Space Interferometry Mission Overview

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SIM
Space Interferometry Mission
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Outline

- SIM project
- Planet Detection
- Astrometry
- Architecture
- Status
- Technology plan
- Major testbeds

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Project Background

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- The foundation of SIM science objectives is tied to the 1991 National Research Council astrophysics decadal report chaired by Bahcall.
  - "Astrometry which is concerned with the measurements of the celestial sources ranks among the oldest and most fundamental branches of astronomy and now is on the verge of a technological revolution".
  - The Bahcall report recommended an Astrometric Interferometry Mission (AIM) as a high priority mission for the '90s with the following attributes:
    - "Measure positions of widely separated objects to a visual magnitude of 20 with precision of 30 micro arcseconds [μas];...a more challenging goal would be 3 micro arcseconds.
    - "...search for planets around stars as far away as 500-light years (150pc)
    - "...trigonometric determination of distances throughout the galaxy
    - "AIM would demonstrate the technology required for future interferometry missions."
- SIM re-confirmed in the 2000 NRC decadal report co-chaired by McKee and Taylor:
  - Strongly suggested a 10 μas maximum for Wide angle astrometry (rather than the 30 μas in the Bachall report).

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- **Salient Features**
- 3 parallel Michelson Stellar Interferometers
- 10 meter baseline
- Visible wavelength
- Launch Vehicle: Atlas V or Delta IV ELV
- Earth-trailing solar orbit
- 5 year mission life with 10 year goal
- SIM is a JPL, Caltech, Lockheed Martin, KSC, NGST, and SIM Science Team partnership

Science Goals

- Perform a search for other planetary systems by surveying 2000 nearby stars for astrometric signatures of planetary companions.
- Survey a sample of 200 nearby stars for orbiting planets down to terrestrial-type masses.
- Improve best current catalog of star positions by >100x and extend to fainter stars to allow extension of stellar knowledge to include our entire galaxy.
- Study dynamics and evolution of stars and star clusters in our galaxy to understand how our galaxy was formed and how it will evolve.
- Calibrate luminosities of important stars and cosmological distance indicators to improve our understanding of stellar processes and to measure precise distance in the distant universe.

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Planet Detection

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- SIM astrometry complements other indirect methods of planet detection:
  - Determines the parameters of the orbit of a planet.
  - Determines mass, the most fundamental parameter of a planet.
- Focus on ~250 stars like the Sun (F, G, K) within 10 pc.
  - Sensitivity limit of ~3 M_{Earth} at 10 pc requires 1 μas accuracy.
  - Is more sensitive than Radial Velocity (3 vs 30 M_{Earth}) with no sin(inclination) ambiguity.
- SIM will determine the architecture of solar systems, telling us whether our solar system is rare or common.
  - Are planetary systems like our own common?
  - What is the distribution of planetary masses?
  - Are there low-mass planets in 'habitable zone' ?
- SIM will also sample 2000 stars within ~25 pc at 4 μas accuracy.
- SIM targets stars within 25 pc that are suitable for follow-up by TPF.

SIM Complements and Paves the Way for TPF

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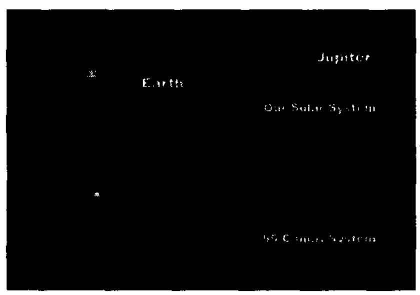
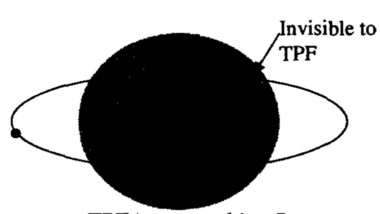
- SIM will tell TPF what stars are likely to be hospitable to terrestrial planets.

  Presence of Jovian planets in the wrong orbits will preclude stable orbits in the habitable zone.
- SIM's orbital information will determine when planets in eccentric/inclined orbits will be at an elongation suitable for direct detection.
- Combination of SIM masses with TPF spectroscopy of hundreds of planets will lead to new era in comparative planetology.

  For stars where SIM doesn't detect a planet, and subsequently, TPF does detect a planet, SIM archival data can determine or constrain the mass of that planet with ~0.5 Earth mass accuracy.

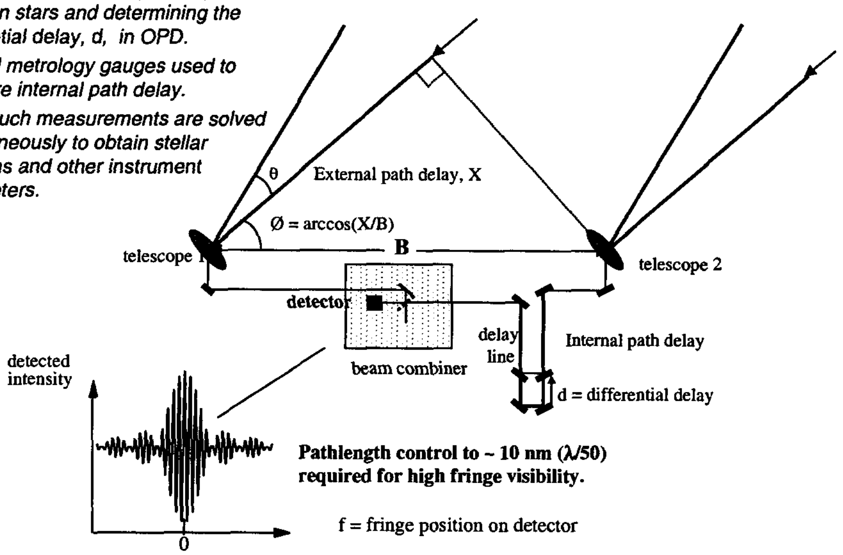




TPF inner working R

Measurements with SIM (Interferometer Sensor)

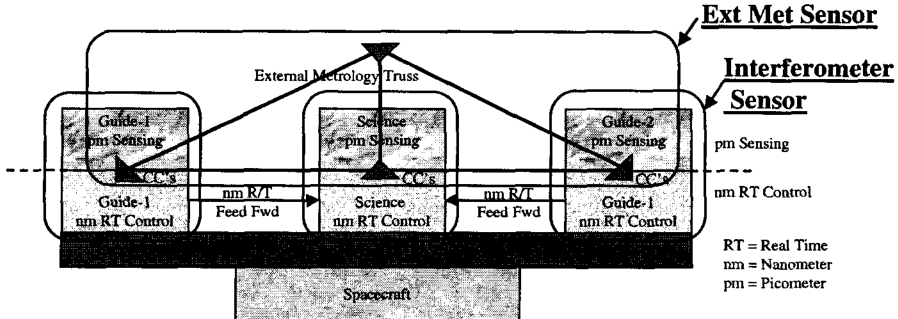
- *Measurements made by "chopping" between stars and determining the differential delay, d, in OPD.*
- *Internal metrology gauges used to measure internal path delay.*
- *Many such measurements are solved simultaneously to obtain stellar positions and other instrument parameters.*



- The peak of the interference pattern occurs at zero OPD to star

SIM Building Blocks

- SIM operates in two distinct regimes: (1) real-time nanometer control and (2) picometer sensing
  - Real-time nanometer control is system-wide and does not depend upon picometer sensing (nm-level external metrology information is used in real-time control)
  - Picometer sensing runs on top of real-time nanometer control (i.e., picometer measurements are taken while the system is operating in the real-time nanometer control), with all data being sent to the ground for mission processing
- Interferometer and external-metrology picometer-sensors are separable and intersect only at fiducials (substantiated at SIMTACs -28 and -29)



SIM Instrument Configuration

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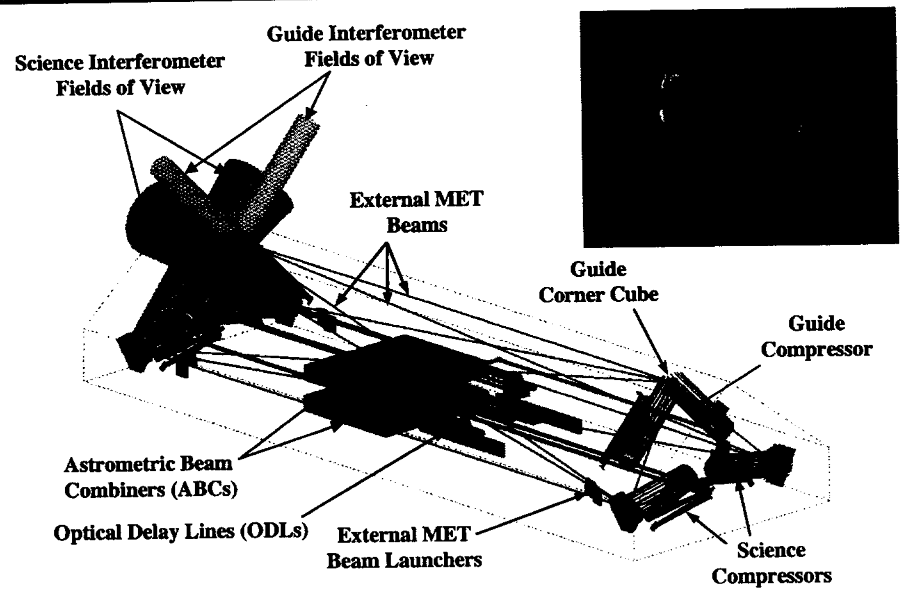

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Flight System Architecture (1)

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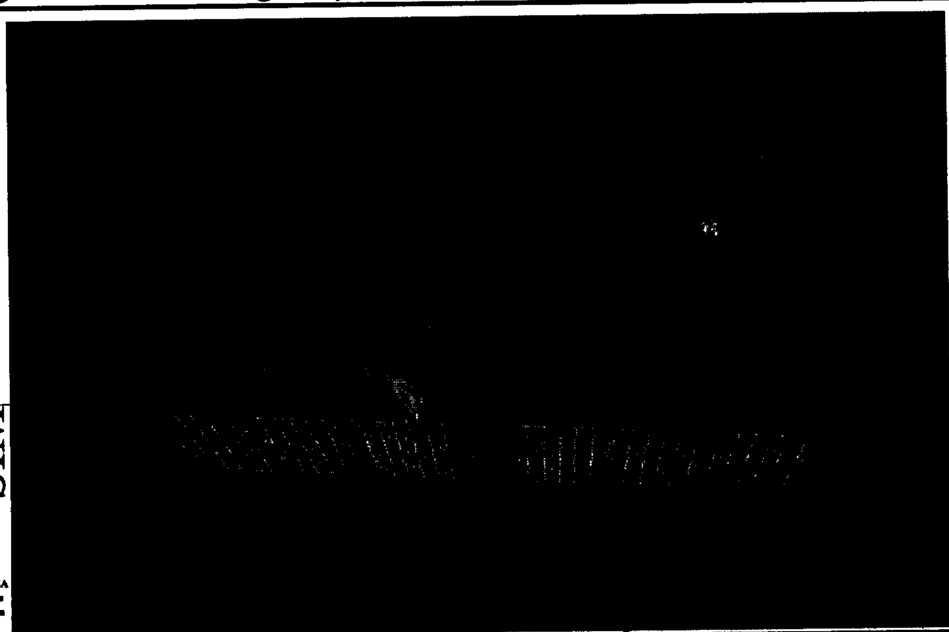

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Flight System Architecture (2)

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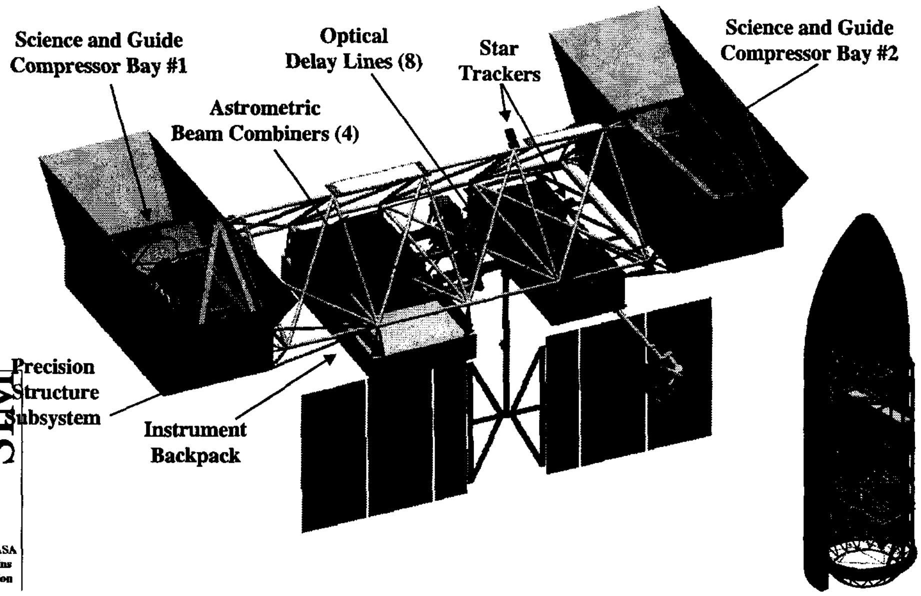

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Mission Status

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- NASA Project Development Phases
  - Pre-Phase A: Advanced Concept Studies
  - Formulation:
    - Phase A: Mission Requirements Definition
    - Phase B: Preliminary Design
  - Implementation:
    - Phase C: Design & Development
    - Phase D: Integration & Test
      - Begins with "...the start of I&T of the full up system..."
    - Phase E: Mission Operations
- SIM has just recently passed through the NASA development Phase A to B gate
  - A very significant milestone that we've been working towards for over two decades (with just under six of the last years of that time being in Phase A).
  - We are actively preparing for the System Requirement Review in November.

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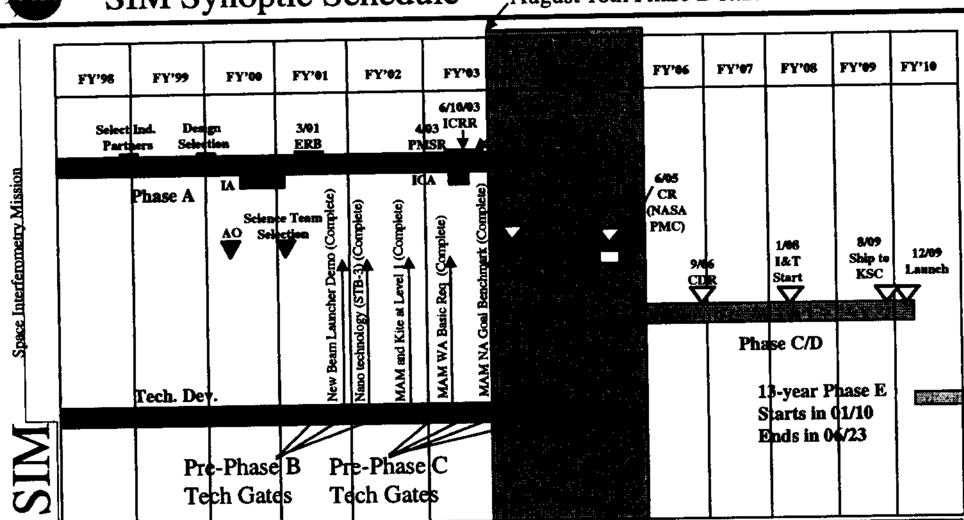
SIM Synoptic Schedule



ATLO = Assy, Test & Launch Ops ERB = External Review Board PMSR = Preliminary Mission & Systems Review SRR = System Requirements Review
CA = Confirmation Assessment IA = Independent Assessment NAR = Non Advocate Review ICRR = Initial Confirmation Readiness Review (JPL GPMC)
CDR = Critical Design Review I&T = Integration & Test PDR = Preliminary Design Review ICR = Initial Confirmation Review (Code S EPMC)
CR = Confirmation Review (NASA PMC) NASA PMC = Programmatic Management Council

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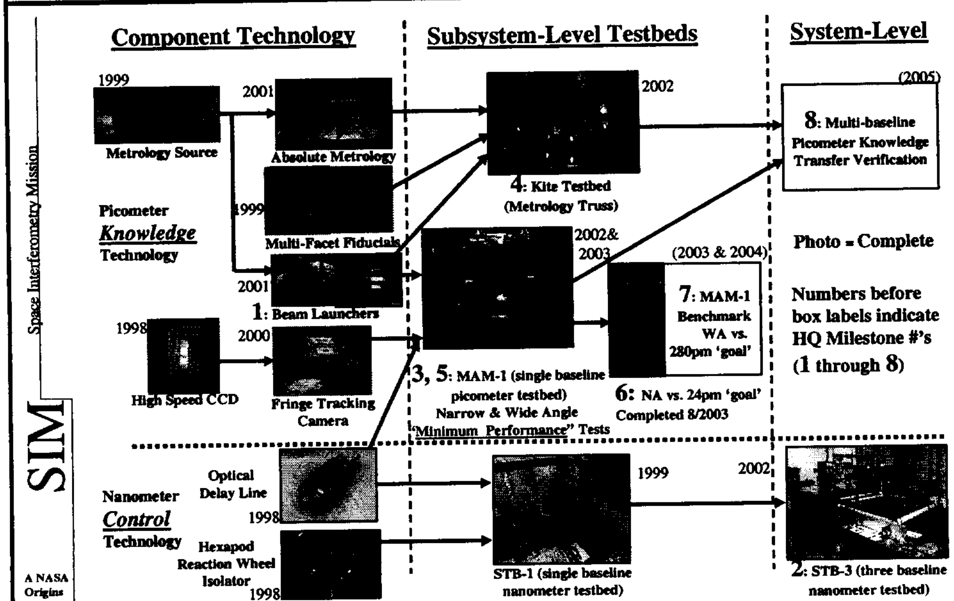
Technology Development Diagram



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MAM testbed (Science/Guide interferometer)

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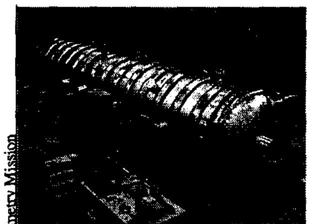
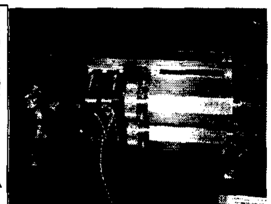
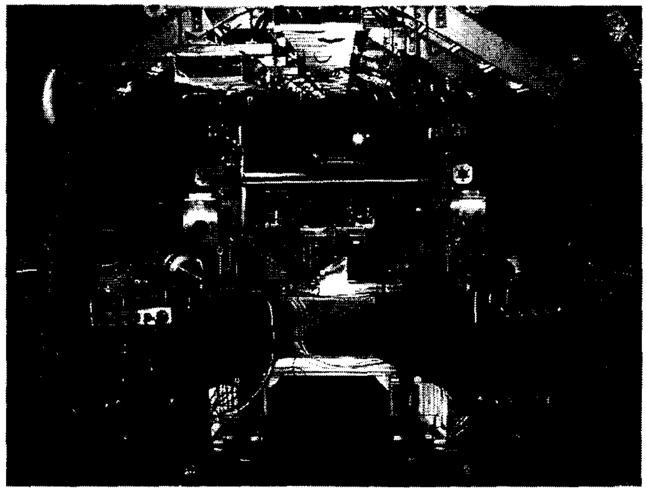


MAM Vacuum Chamber

Internal Metrology
Beam Launcher





- 24 picometers agreement between internal metrology and white light fringes in the Narrow Angle field of view.
- 280 picometers agreement in the Wide Angle field of view.

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Kite testbed (external metrology truss)

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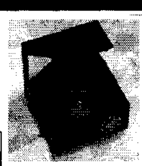
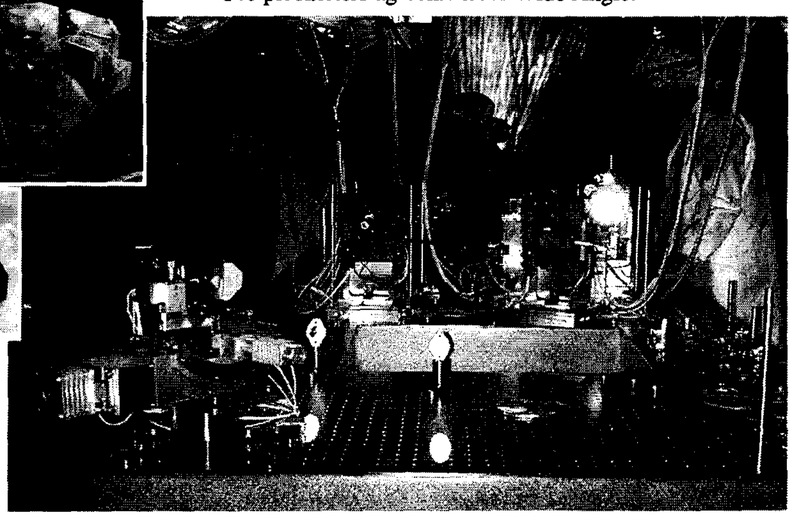
External Metrology
Beam Launcher

- 8 picometers per metrology gauge agreement within the truss in the Narrow Angle field of view.
- 140 picometers agreement for Wide Angle.



Triple
Corner
Cube



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System Testbed 3 (Dynamics and Control)

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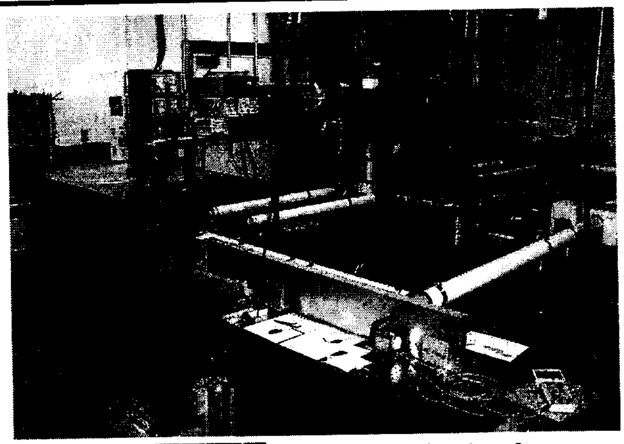
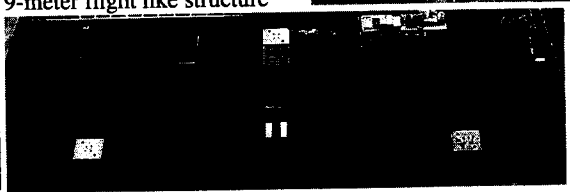
- Pathlength Feed-Forward demonstration:
- Pathlength stabilization of the science interferometer fringes to 30 nanometers rms open loop, using only the guide interferometers.
- 80 dB rejection of the spacecraft attitude.



3 baseline interferometer

9-meter flight like structure



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Flight System I&T Flow

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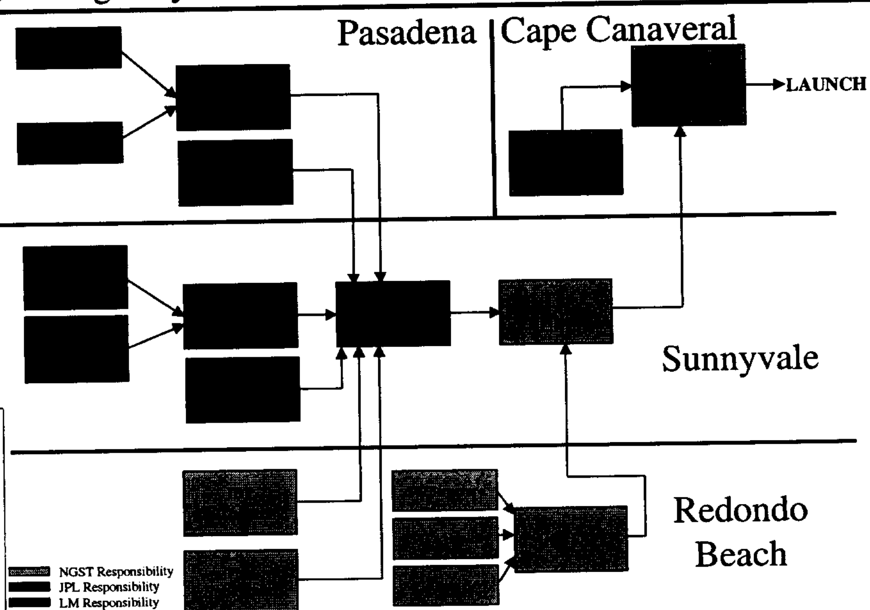

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Conclusion

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- SIM will observe about 250 stars like the Sun within 10 pc to detect the presence of planets down to 3 Earth masses at 10 pc.
- SIM will tell TPF what stars are likely to be hospitable to terrestrial planets.
- SIM's orbital information will determine when planets in eccentric/inclined orbits will be at an elongation suitable for direct detection.
- SIM technology development is quite mature.
- SIM has a stable design for the flight system.
- SIM just entered phase B.
- Scheduled launch is December 2009.

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