Spitzer Thermal Architecture

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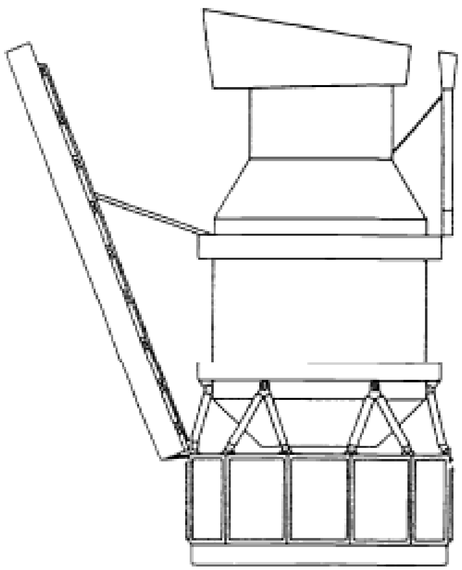
Spitzer History

Titan SIRTF



5500 kg

3800 liters LHe

M. Werner, 1993

1971-1983 Shuttle-IRTF

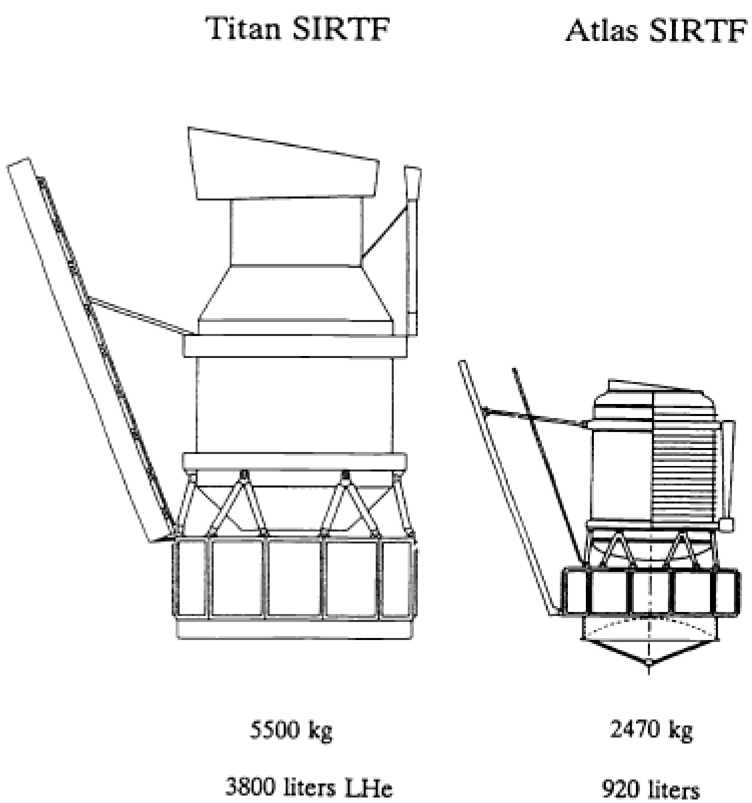
1978 Detector development begins

1983 Shuttle mission would be blinded by contamination

1989-1991 Gigantic and expensive Titan version in high earth orbit. JPL staff 50

1991 faster better and cheaper, Titan-SIRTF cancelled

Atlas launched mission in solar orbit



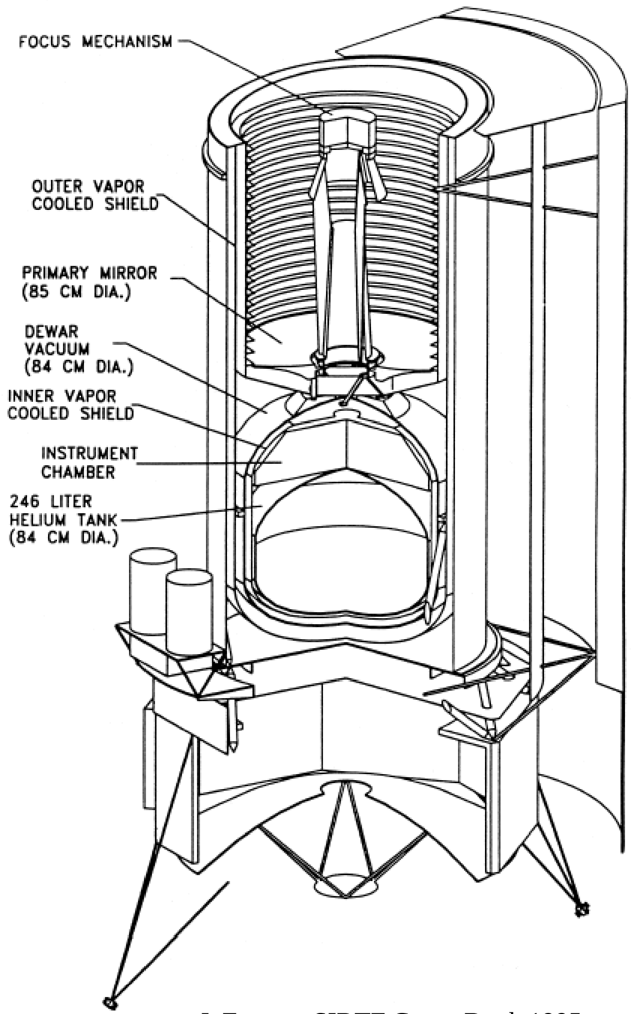
M. Werner, 1993

1992 Solar orbit (J. Kwok)

- Lower launch energy than HEO
- Reduced heat input to dewar
- Simpler propulsion system
- Simplified operations, no earth/moon avoidance
- Needs high gain antenna / DSN or optical communication
- Reduced mass: 5700 to 2500 kg
- Shorter lifetime: 60 to 36 months

Still not faster, better or cheaper enough

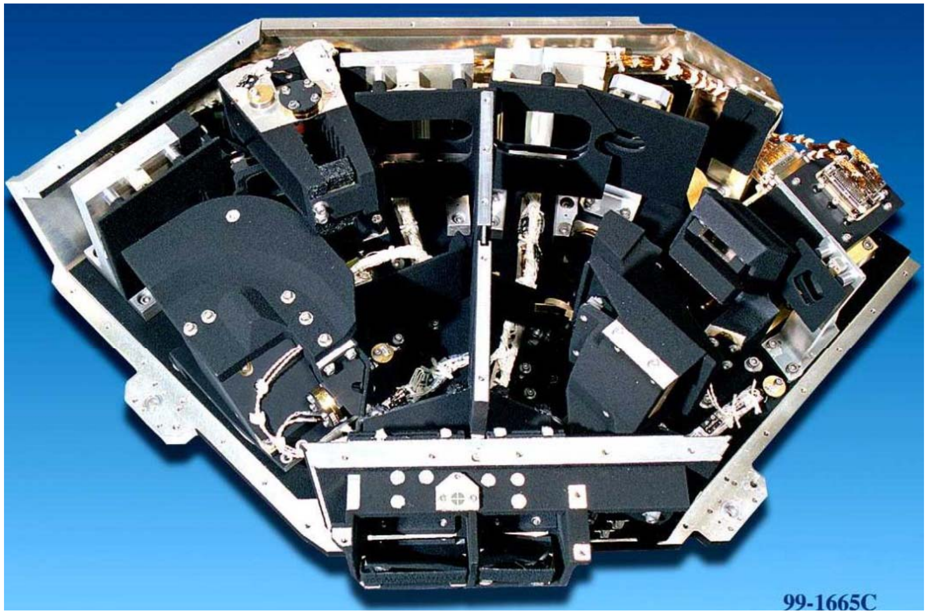
Delta-launched mission



J. Fanson, SIRTF Green Book 1995

- 1993-4 Delta launched mission
  - Reduced science requirements
  - Simpler instruments: bolt-together, no on-orbit adjustments, minimum mechanisms
- Warm-launched design (F. Low)
  - Lower mass, smaller vacuum vessel
  - Eliminates cold vibration of telescope
  - Requires vacuum valve in optical path
  - Requires stable alignment between instruments and telescope
  - Enabling technology for future missions
  - 2.5 year lifetime, 701 kg, $400M

Phase A Technology Development

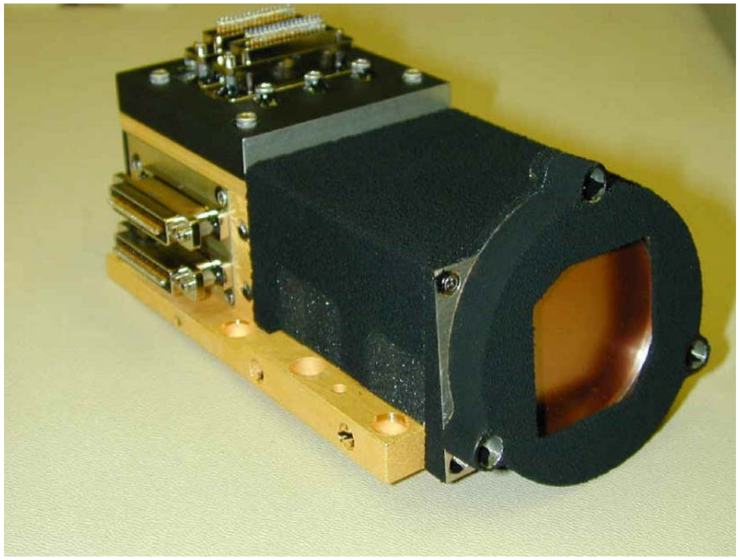


Excellent involvement from science PIs in instrument and mission development

- Science Working Group unchanged over 20+ years

Development of instrument/detector technology

- Began in 1978
- Established many design parameters early, including power dissipation

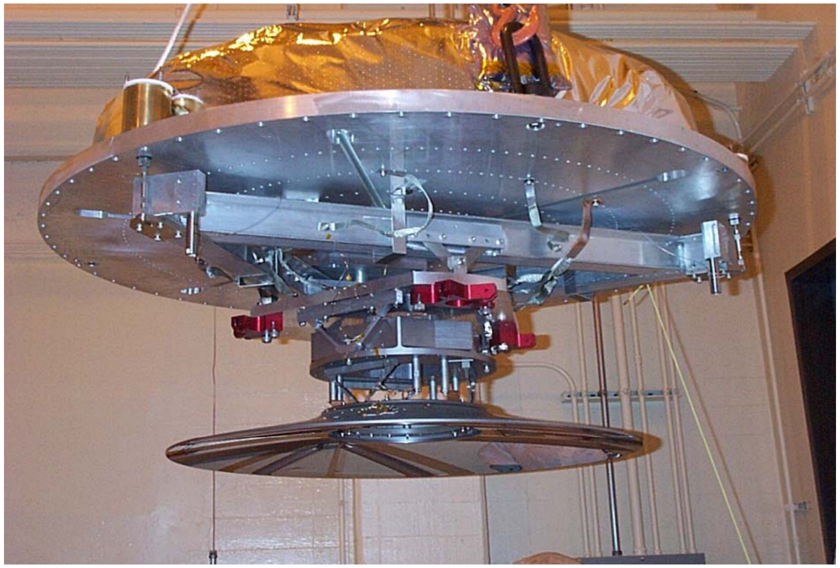


Photos from MIPS website, http://mips.as.arizona.edu/

Phase A Technology Development

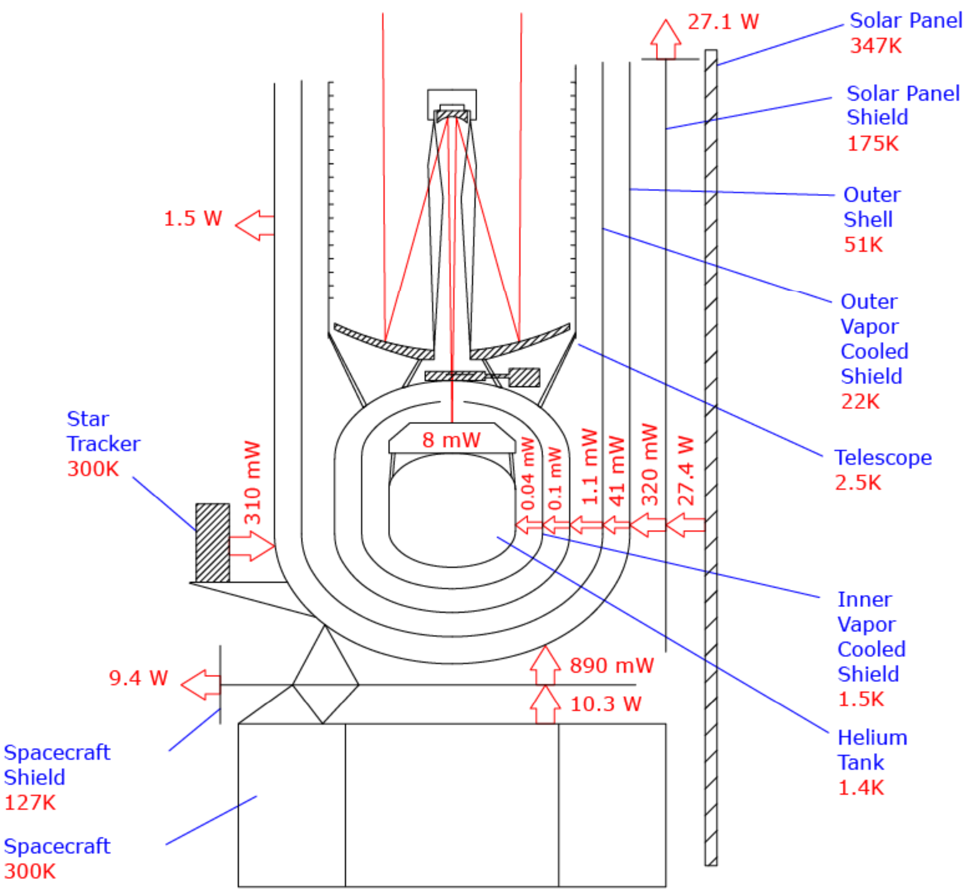
Telescope development program

- Light-weight beryllium telescope (HDOS)
- Cryogenic telescope test facility (JPL)
- Proved cryo-figuring of telescope
- Established telescope performance and mass



- Contamination control studies
- Wide dynamic range porous plug, (D. Petrac, A. Nakano)

Phase A Trade Studies



Phase A thermal model

Warm/Warm architecture

- Needs heat switch or fountain pump
- Eliminates aperture door
- Improved alignment stability
- Reduced mass

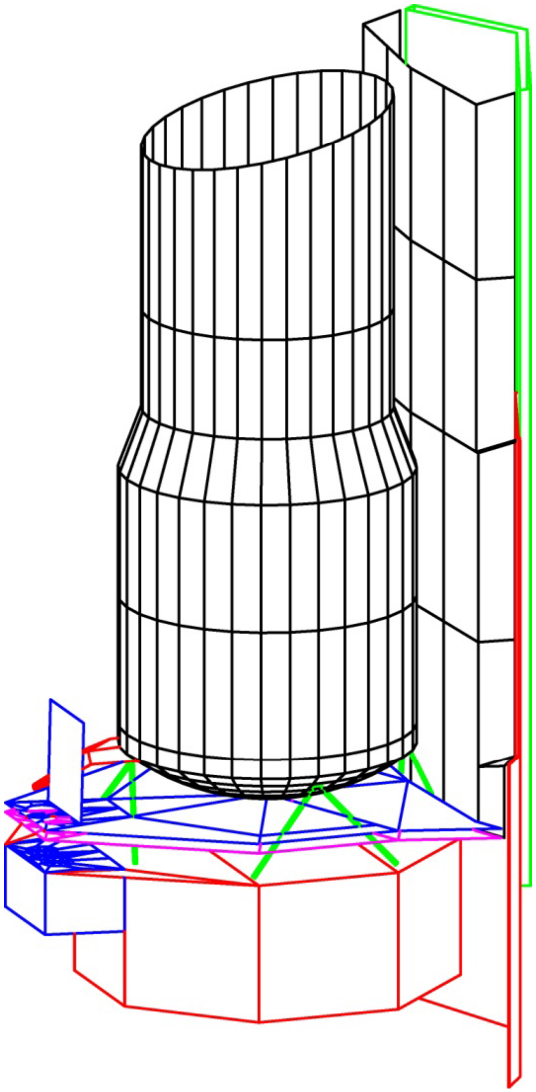
Combined spacecraft & bus and solar panel

- Reduced heat input
- Expensive, custom spacecraft bus
- Hard to fit into rocket fairing

Telescope/instrument subassembly testing

- Cost for long wavelength baffling was excessive

Phase B Development



Strong industry partnership

- Well defined thermal interfaces. Ball responsible for full cryogenic performance.
- Contractual incentives for thermal performance

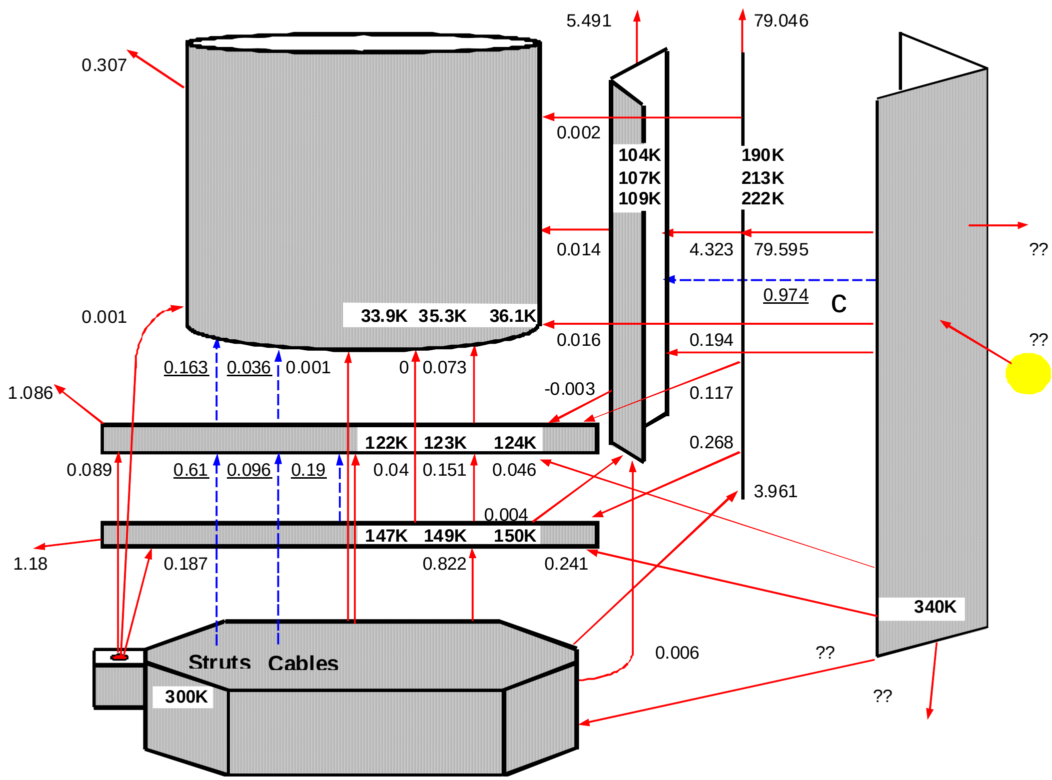
Margin approach

– 2.5 year lifetime with stacked worst case parameters

– Dewar allows trade between heat flow and lifetime

– Recognized thermal performance not testable

Phase B Development



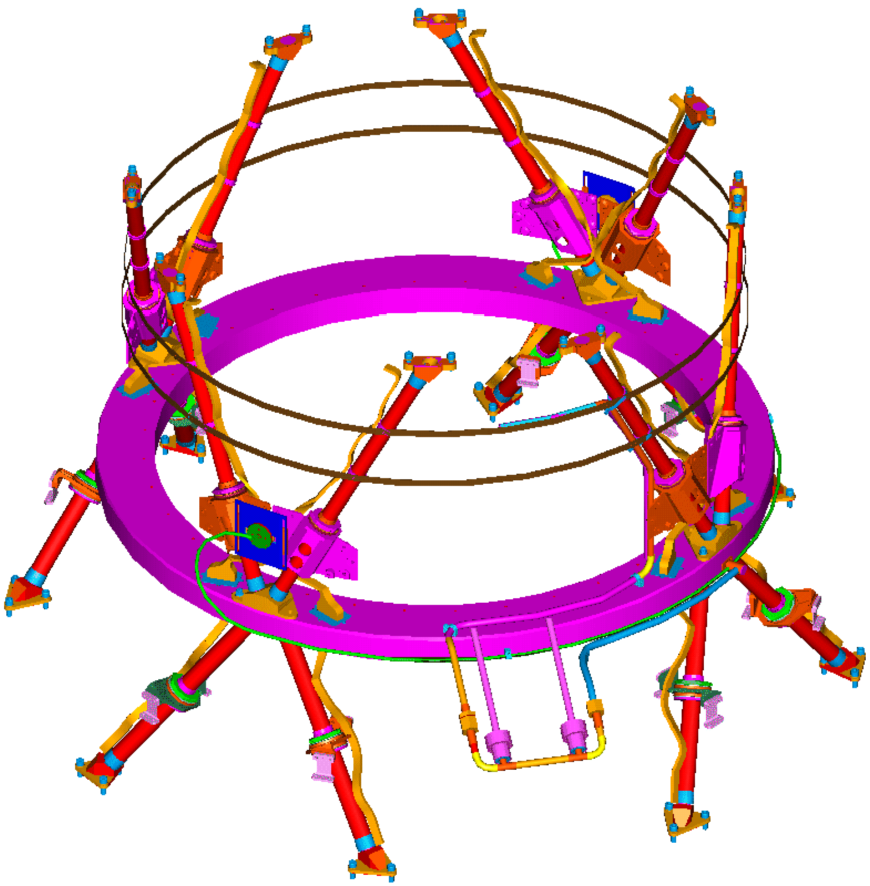
Cryogenic design

- Ball, Lockheed & JPL refine thermal design
- Low-e surface emissivity measurements
- Detailed design of all components
- Thermal/mechanical stability

Changes

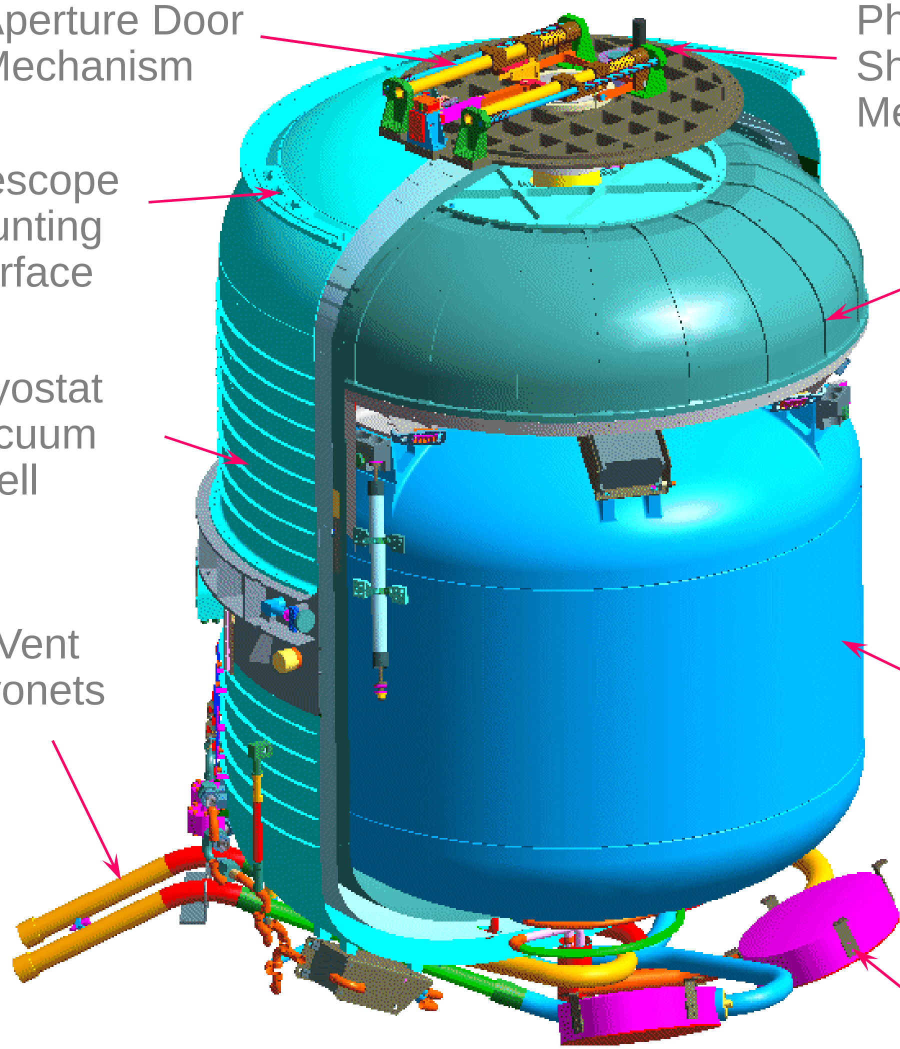
- Increased dewar volume to 360 l
- Star tracker moved beside SC bus
- Eliminated radiators on SC shield and top of SP shield
- Eliminated heat switch between the outer shell and telescope baffle
- Solar panel supported by SC only
- Predicted nominal 4.9 year lifetime, 35K outer shell temperature

Phase C/D Development



- Detailed thermal model – SINDA/TSS
- Study of “BIRB” black paint emissivity at low temperature (GSFC)
- Detailed design and test of gamma-alumina struts
- Ventline study, nozzle characterization & alignment
- Wide dynamic range porous plug detailed design. TAO study
- Pointing reference sensor development (Lockheed)
- Study use of make-up heater to control telescope temperature

Phase C/D Development

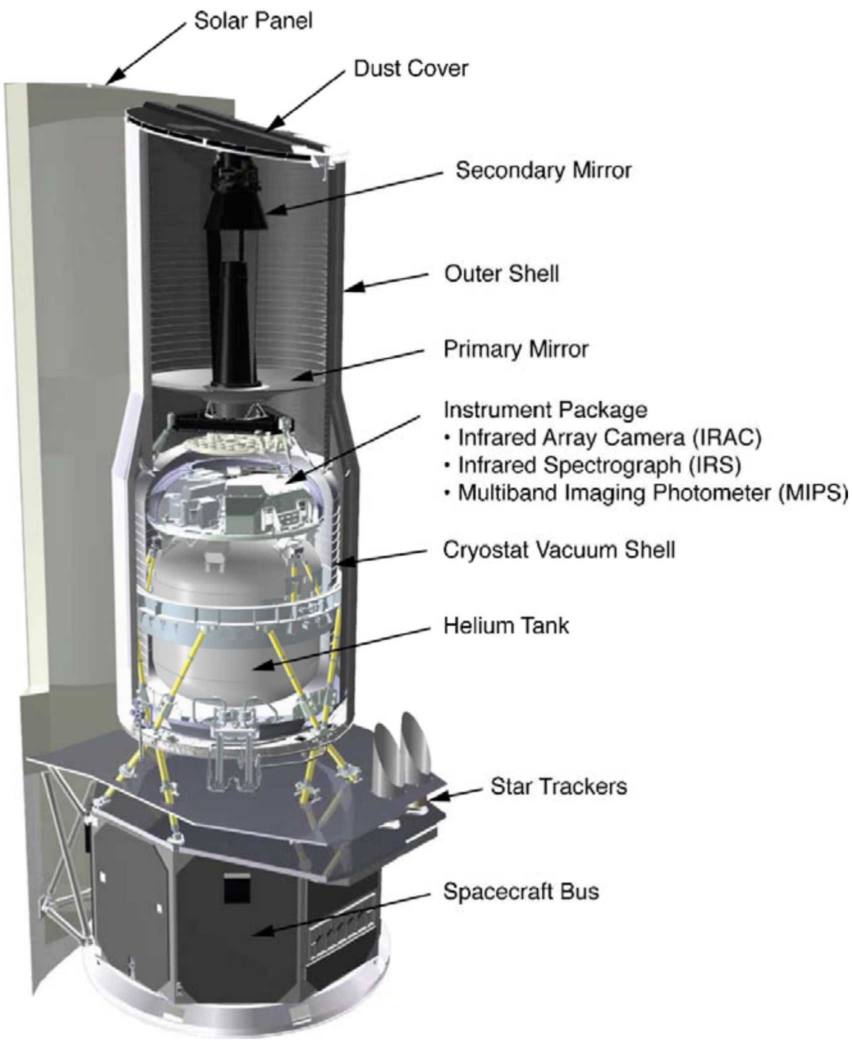


- Aperture door mechanism
- Photon shutter
- Focus mechanism
- Detailed study of mechanical/thermal stability
  - Telescope to instruments
  - Telescope to star tracker on spacecraft
  - Within spacecraft
- Eliminated isogrid machining of dewar

Verification and Validation

- Scale model testing abandoned early
- Helium shroud testing considered during phase B
- Brutus test with outer shell cooled to verify optics and detectors (except MIPS)
  - Significant unexplained stray heat loads to telescope and dewar
- Observatory level test in 77K shroud
  - Only verified warmest shields
- No verification of last layer of thermal shields around observatory
- Test data plus worst-case modeling predicted 2.5 year lifetime

Flight Performance



Thermal performance close to prediction

- SP shield 25K high
- Parasitic heat flow < 1mW
- Mass gauging predicted 60+ month lifetime

Anomalies and problems

- Radiation coupling to black strip on solar panel shield radiator edge
- 1 cryo-ribbon cable/connector failure out of 140 before launch
- Spare primary mirror damaged during build.

Conclusion and Future Missions

- About 20 years of science and mission concept development before phase A
- Faster, better, cheaper approach forced Spitzer to simplified instruments, solar orbit and warm-launch architecture
- Large lifetime margin permitted launch with limited verification of thermal performance
- Spitzer had a well-funded technology development program ($65M RY Phase A-B) yet still had considerable technical and financial problems during implementation
  - Early technology development reduced overall mission cost
  - Competed missions with significant technology development during implementation will not easily maintain schedule or control costs
  - Internal R&D funding is insufficient to develop mission-specific technologies for smaller missions