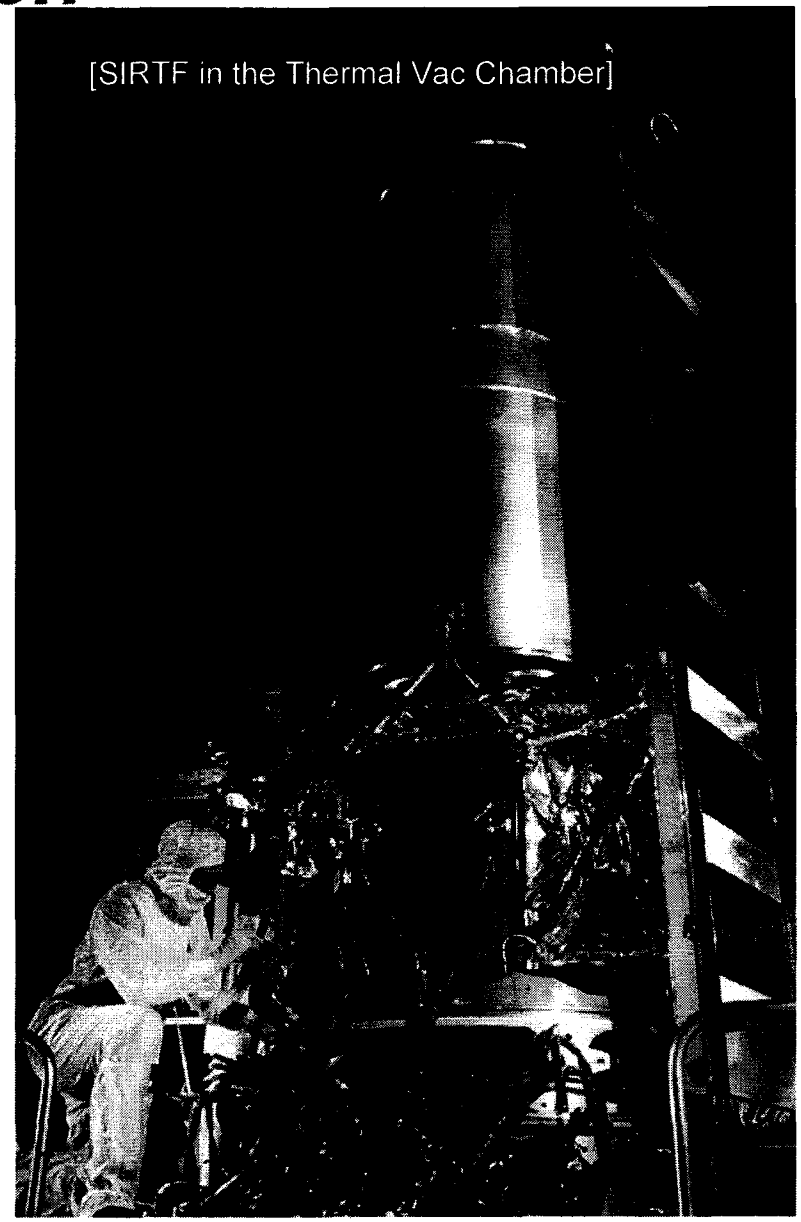
General Observer (GO) Investigations
+ DDT

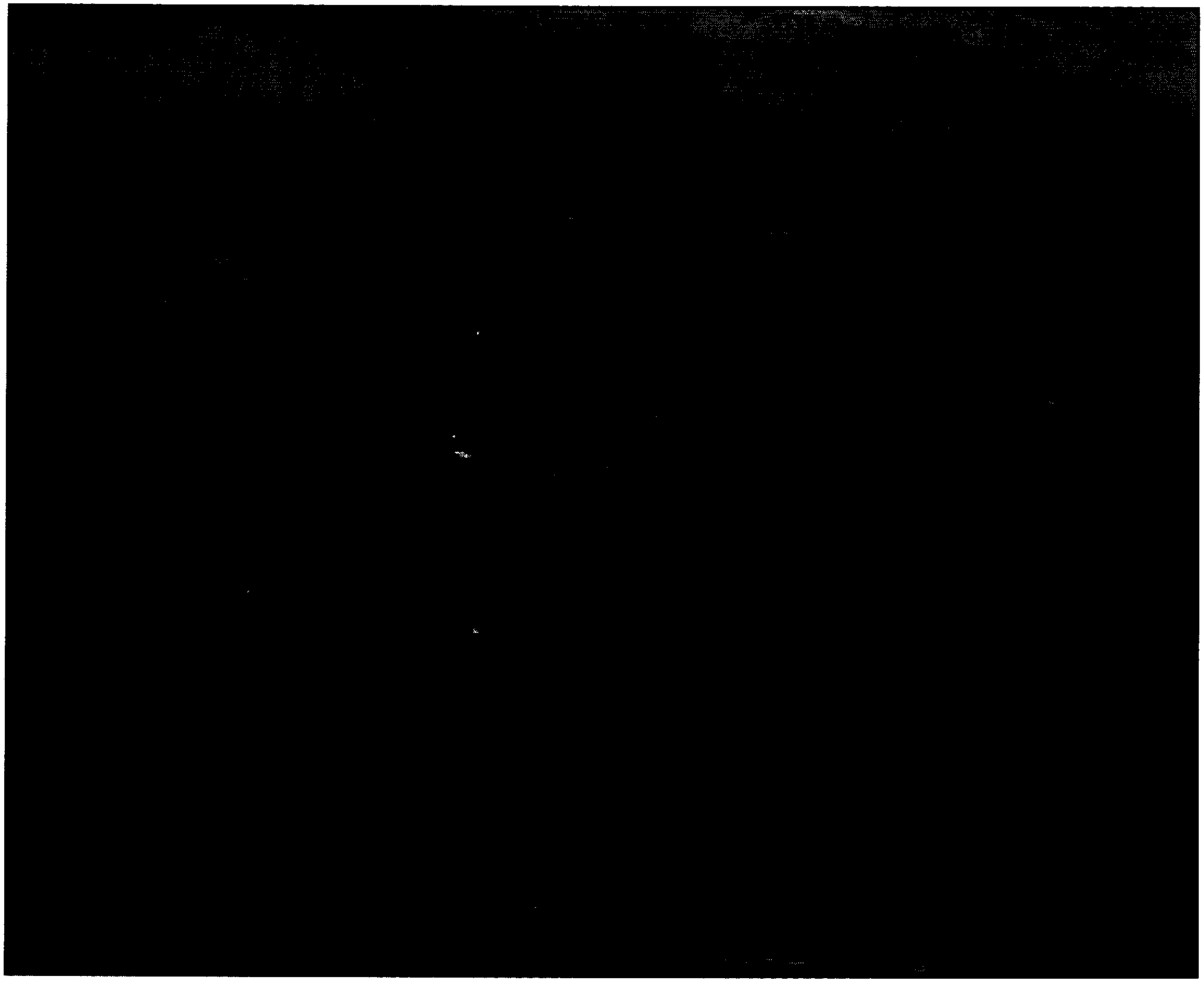
First General Observer proposals due 5 months after launch



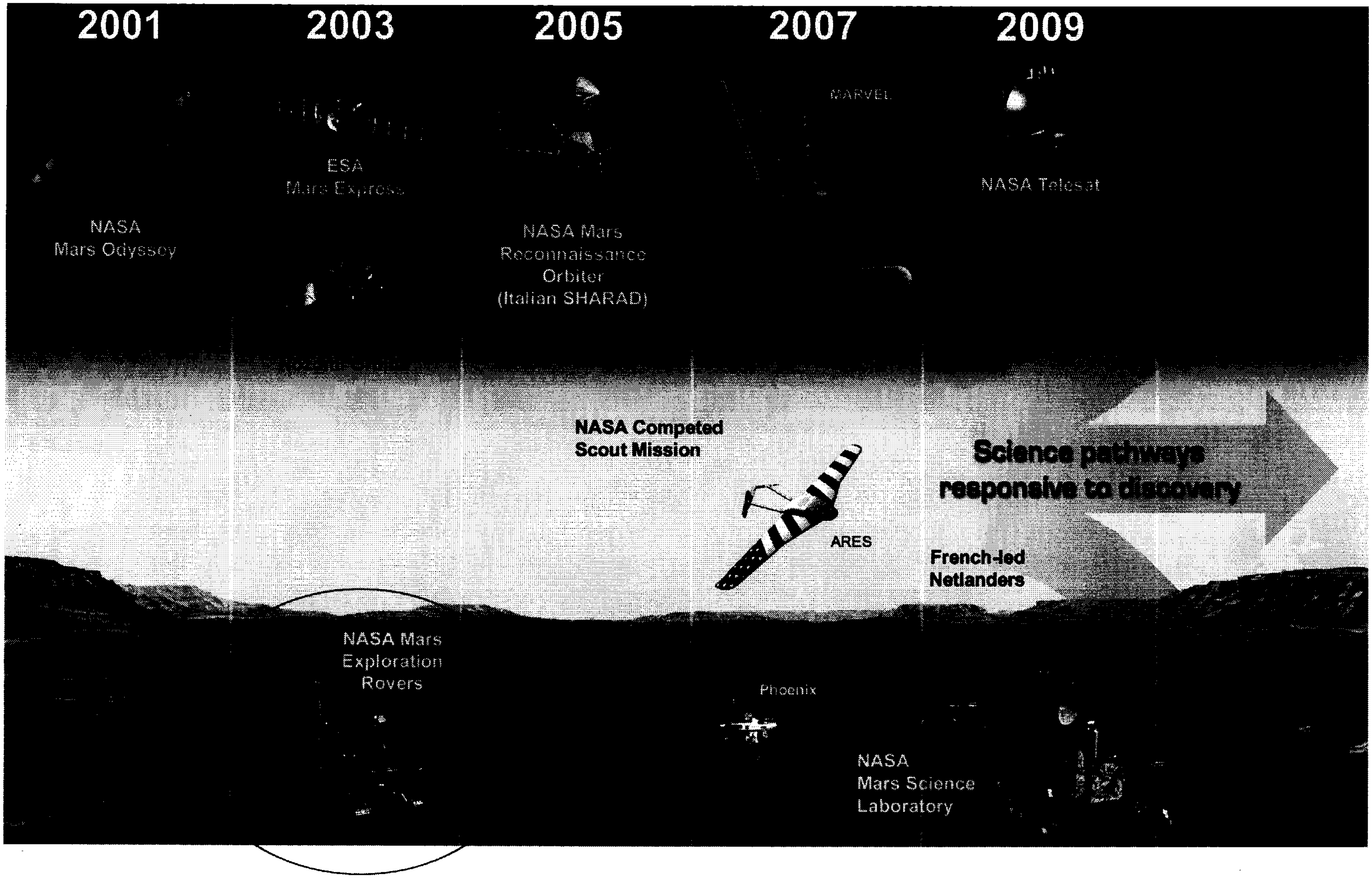
SIRTF: The Road to Launch

- The assembled SIRTF Observatory has been under test for more than a year
- The hardware is complete, and all environmental tests have been completed successfully
- The final refinements to the flight software and to the operational systems have been made
- The observatory is in place at the Cape and has been checked out extensively
- The scientific programs for the first year of the mission have been defined
- Education and public affairs activities underway
- Remaining milestones:
  - April 15 – launch window opens
  - Launch + 3 mos – start of science ops
  - Launch + 4 mos – first data release
  - Launch + 5 mos – Cycle 1 proposals due
  - Launch + 8 mos – Cycle 1 observing starts



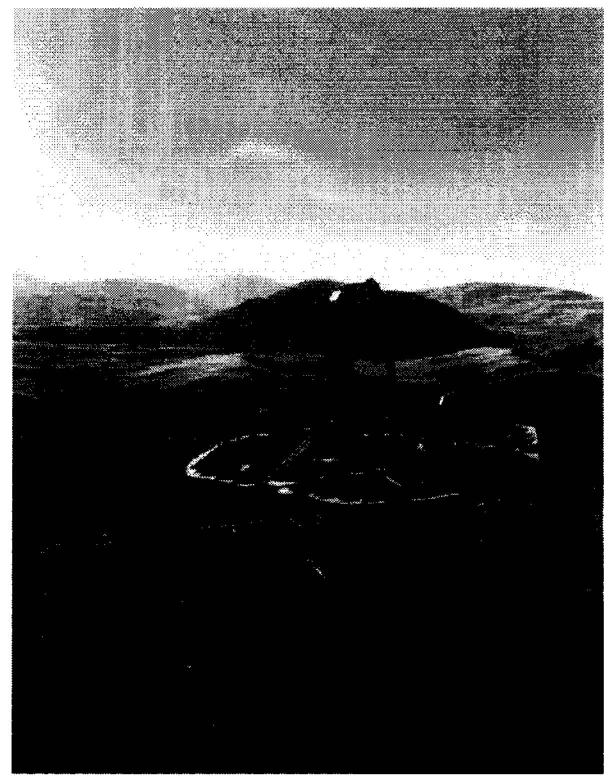


Mars Missions: 2001-2009

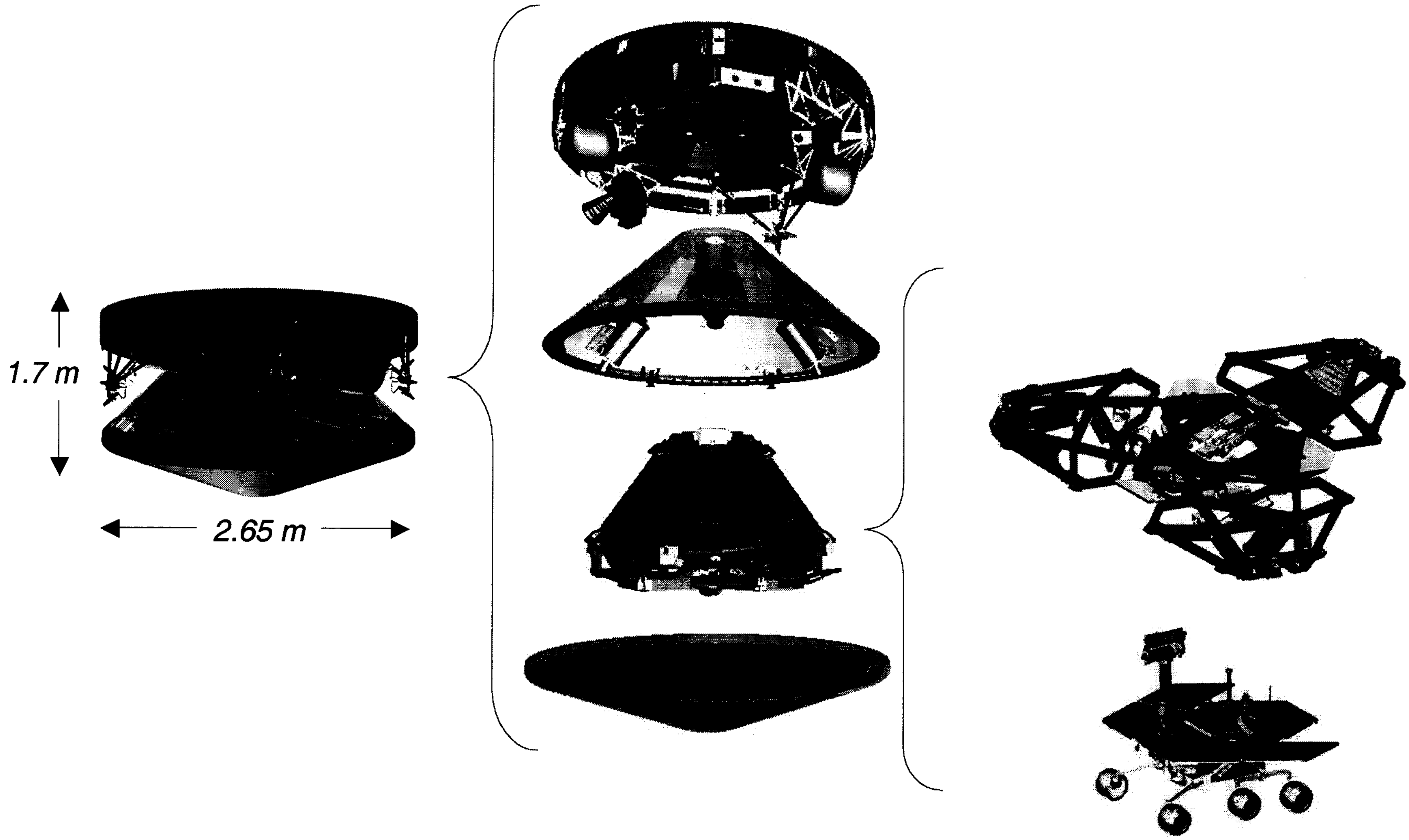


Mars Exploration Rover Mission
Key Features

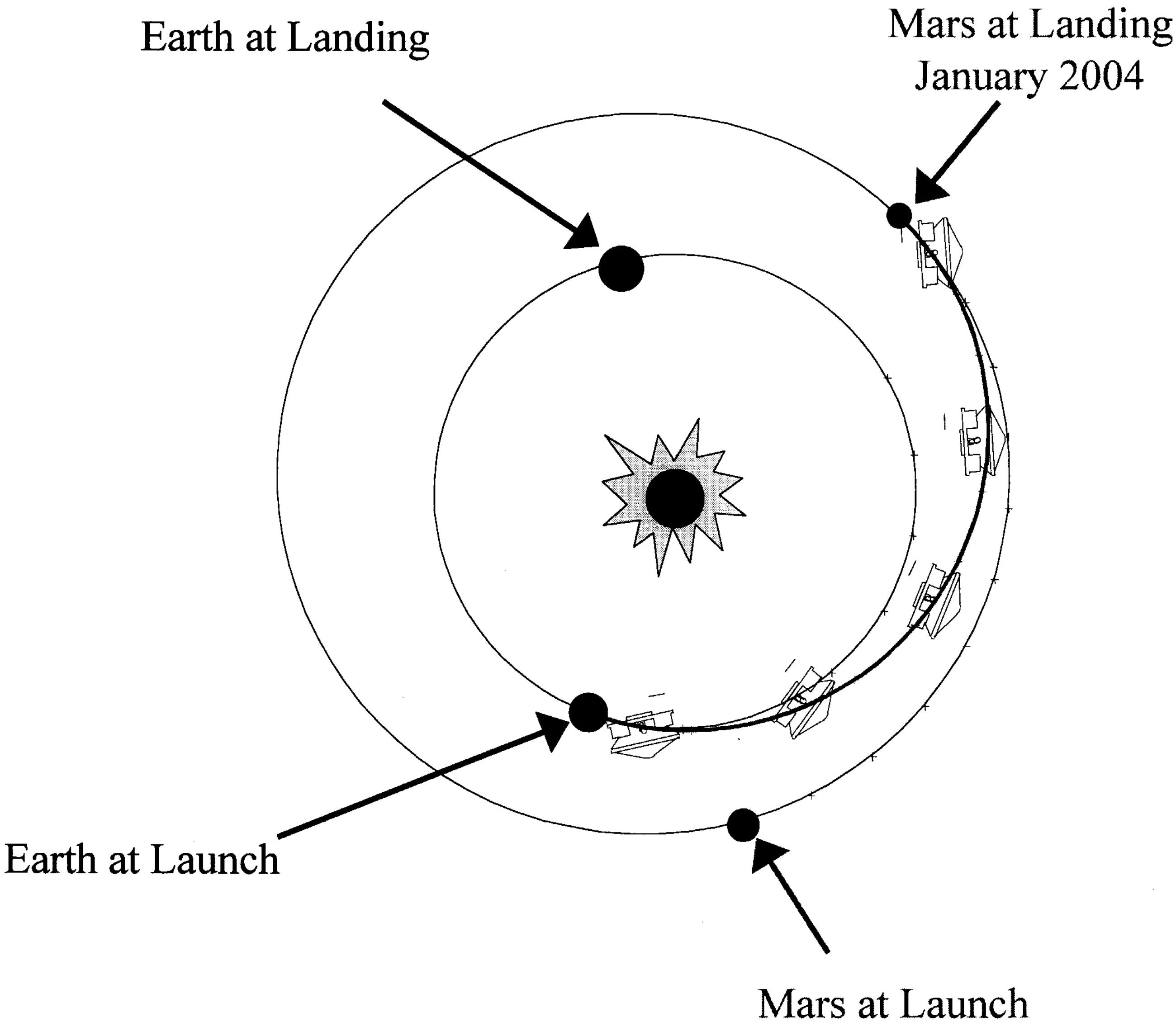
- Two identical landers launched in May-July 2003
- Targeted to two sites on Mars, landings in January 2004
- Each delivers a highly capable rover carrying a science payload
- Two surface missions of 90 Martian days
  - 600 meter odometer traverse
  - Investigate ~ 4 distinct locations
  - Measure ~ 6 targets: one soil, five rocks
  - Return ~ 3 to 4 Gbits total data
  - Your mileage may vary!



Parts of the Spacecraft

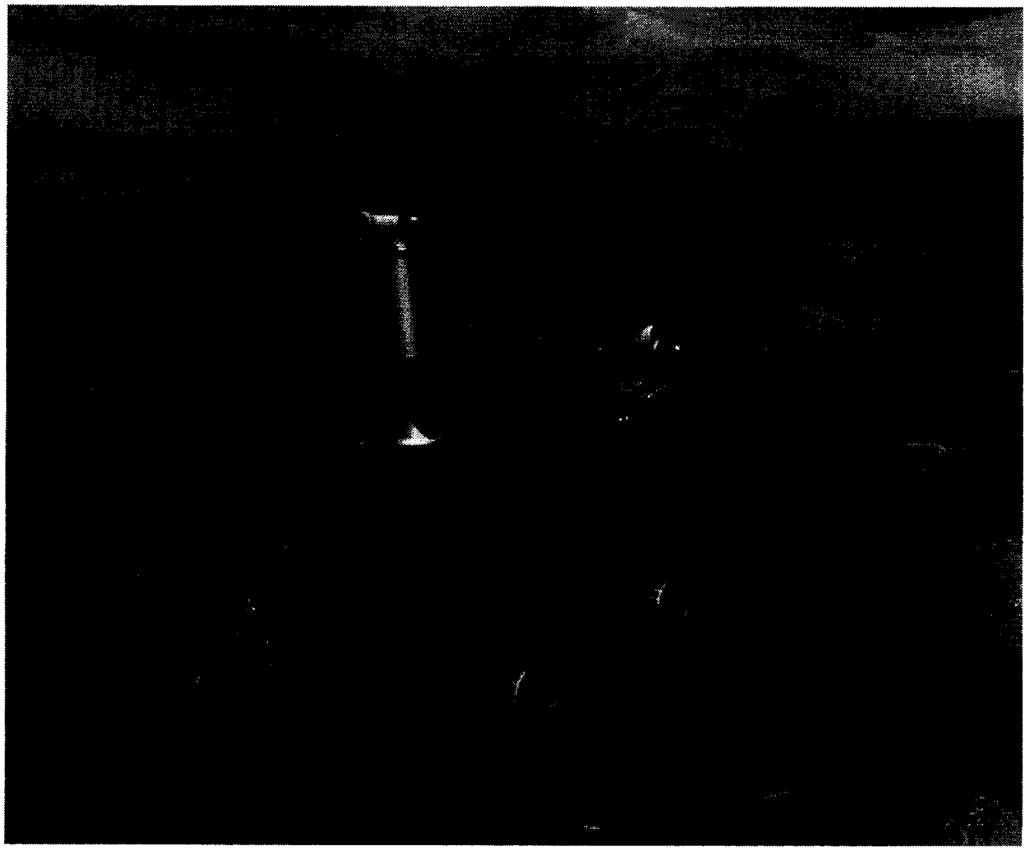


7 month trip to Mars



Comparison: MER Rover and Pathfinder Sojourner Rover

JPL



185 kg, 157 cm tall
9 cameras (1024 x 1024)
3 spectrometers
4 magnets, 1 rock grinder

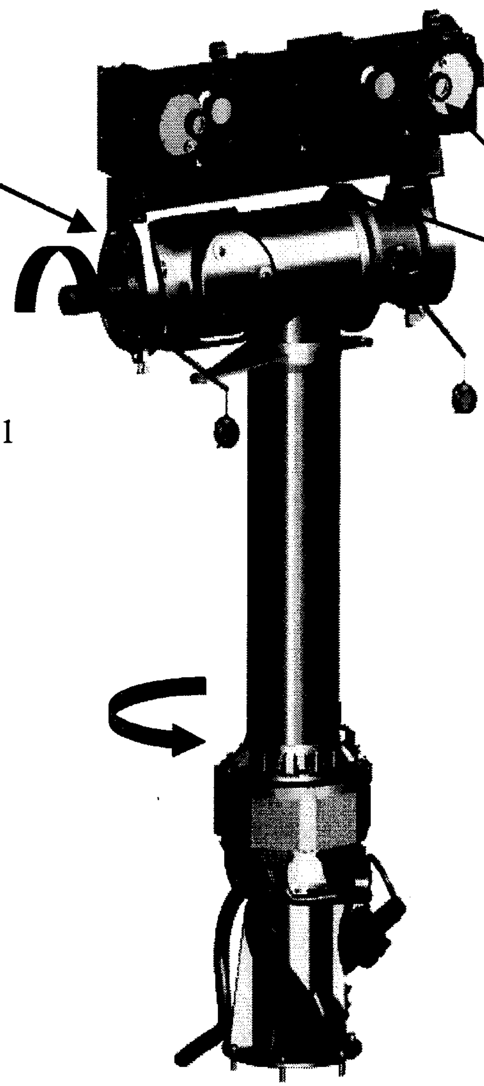
11 kg, 32 cm tall
3 cameras (768x484)
1 spectrometer

Meeting our Science Objectives

- Choose a landing site that shows evidence for the action of liquid water
- Use the instruments and rover mobility to:
  - characterize the geology at each landing site (landscape and geologic processes)
  - search for and characterize a diversity of rocks and soils that hold clues to past aqueous activity and past environmental habitability
  - select rock and soil targets for close-up examination, those most likely to reveal clues as to how they were formed and altered. Drive the rover to those targets and examine them in detail using the full set of instruments
- Calibrate and validate orbital remote sensing data

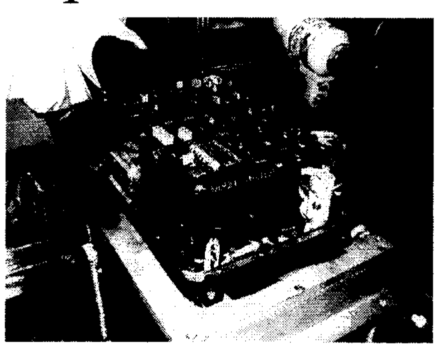
Remote Sensing Science Instruments

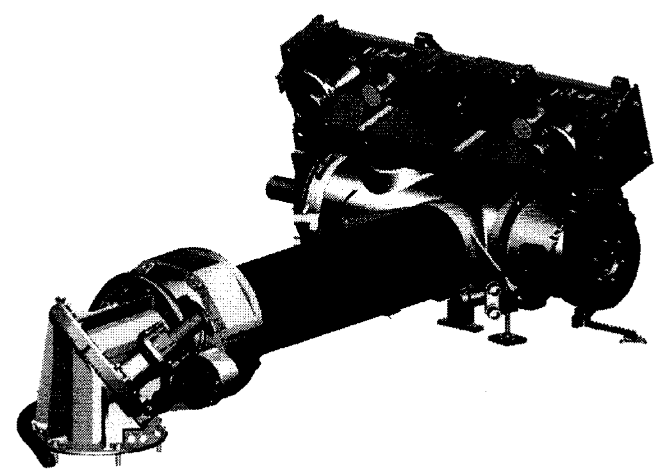
Mini-TES
infrared
spectrometer
viewing port
5-29 μm,
resolution 10 cm^{-1}



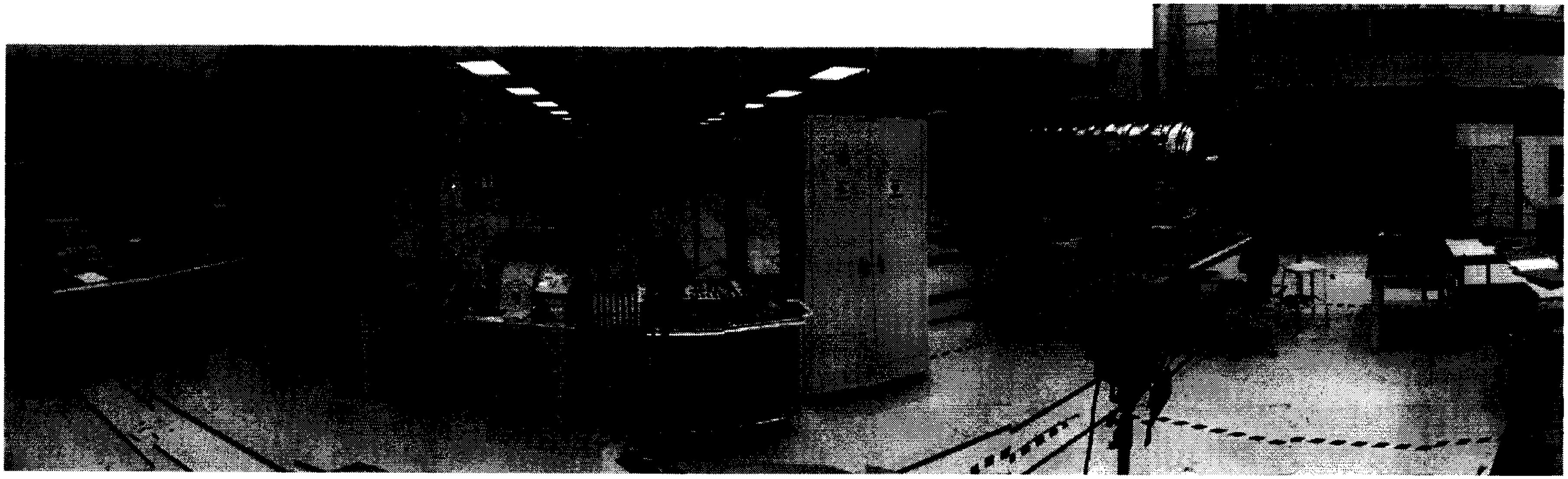
Pancam stereo
panorama cameras
(17^{o} x 17^{o})
15 color filters over
0.4-1.0 μm

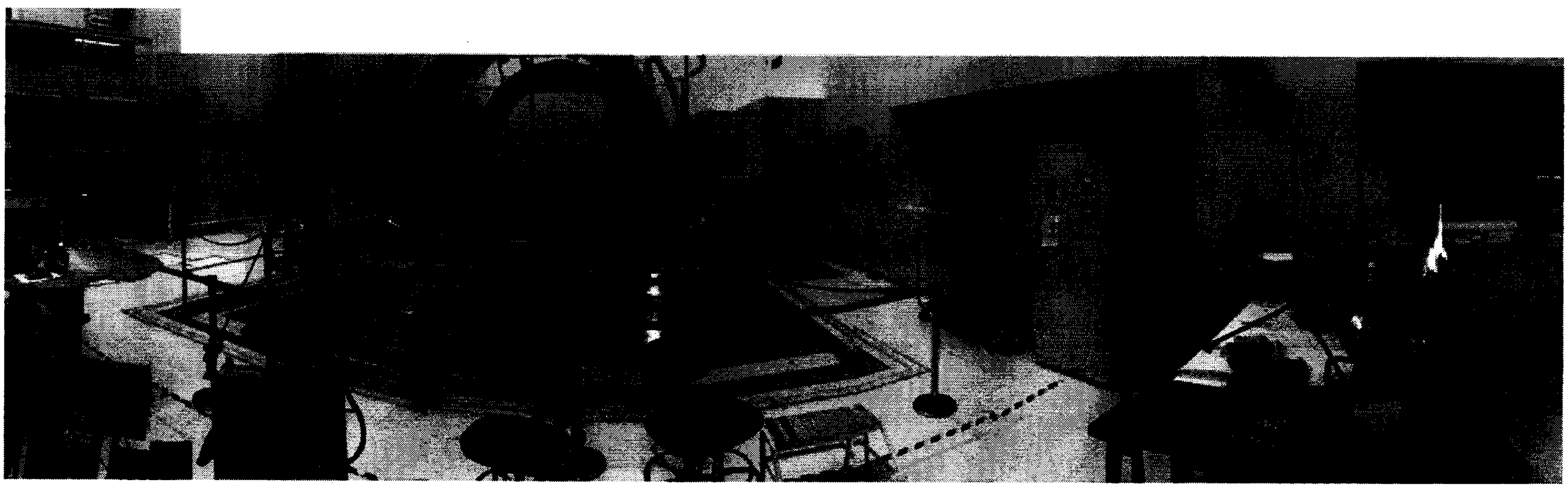
Mini-TES
spectrometer



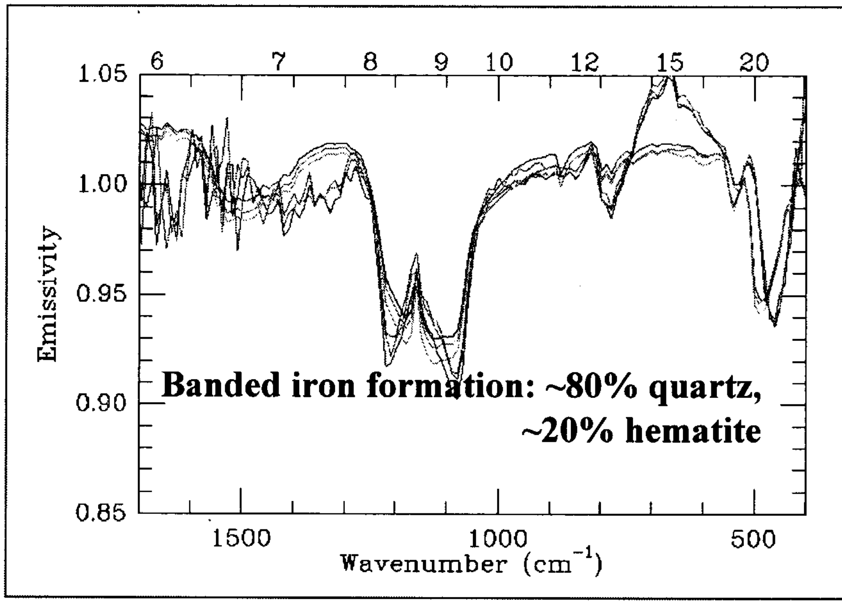


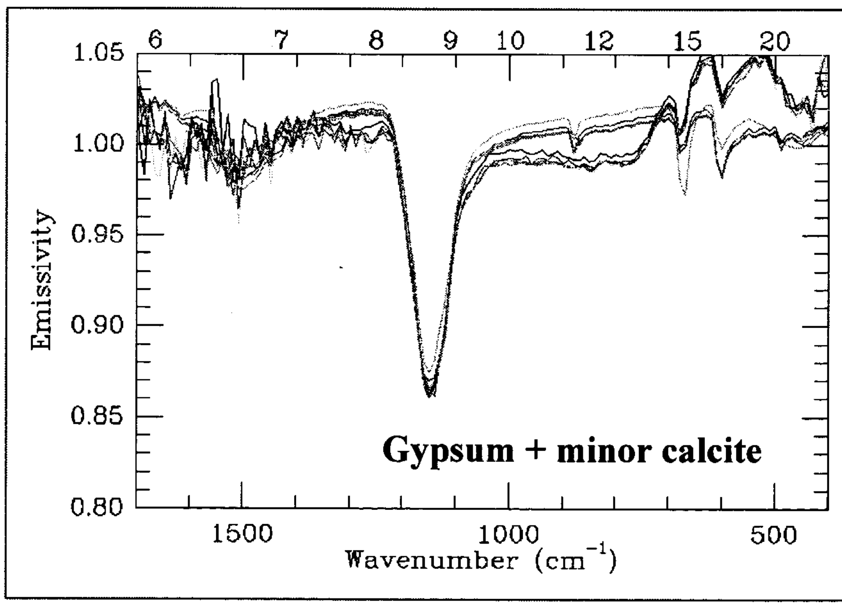
360° Pancam Panorama *(10x Subsampled)*

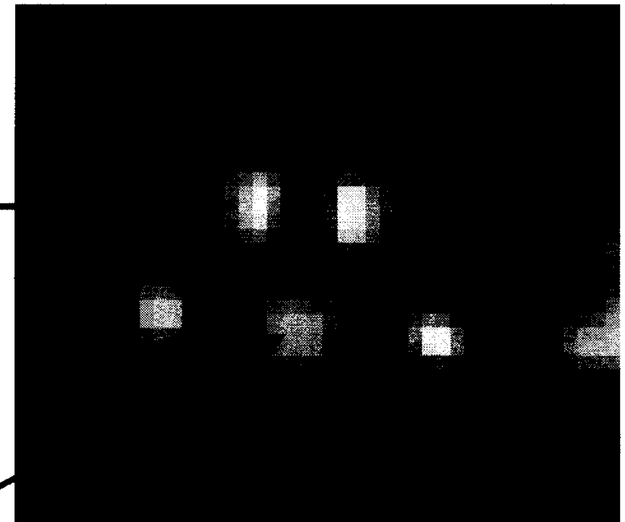




Mini-TES spectra

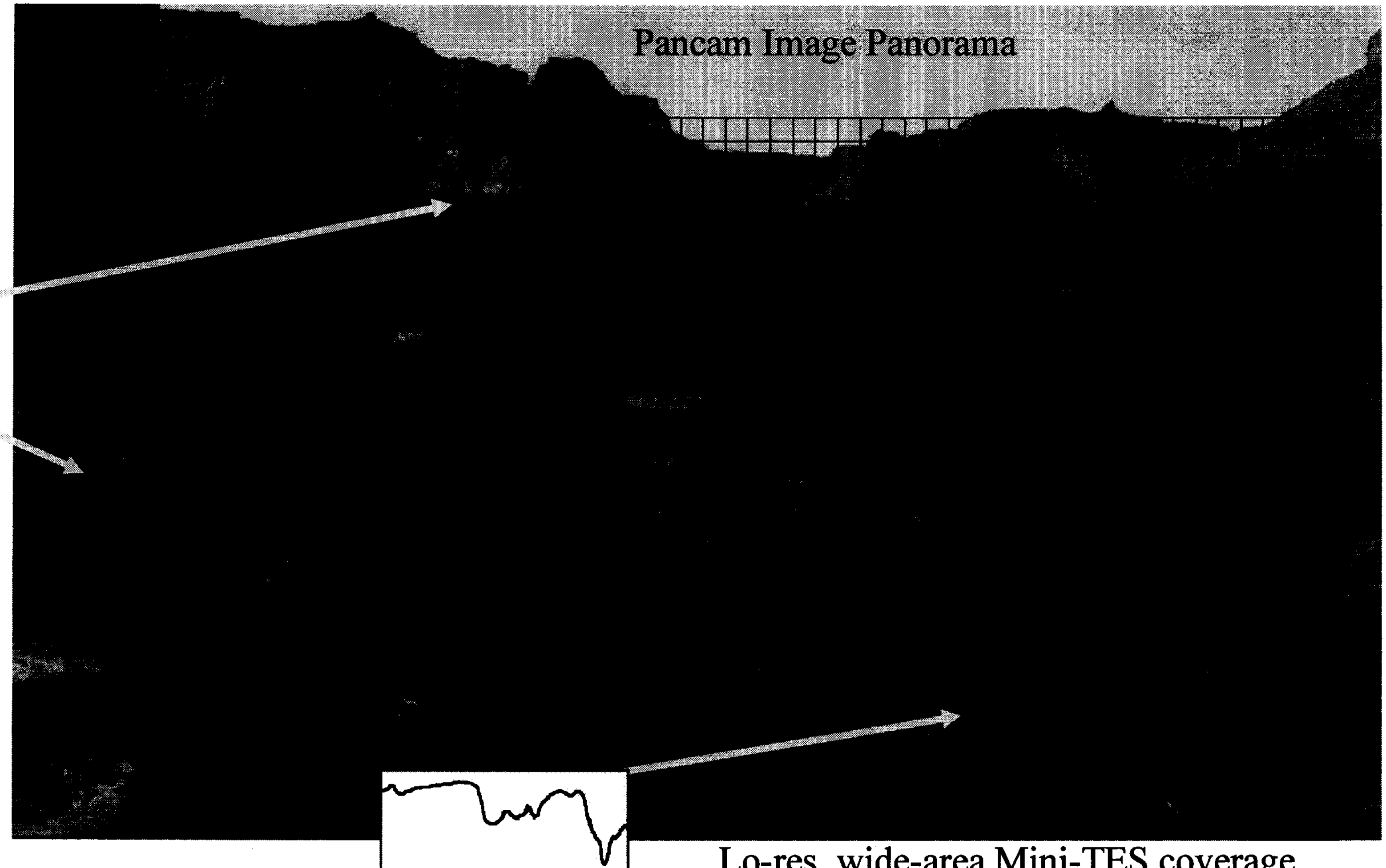






Using Pancam and Mini-TES Together

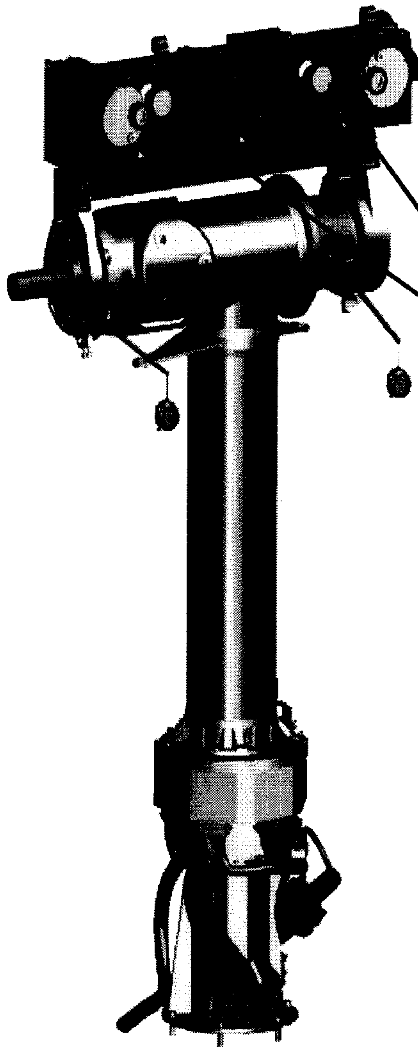
Hi-resolution, local Mini-TES coverage



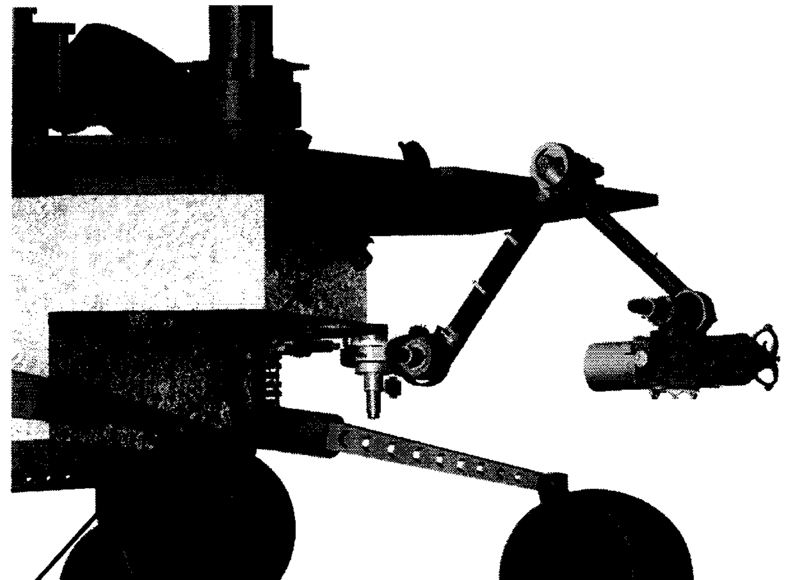
Full spectrum for each Mini-TES pixel

Lo-res, wide-area Mini-TES coverage

Engineering Cameras

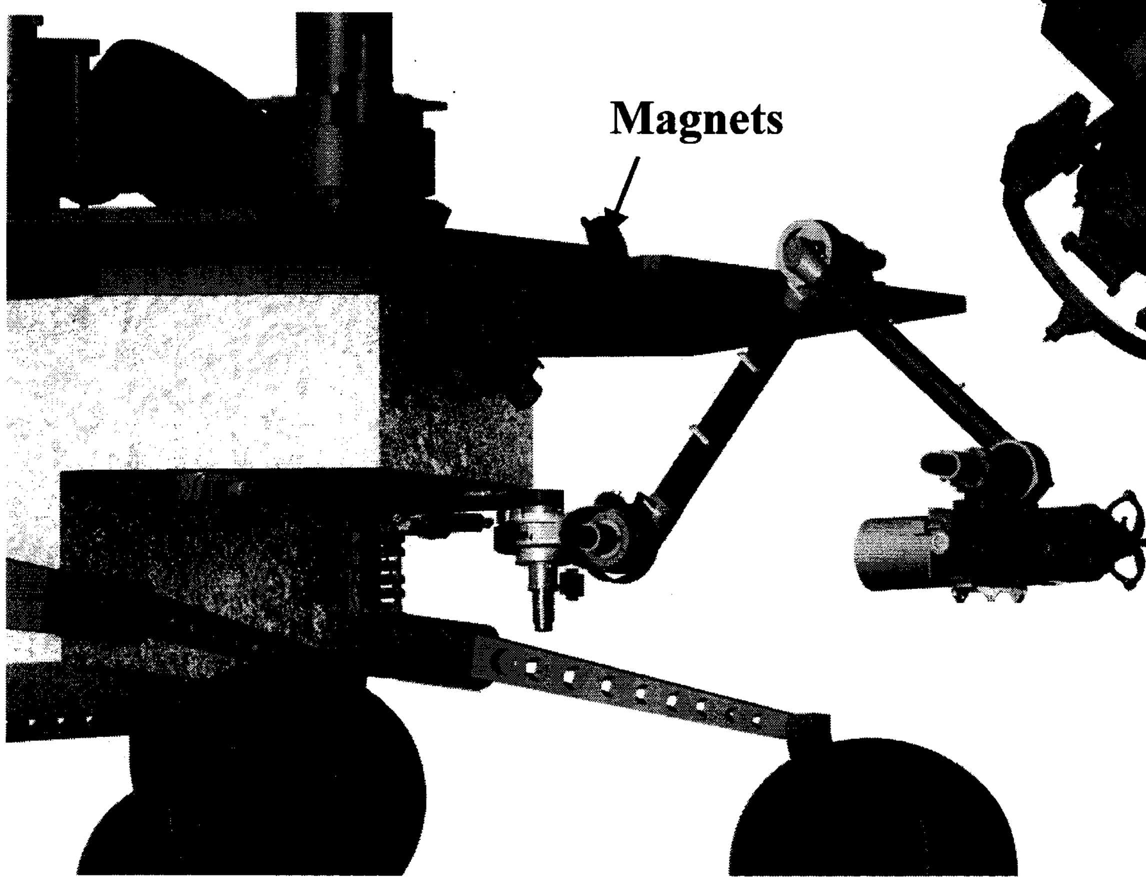


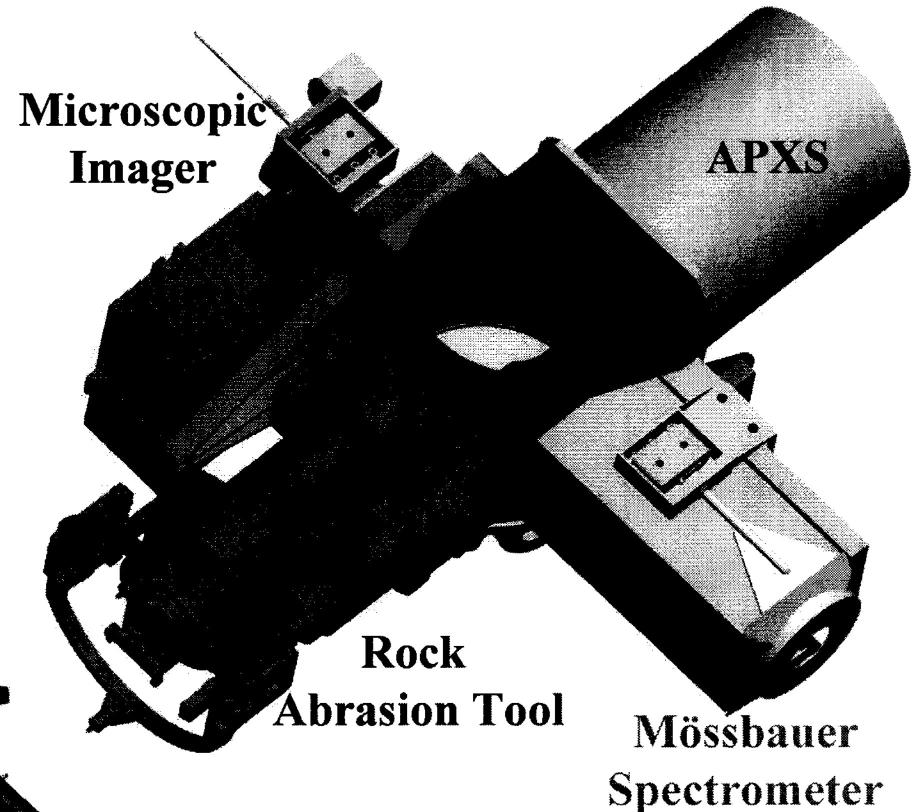
Navcam
stereo cameras
(45° x 45° FOV)

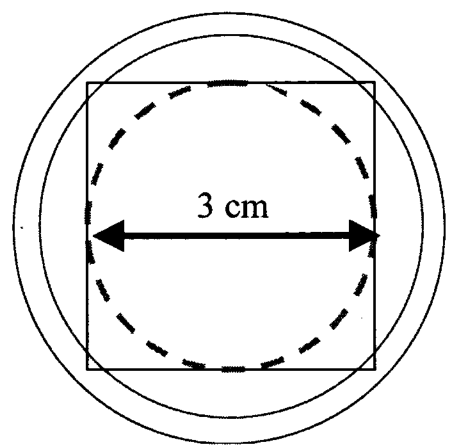


Front and Rear Hazcam
stereo cameras
(120° x 120° FOV)

In-Situ Science Payload

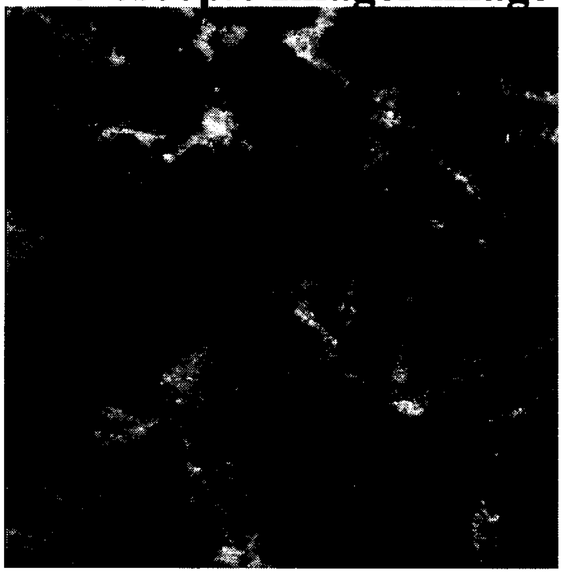


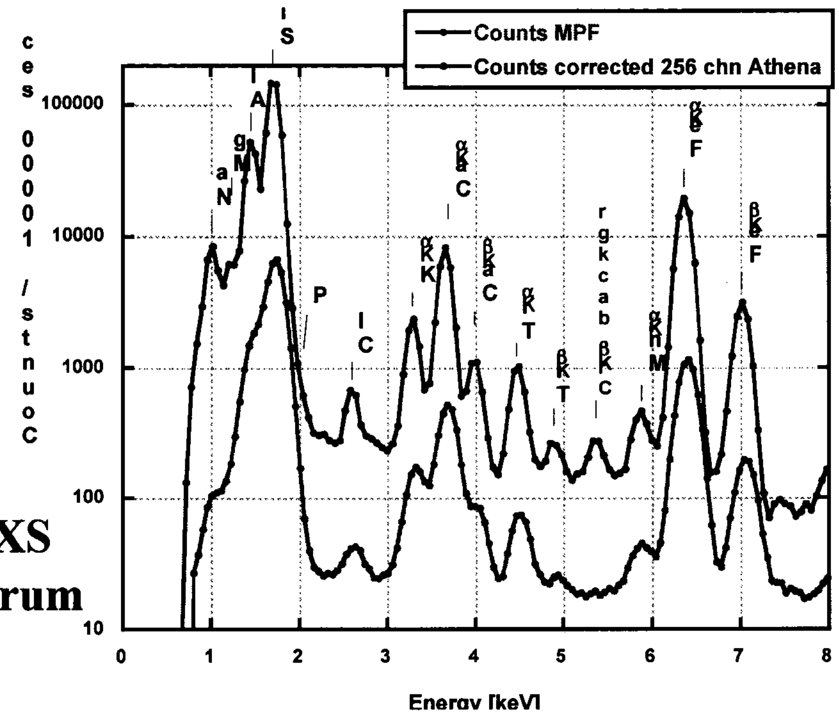




In-Situ Science Payload

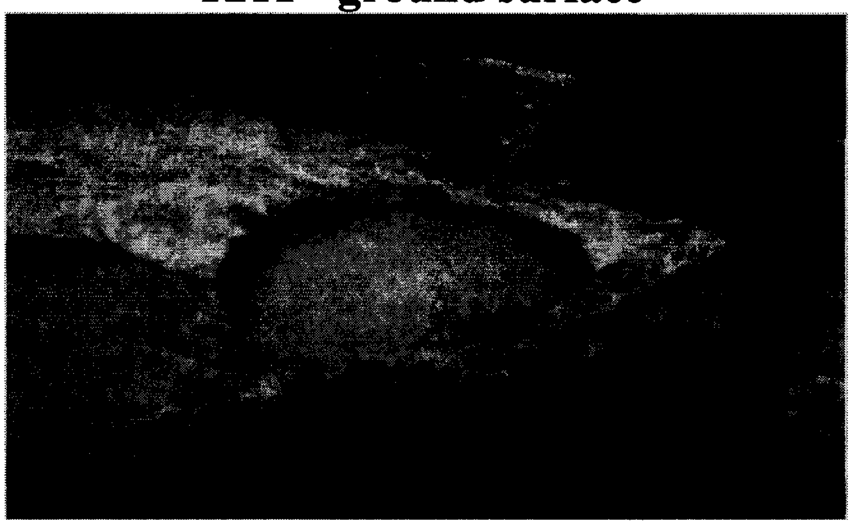
Microscopic Imager image



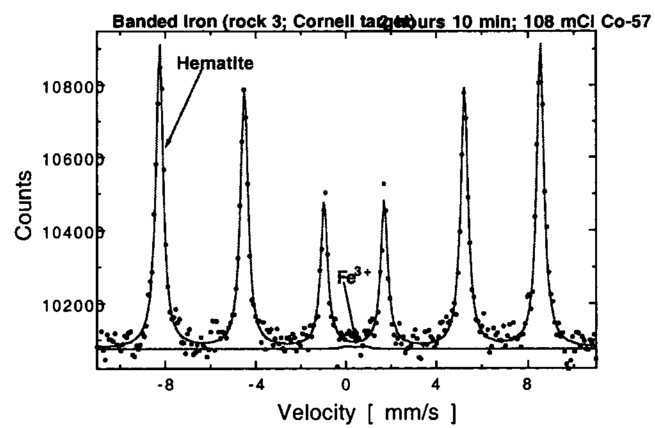


APXS spectrum

RAT– ground surface



Mössbauer Spectrum: hematite



4 Landing Site Candidates

Mars Exploration Rover "Firsts"

- Much greater mobility capability on the surface than we've had before
- First remote sensing spectrometer on the surface: A high spatial & spectral resolution mid-infrared panoramic spectrometer
- Stereo color panorama at 3x higher spatial resolution than ever before
- First look at mineralogy, texture, and composition of the interiors of rocks and comparison to their exteriors
- First "hand lens" on Mars: Examination of rocks and soils on Mars at 10x higher spatial resolution than ever before
- First unambiguous in-situ identification of Fe-bearing minerals (Mössbauer spectrometer)
- First high-quality elemental analysis (APXS)
- First in-situ ground-truth mineral identification
- First determination of mineralogy of the magnetic component of the airborne dust

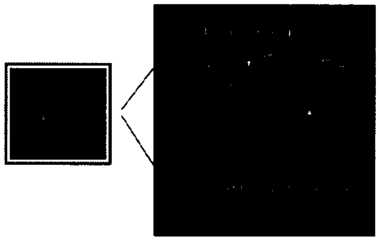
Jupiter Icy Moons Orbiter

Exploring the habitable water worlds of Jupiter

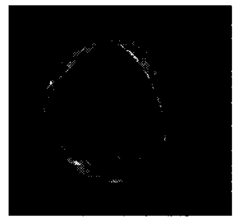
Water, Chemistry, Energy ⇨ Life(?)

Global Liquid Water Oceans

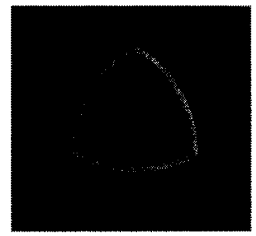
Europa



Ganymede



Callisto



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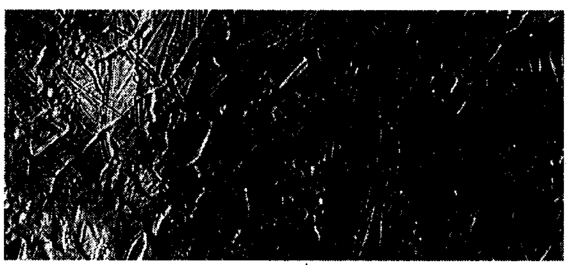
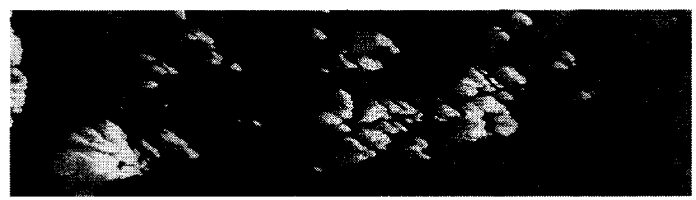
Geologically young surfaces with salts and organics





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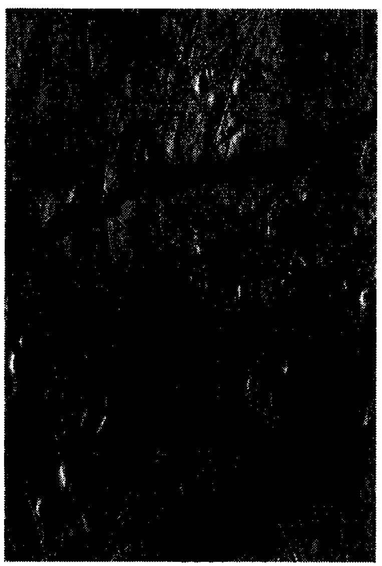
Radioactive and Tidal Heating => **LIFE ??**

JUPITER ICY MOONS ORBITER

Science Background



- Europa, Ganymede, and Callisto very likely have global liquid water oceans beneath their icy crusts.

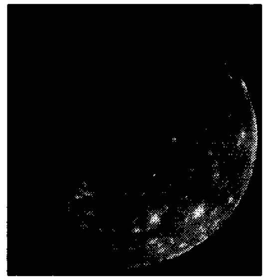
  ...one of the major discoveries in solar system science in the last decade.

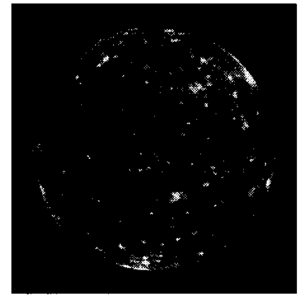
- There is spectral evidence for salts and organic materials on their surfaces, and geologic evidence that the Europan ocean may have been in contact with the surface in the geologically recent past (less than about 100 million years).

  ... these bodies are among the most exciting in the solar system for geophysical, geochemical and astrobiological exploration.

- Strongly responsive to the Nat'l Academy of Sciences priorities
  - Europa exploration was 1st priority flagship mission in Decadal Survey of solar system exploration
  - Decadal Survey also recommends studies of Ganymede and Callisto

Charting the Water Worlds of Jupiter





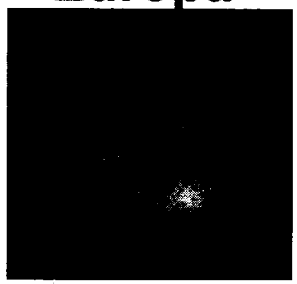
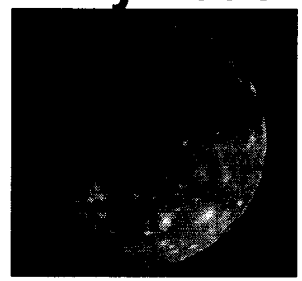
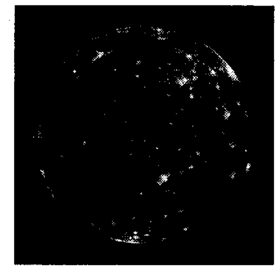
Completely new level of exploration not possible with chemical propulsion orbiters:
Full orbital characterization of all three icy moons with the same experiment complement

- Confirm the existence of oceans on multiple Jovian moons
- Characterize ice crust thickness and ocean depth
- Identify areas on Europa where the ocean has recently exchanged with the surface and/or where the ocean is most accessible beneath the surface
- Locate and characterize organic material and begin the astrobiology exploration of these moons, identifying regions of prime interest for future exploration.

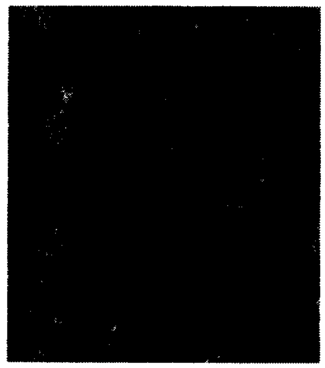
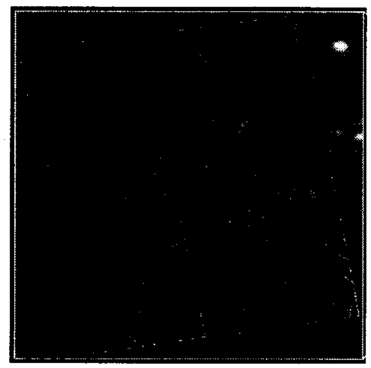
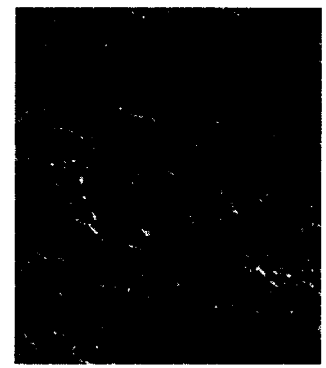
JOVIAN MOONS

Europa | Ganymede | Callisto

Resolution
Voyager:
~10 km Global

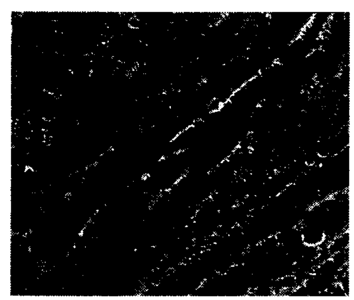




Galileo:
~100 m Regional

JIMO:
<10 m Global !!

(Galileo:
~10-20 m < 1%)


Space Propulsion & Power

- <u>Today (chemical propulsion & radioisotope power)</u>
  - Launch, then coast
  - Constricted ability to operate science instruments (power limits)
  - Constricted ability to transmit science data to Earth
  - Constricted launch opportunities (due to gravity assists)
  - Cannot orbit multiple moons of outer planets
    - Limited to fleeting observation from flyby
  - Cannot change target mid-mission

- <u>Future (nuclear electric propulsion)</u>
  - Much greater ability to change speed
  - Much greater (practically unlimited) power for instruments
  - Vastly greater ability to transmit science data to Earth
  - No launch constraint to use gravity assists
  - Can orbit multiple objects or moons
    - Vastly greater, persistent observation time
  - Can change target mid-mission (to support change in priorities)

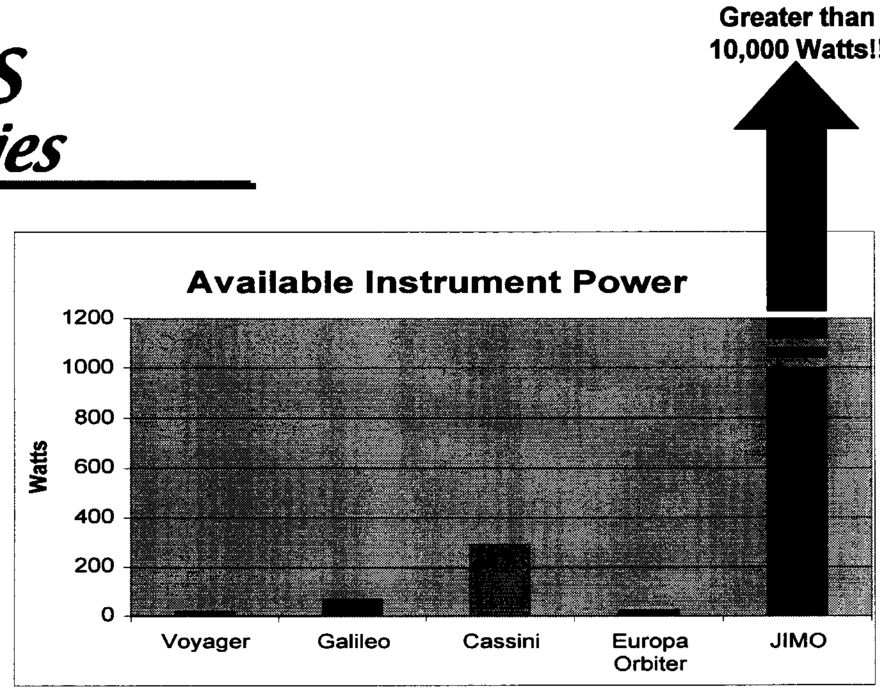
PROJECT PROMETHEUS
Revolutionary Capabilities

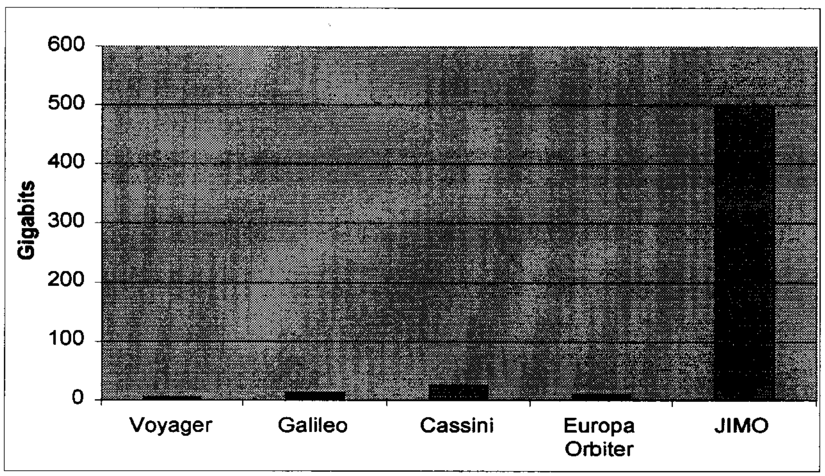
	Voyager	Galileo	Cassini	Jupiter Icy Moons Orbiter	Future Capabilities
On-Board Power Generation (watts)	480	570	875	~ 100,000	~ 250,000
Power for Science Instruments (watts)	< 100	< 100	290	> 10,000	> 10,000
Power for Communications (watts)	approx 70	approx 60	60	~ 1,000 to > 5,000	> 5,000
Rate of Data Communications (kbps)	115	134 (with HGA)	165	~ 10,000 to 100,000	~ 10,000 to 100,000
Total change in speed due to propulsion not including gravity assists (km / sec, from LEO after launch)	0	1.4	2	~ 40	50 to 70
Need interplanetary gravity assist ?	Yes	Yes	Yes	No	No
Orbit or Flyby ?	Flyby	Flyby (moon)	Flyby (moon)	Multi-moon orbit	Multi-moon orbit
Science Observation Time of Moons	~ 1 hours within 1000 km of moons	< 5 hours within 1000 km moon flybys	< 5 hours within 1000 km moon flybys	~ 7 months @ <1000 km orbits of icy moons. ~ 2.5 year tour of Jovian Moons	~ 6 months or more of continuous observations from orbit around each moon

Note: Time to reach an object in the Solar System depends upon the mass of the spacecraft, magnitude of thrust, duration of thrust, and launch vehicle.

PROJECT PROMETHEUS
Revolutionary Capabilities

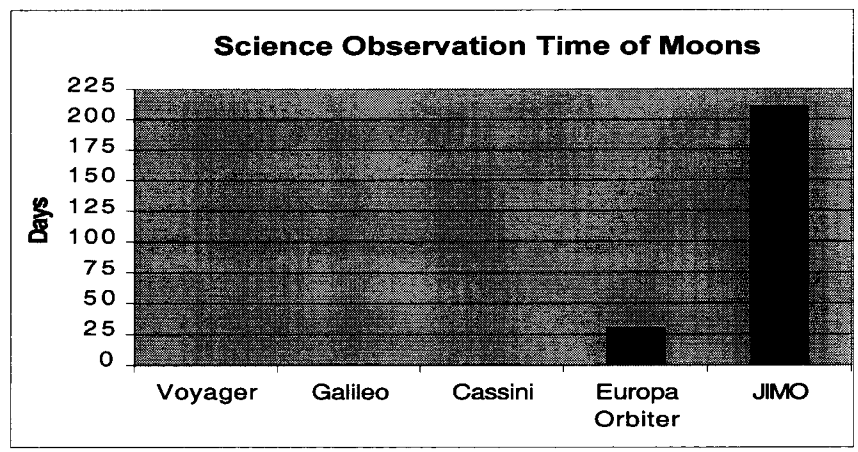
Amount of power available to science instruments
One bedside reading lamp compared to a stadium light



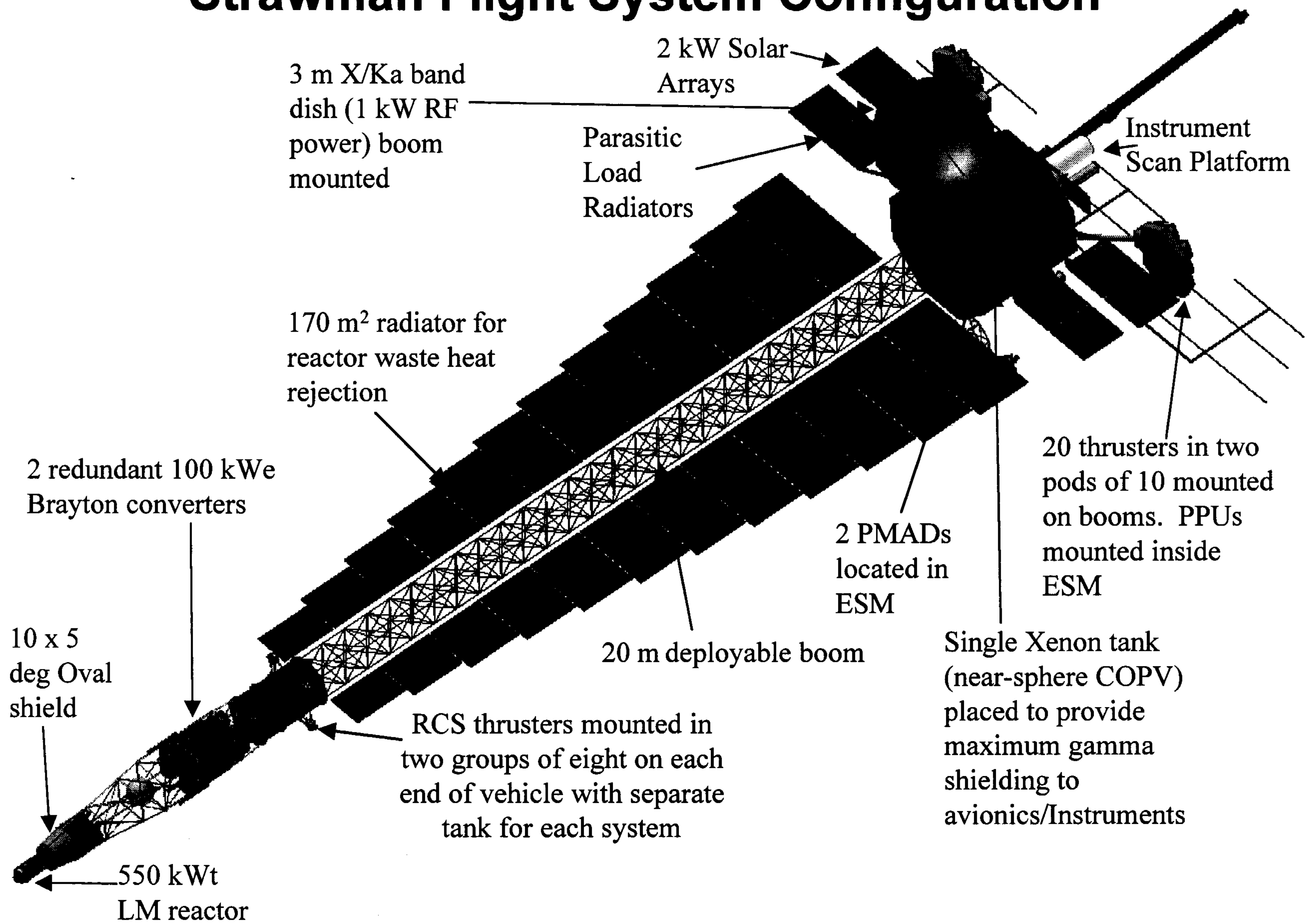


Amount of science data return
1 - 2 floppy disks as compared to 120 CD-ROMs

Time available for science observation of moons
1 to 5 hours compared to 180 days

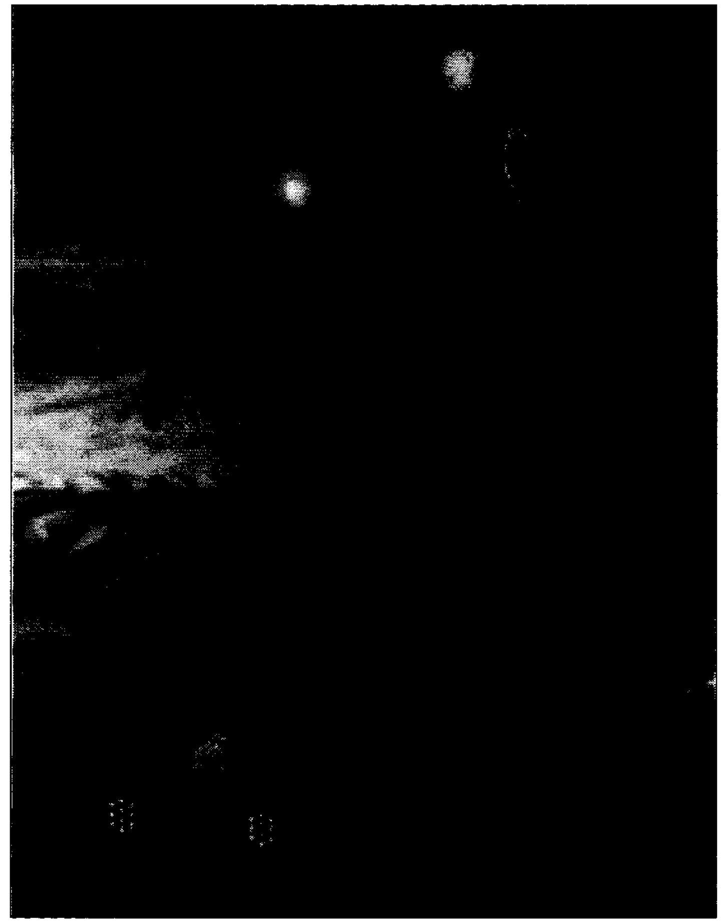


Strawman Flight System Configuration



Project Prometheus:
Jupiter Icy Moons Orbiter (JIMO)

- JIMO ~~will~~ would be the first flight mission to use nuclear power and propulsion technologies.
- JIMO ~~will~~ would search for evidence of global subsurface oceans on Jupiter's three icy moons: Europa, Ganymede, and Callisto.
- This mission ~~responds~~ would respond to the National Academy of Sciences' recommendation that a Europa orbiter mission be the number one priority for a flagship mission in Solar System exploration.



- This mission ~~will~~ would set the stage for the next phase of exploring Jupiter and will open the rest of the outer Solar System to detailed exploration.

Artist's concept