



Terrestrial Planet Finder (TPF) Update

Charles Beichman
Pre-Project Scientist

and

Dan Coulter
Pre-Project Manager

July 12, 2001

Recent Highlights

- Completed successful 1st Phase of the TPF Architecture Study Contracts with the Preliminary Architecture Review (12/00)
 - Continue to investigate IR interferometer design
 - New deformable mirror technologies may make visible coronagraphs/apodized telescopes a plausible architecture
 - Several other potentially viable architectures identified
- Significant progress on IR nulling building on earlier SIM work in the visible
 - Successfully operated the University of Arizona's BLINC IR nulling camera on the new MMT (8/00)
 - Assembled and achieved first light on mid-IR nulling testbed at JPL (2/01)
- Initiated high contrast imaging technology development (3/01)
- Publishing White paper on biomarkers for visible-mid IR (6/01)

Recent TPF Science Activities

- Two SWG meetings (9/00, 12/00)
 - Developed architecture neutral TPF Design Reference Program
 - Developing white paper led by TPF astrobiologists to identify biomarkers in the visible, near IR and mid IR spectral regions
- Supported international aspects of TPF
 - IACG task force investigating possible international collaboration
 - TPF and Darwin share science team members
 - Added team member from Japan
- Major presence at January AAS meeting in San Diego
 - 13 technical papers on TPF
 - Standing Room only evening session to discuss TPF science and mission concepts
- Major presence at June AAS meeting in Pasadena
 - All day session on interferometry
 - Many TPF related papers
- Numerous popular articles, webcasts, and interviews on TPF

The logo for the Terrestrial Planet Finder (TPF) mission, featuring the letters 'TPF' in a large, bold, serif font. Below the letters is a stylized illustration of a space telescope with a large primary mirror and a secondary mirror, mounted on a complex structure.



TPF Architecture Studies- Phase 1

- The first phase of the TPF Pre-Phase A Architectures Studies was completed in December, 2000, with the Preliminary Architecture Review (PAR) held in San Diego, CA
- Four industry/academia teams reported results to TPF Management, TPF-SWG and NASA HQ Personnel
 - Teams evaluated ~30 concepts to perform the TPF science
 - IR nulling interferometers
 - Visible coronagraphs/apodized telescopes
 - Out of the box concepts
 - Possible Pathfinders for science and technology
 - SWG Recommendations for Phase 2 study
 - Careful study of IR nulling interferometers and visible coronagraphs/apodized telescopes required
 - Study of hyper-telescopes, IR coronagraphs, Fresnel coronagraph and free-flying occulter desirable
 - Pathfinder options should be carefully considered

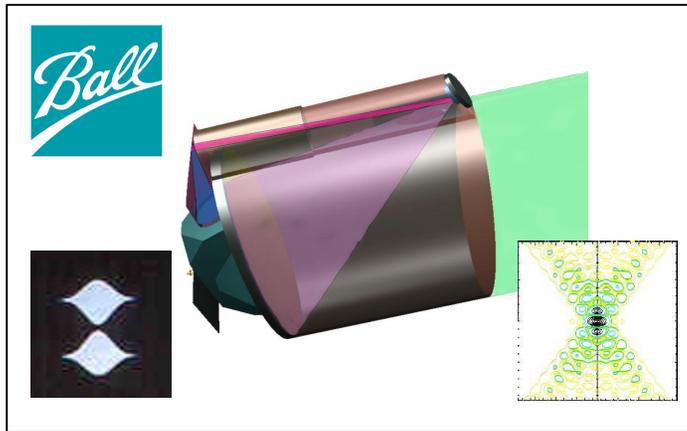
TPF Architecture Studies- Phase 2

- Original plan called for each team to study two architecture options in Phase 2- one of their choice and one chosen by JPL
- Budget reductions (50%) required descope of the studies
 - Each team funded to study one concept in detail
 - Several teams are studying additional concepts at a low level or to a greater extent under their internal funding
 - Final Review in November, 2001
- Phase 2 studies over remainder of this year
 - Major system trades between competing design concepts
 - Technology development approaches and roadmap
 - The efficacy of TPF precursor missions
 - Next level refinement of the programmatic issues
 - Cost, cost profile
 - I&T issues and identification of any required special facilities
 - Launch strategy
 - Schedule related issues
 - Recommendations on acquisition and international partnering strategies



TPF Architecture Concepts

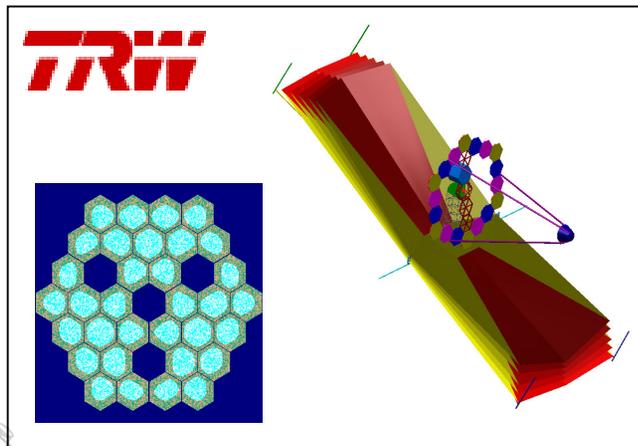
Terrestrial Planet Finder



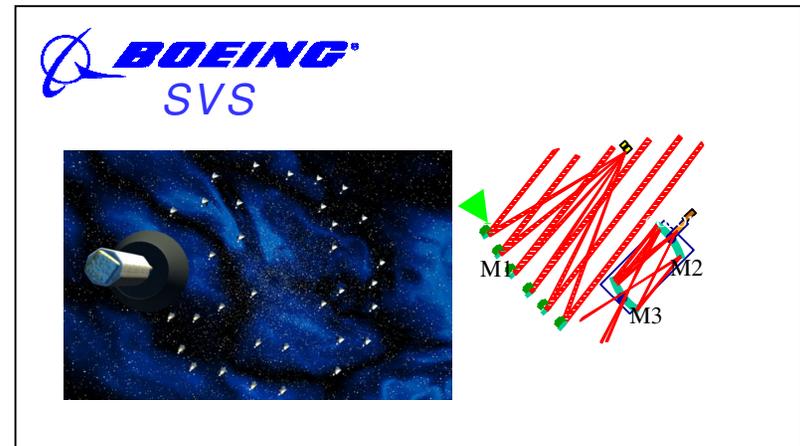
Variable-Pupil Coronagraph



IR Nulling Interferometers

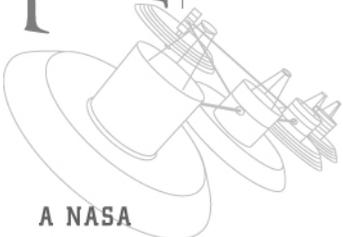


Large Aperture IR Coronagraph



Hyper-telescope

TPF

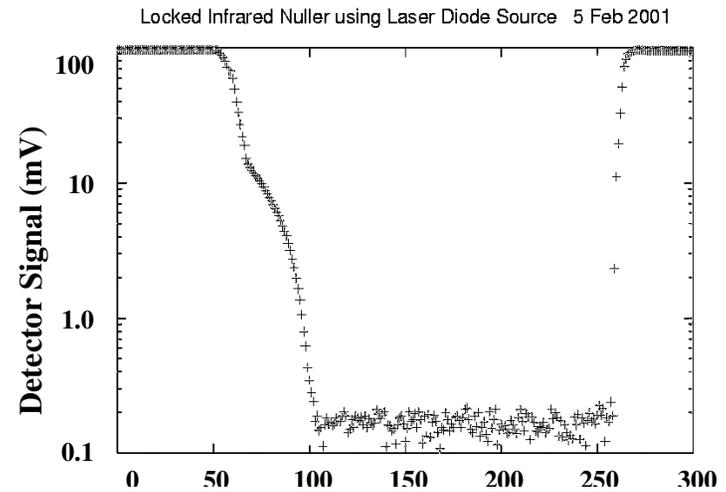
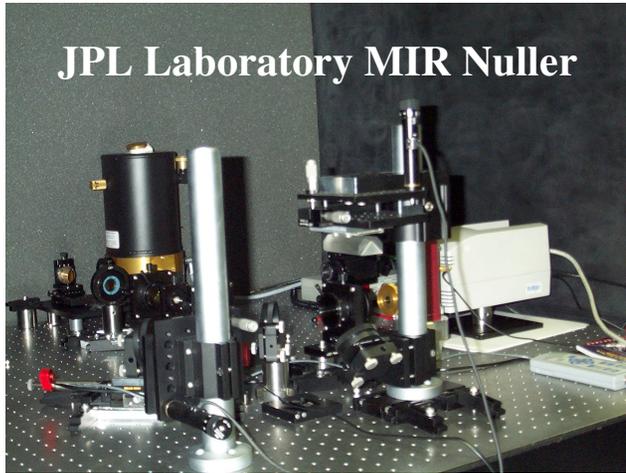


Discriminating Technologies Supporting Architecture Comparisons

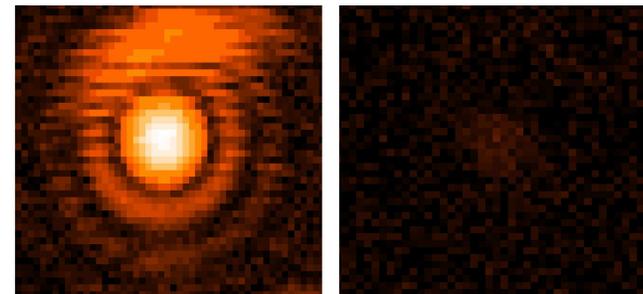
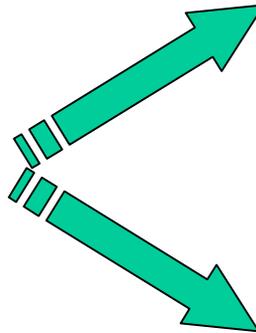
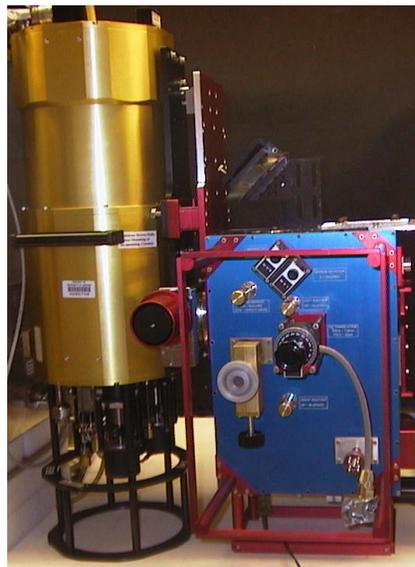
- Precision Formation Flying
- Cryogenic Achromatic Nulling
- Low Vibration Cryo-Coolers
- High Contrast Imaging
- Wavefront Sensing and Control
- Cryogenic Opto-mechanics
- Large Lightweight Optics (cryo or high precision)

Progress on Nulling

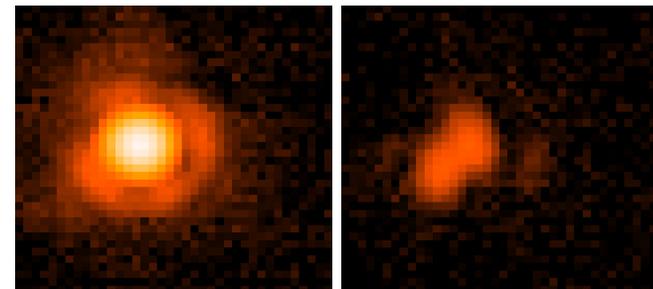
Terrestrial Planet Finder



≈1/1000 IR nulls @ 10μm; 5% BW



≈1/3500 IR null; 10μm CO₂ laser



≈1/100 IR null @ 10μm on the new MMT (w/o AO)

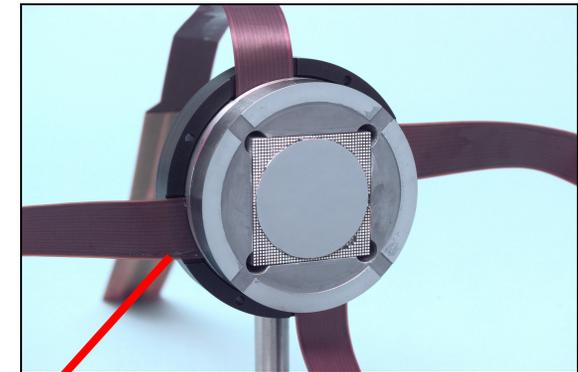


University of Arizona BLINC
Cryogenic IR Nulling Camera

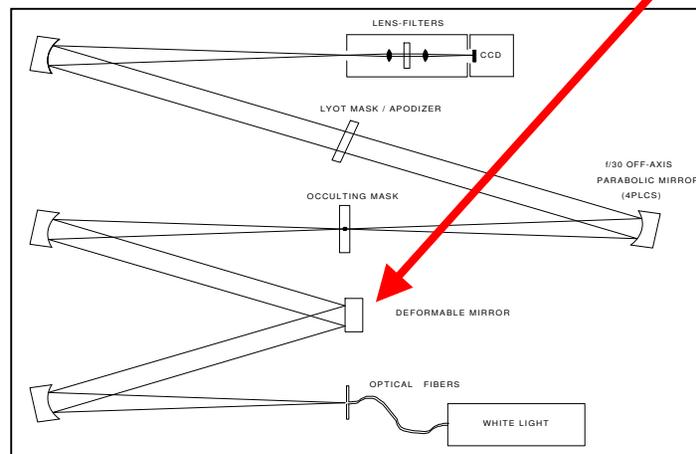
Progress on High Contrast Imaging

Establishing a testbed capability to evaluate high contrast imaging performance of coronagraphic/apodized pupil concepts.

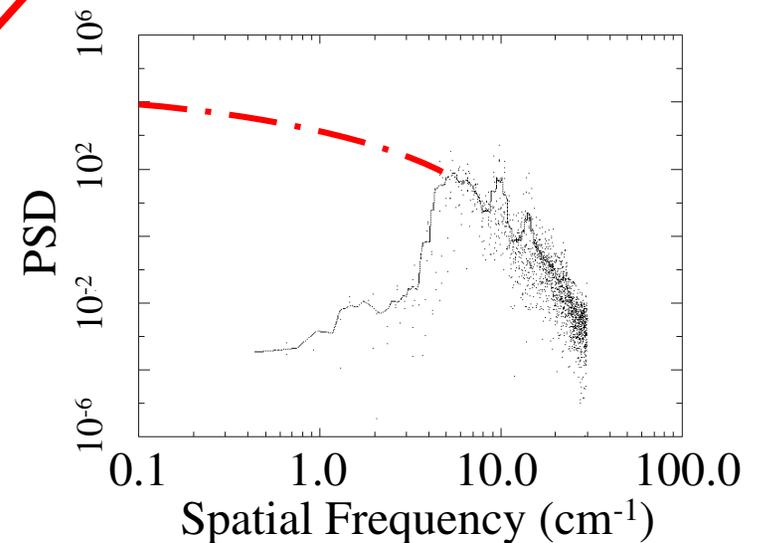
- Key Technologies
 - High actuator density deformable mirror
 - Apodization techniques for stops/masks
 - Stray-light models and control baffles
 - Coating uniformity
 - Algorithm development
 - Performance predictions/optimization
 - Science scene models
 - Alignment and wavefront tolerancing
 - Dark hole algorithms

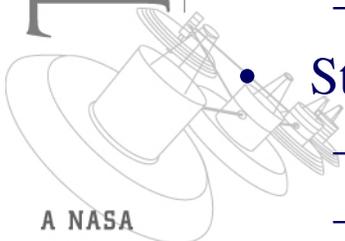


High Actuator Density Deformable Mirror



High Contrast Imaging Testbed Layout

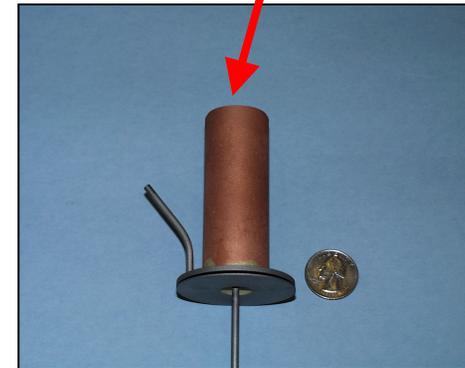
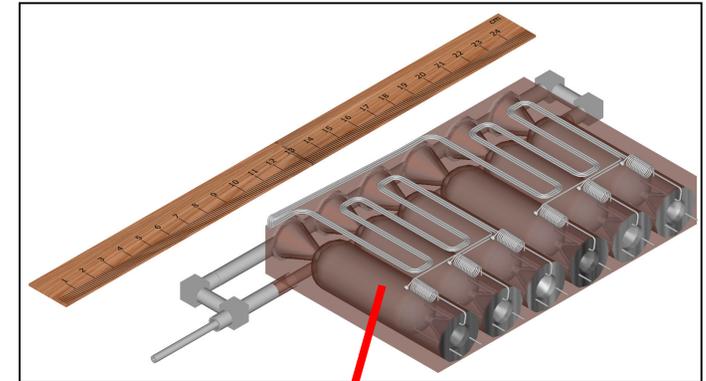




Progress on Sub-10K Cryo-Coolers

- Required for all mid-IR based TPF architectures
 - Previously assumed heritage from NGST is unlikely
- Jointly funded this year at a low level by TPF and Cross Enterprise Program
- He-Charcoal Sorption Cooler
 - Lower temperature implementation of 18K Planck cooler
 - ~10mW cooling power @ 4-8K
 - <5kg
 - Long life, zero vibration
 - Can include redundancy
- Status:
 - Conceptual design completed
 - Compressor breadboard under development

Artist's conception of a 10 mwatt He-charcoal sorption cooler



Prototype charcoal compressor for laboratory breadboard



Significant Events in FY01 impacting TPF

- Mid-year reduction in FY01 and FY02 budget
 - 4.5M and \$5.7M respectively (~50%)
 - Scaled back on Architecture Studies
 - Drastically reduced technology investments
- Identification of new mission architecture classes
 - Visible and IR coronagraphs/apodized telescopes, Hyper-telescopes,
- Emergence of the Eclipse as a possible coronagraph precursor
- Changes in the SIM project
 - Launch and technology readiness dates slipping
 - Descope (eliminate nulling)
- Changes in the NGST project
 - Technology readiness date slipping
 - Descopes (heavier mirrors; replacement of cryocooler with cryostat; raise temperature)
 - Continuing uncertainty with regard to mid-ir instrument
- Impending loss of up to \$3M/yr of Cross Enterprise funding
 - Multiple (>2) spacecraft formation flying
 - Wavefront control for high contrast imaging
 - <10K Cryocoolers
 - Cryogenic opto-mechanics

Project Response to FY01 Events

- Complete ongoing round of architecture studies and down select to two architecture classes in mid-FY02
- Identify key architecture discriminating technologies and metrics to achieve TRL 4/5 and enter ~3 year parallel (two architecture) technology development effort to facilitate final architecture selection in mid FY06
 - Project has developed a preliminary technology plan consistent with proposed TPF schedule, SIM/NGST slips and descopes, and loss of Cross Enterprise funding (still assumes StarLight flies)
 - Technology Plan will be finalized after ongoing architecture study final reports are available including proposed technology plans (mid- FY02)
 - Technology Development to include
 - Competitively selected external efforts (JPL RFPs or OSS NRA winners)
 - In-house efforts where unique capabilities exist
- Proposed to enter Phase A in FY'07 and Phase B in FY'09
 - Two Phase A studies of same architecture class
 - Original 5.75 year Phase A/B shortened to 4.25 years as a result of increased technology maturity and early architecture selection
- New schedule enables launch and operation of TPF science/technology precursors in Phase A or at latest early Phase B



Technology Plan Assumptions

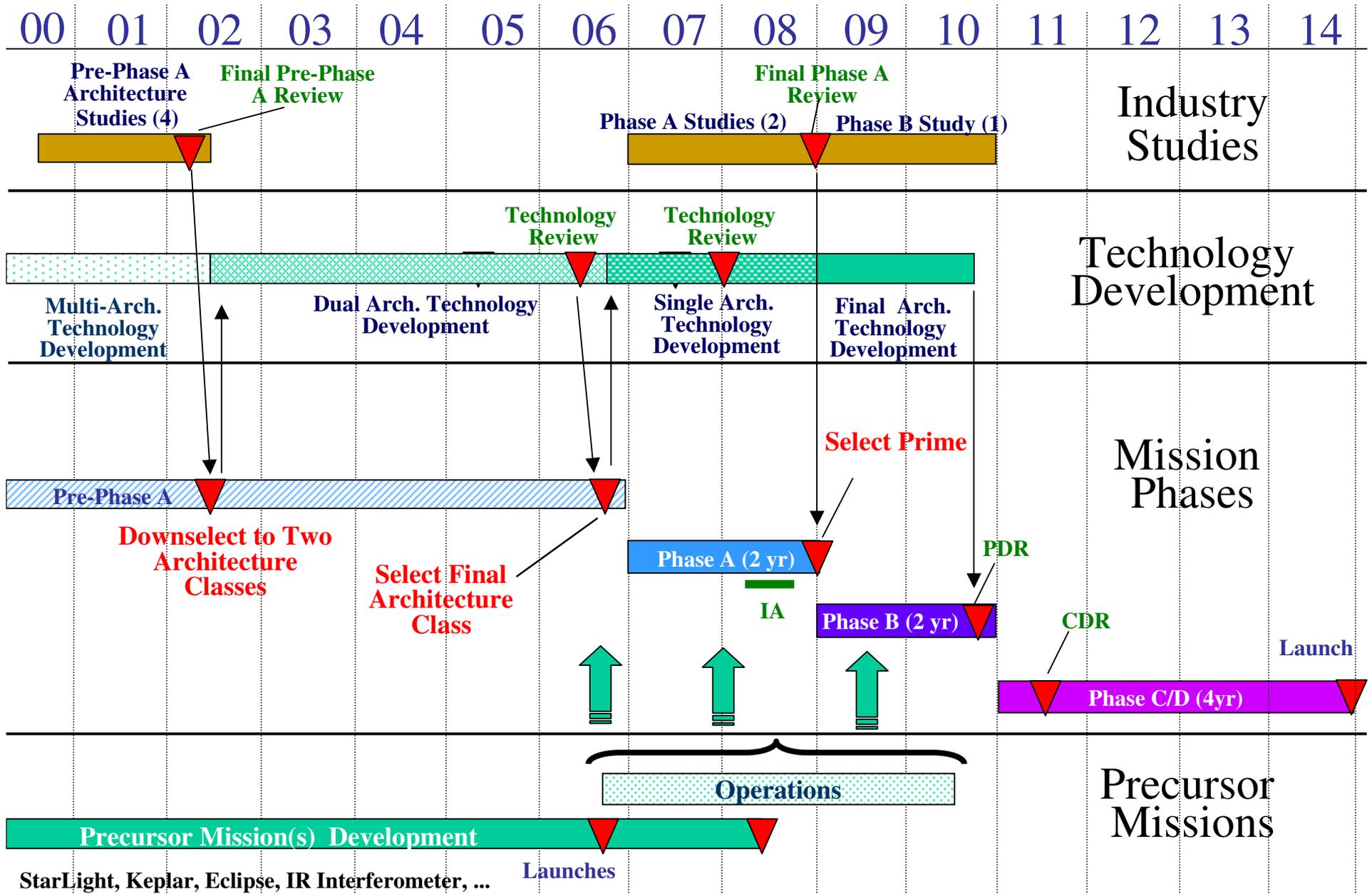
- TPF mission science goals/objectives are unchanged
- TPF carries 2 architecture classes from mid-FY'02 through the end of FY'06, and develops relevant technologies to TRL 4-5 in parallel, leading to TPF technology readiness assessment in FY'06
- SIM and NGST mission plans (scope, schedule, technology readiness...) remain consistent with current (5/01) understanding
- StarLight flies as currently defined in FY'06
 - Kepler COULD fly as a Discovery Mission in FY'05 and provides data on the fraction of stars with Earth-like planets
 - Eclipse COULD FLY as a Discovery Mission in FY'08
- No Cross Enterprise Technology funding after FY'01
 - Funding for FY'01 is not withdrawn / reprogrammed

Technology Development Approach

- Bring discriminating technologies to a level (TRL 4-5) to facilitate architecture selection
 - Consider four current architecture classes through end of current studies
 - Assume down-selection to two competing architectures in mid-FY'02
 - Assume down-selection to final architecture at the end of FY'06
- Pursue a range of technological approaches
 - Best ideas identified from pending OSS NRA studies
 - JPL competitively selected industry and university proposals
 - In-house JPL efforts where unique competencies exist
- Implement an integrated plan for development, validation and selection of enabling TPF technologies from bench top breadboard demonstrations, through testbeds and flight validations consistent with available budgets and on a schedule to support key TPF project decision points culminating with the NAR/PDR in FY'10



Revised TPF Schedule





Summary

- TPF is hard!
 - Combines the worst of SIRTf, SIM, StarLight, and NGST
- Multiple architectures complicate technology planning but offer robustness
- It is prudent to have most critical technologies well in hand (TRL 4-5) prior to entering Phase A
- Previously assumed TPF technology base has eroded
- TPF has replanned to allow time for necessary technology development
- *Complete* success is not assured! But, NOW is the time to start----or none of the roads will ever lead us to TPF and a picture of that little blue dot (at least not in our lifetime)