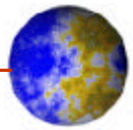
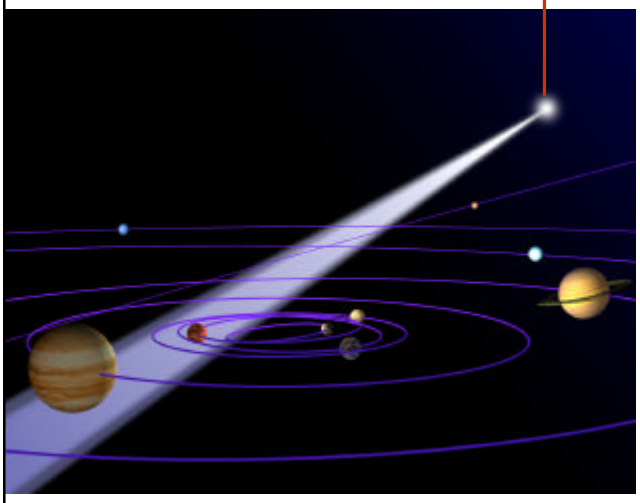
Origins Program: a Long-Term Vision





A Strategy for Understanding Origins of Galaxies, Stars, Planets, and Life and … a Search for Life Outside the Solar System

Ultra Lightweight Space Optics Challenge Workshop

Rich Capps
Origins Theme Technologist
jpl

The Goals of Astronomical Search for Origins

An Overarching Theme of Searching for the Origins of Life and Its Existence Beyond the Solar System

1- To understand how galaxies formed in the early universe and to determine the ***role of galaxies in the appearance of*** stars, planetary systems and ***life***

2- To understand how stars and planetary systems form and to determine ***whether life-sustaining planets exist*** around other stars

3- To understand how ***life*** originated on Earth and to determine if it began and may still ***exist elsewhere as well***

4- To find a ***definitive proof of life on an extra-solar planet***

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Capability Building Blocks for Far-term Missions

- It is premature to design a mission two decades in the future
  - Instead, support early development of scientific and technological capabilities
- ***Concepts*** for far-term missions should be used to identify needed capabilities and investment strategies
- These capabilities will be used to synthesize the right mission as the time horizon to the mission gets shorter
  - Nearer term missions provide further science and technology knowledge

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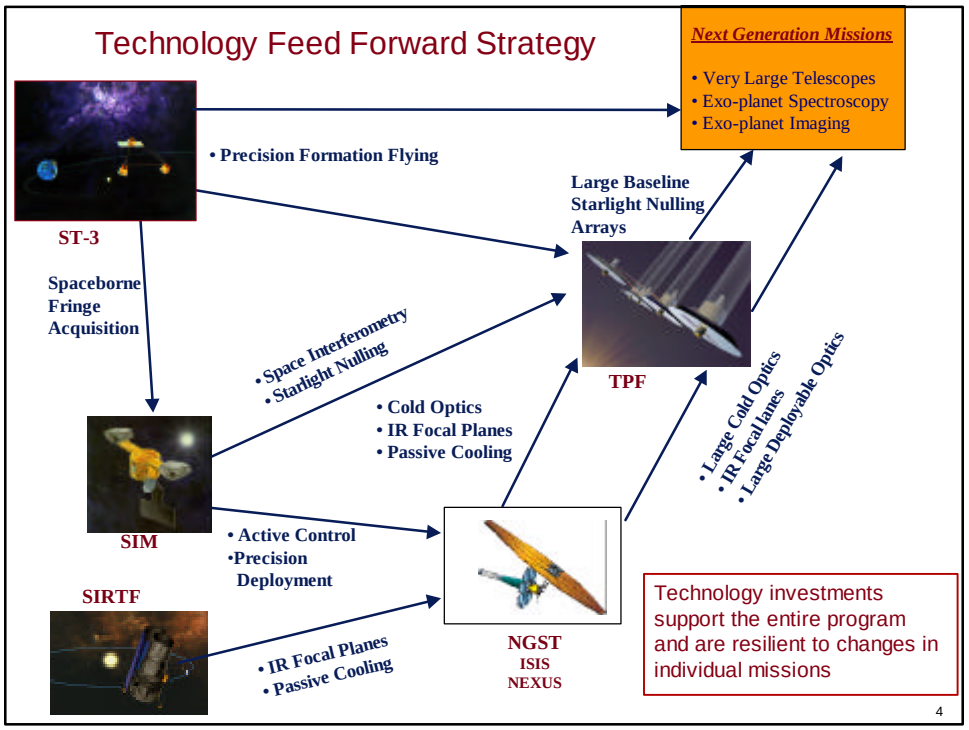
Technology Feed Forward Strategy



Technology investments support the entire program and are resilient to changes in individual missions

4

Examples of Imaging Systems Output

A 25x25 Image of Earth

- Will require a 25-node array with a 40m telescope at each node nulling the starlight to 10^{-10}. Array baseline is 360 km

A 100x100 Image of Earth

- Will require a 100-node array with a 320m telescope at each node nulling the starlight to 10^{-10}. Array baseline is 1,440 km

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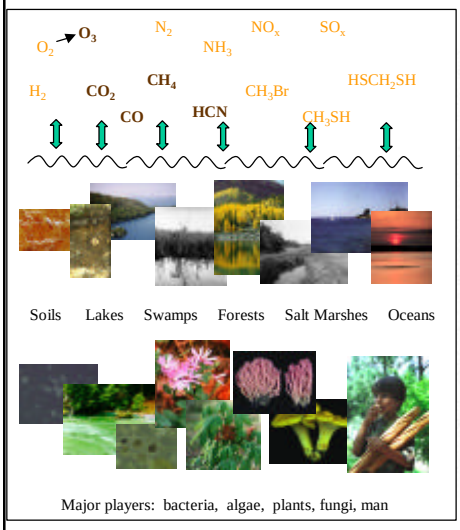
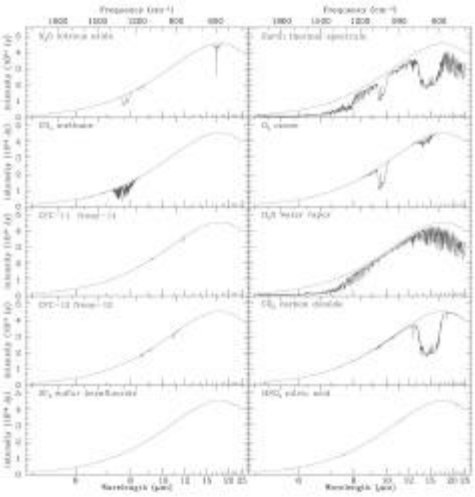
Biological Production and Consumption of Gases

and Their Spectral Signatures





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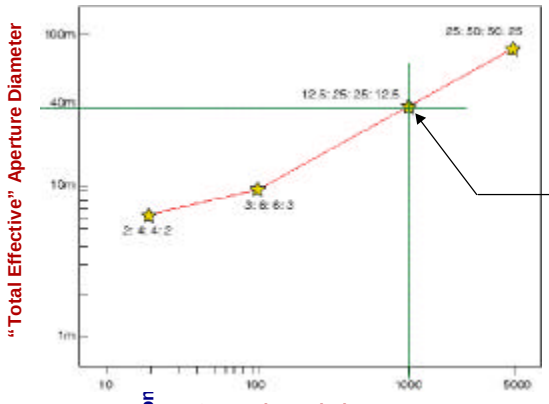
Required Spectroscopic Capability in the IR

A Parametric Look



Four distributed apertures With diameter ratio of 1:2:2:1 with a total collecting area equal to a 40m aperture

bulk gases: carbondioxide, ozon

temperature profiles

trace gases: terrestrial methane

Assumptions

λ = 7-17 µm

10^{-6} starlight nulling

1 month of integration

exozodi = 1 Solar zodi

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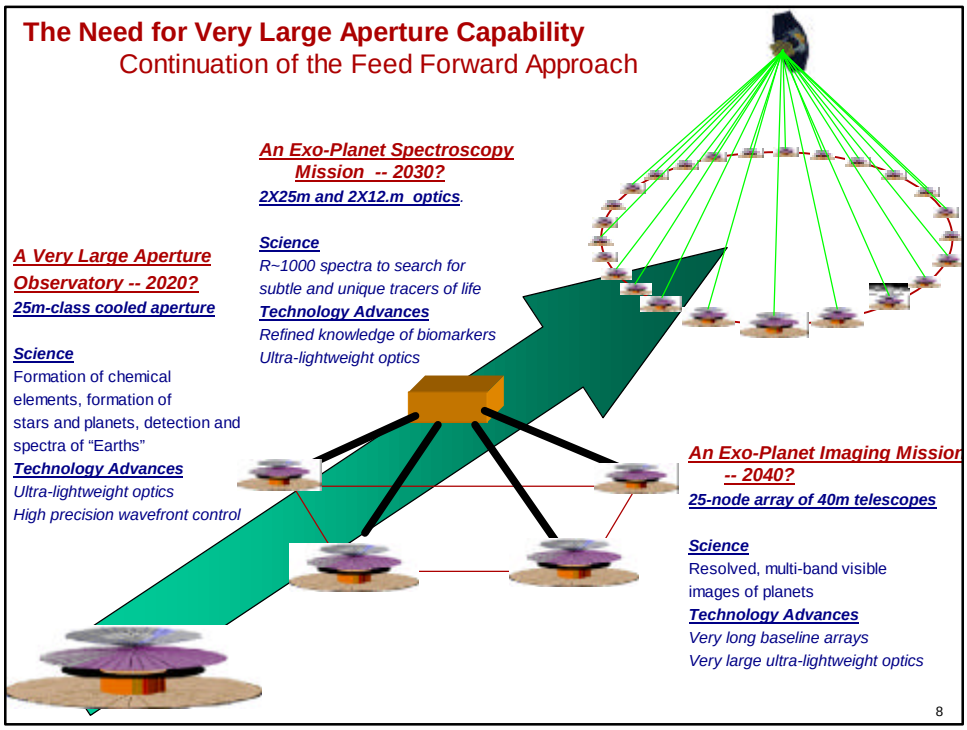
The Need for Very Large Aperture Capability

Continuation of the Feed Forward Approach



An Exo-Planet Spectroscopy Mission -- 2030?

2X25m and 2X12.m optics.

Science

R~1000 spectra to search for subtle and unique tracers of life

Technology Advances

Refined knowledge of biomarkers

Ultra-lightweight optics

A Very Large Aperture Observatory -- 2020?

25m-class cooled aperture

Science

Formation of chemical elements, formation of stars and planets, detection and spectra of "Earths"

Technology Advances

Ultra-lightweight optics

High precision wavefront control

An Exo-Planet Imaging Mission -- 2040?

25-node array of 40m telescopes

Science

Resolved, multi-band visible images of planets

Technology Advances

Very long baseline arrays

Very large ultra-lightweight optics

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Other Large Aperture Applications

Space Science

- Structure and Evolution of the Universe (SEU)
  - Radio and Sub-mm Astrophysics
    - Filled Apertures
    - Interferometers
  - High Energy Astrophysics?

Earth Science

- Remote Sensing
  - Passive Microwave Imaging
  - Sensor Location Options Beyond LEO

Other Agencies

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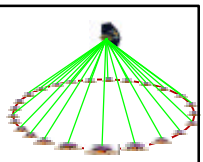
Summary of Far-Term ASO Capability Needs

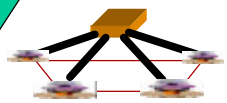
Technologies and Capabilities Expected from the Planned Missions and Technology Programs

- *Precision Formation Flight*
- *Space-based Optical Interferometry*
- *Large Lightweight Deployable Space Optics*
- *Large Format UV, VIS, IR, Sub-mm Detector Arrays*
- *Deep Optical Nulling (Starlight Suppression)*
- *Full Aperture Wavefront Sensing and Control*
- *Integrated Optical System Modeling*
- *Lightweight Precision Space Structures*
- *Large Optical System Integration and Test*
- *Effective Ground Testbed Design and Utilization*
- *Flight Technology Demonstrations*
- *Large Optical System Architectures*
- *Sparse Aperture Image Analysis*

Very Large Aperture Observatories



Exo- Planet Imaging



Exo-Planet Spectroscopy

TPF

NGST

SIM

ST-3

Likely Characteristics of Far-term Optical Systems

- *20-40-? Meter Apertures - Cryogenic Temperatures*
- *Visual to Infrared Wavelengths - Diffraction Limited*
- *Kilometric-scale Formation Flight Collector Arrays*
- *Large "As Deployed" Optical Surface Errors*
- *Time Dependent Wavefront and Alignment Errors*
- *Full Time, Active, Multi-layer Wavefront Control*
- *Ultra Lightweight Materials and Structures*
- *Very Large Thermal Management Structures*
- *Deep Space Trajectories and Operations*

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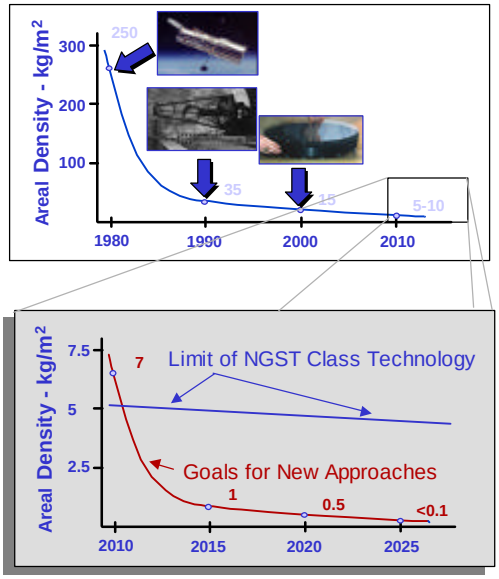
Large Space Aperture Manufacturing Challenge

- *High resolution imaging/spectroscopy requires enormous collecting areas*
  - NGST Benchmark - 50m²
  - Planet Spectroscopy >1000m²
  - Planet Imaging > 25,000m²
- *Traditional Limitations*
  - Manufacturing by physical removal of hard material is too slow
  - 1g self-supporting substrate limits achievable mass reduction
  - Cost ~ $1-2M/m²
- *Manufacturing Issues*
  - Remove the traditional limitations
    - Manufacturing Speed
    - Manufacturing Cost
  - Affordable System Architectures
    - Extremely low areal density
      – Potentially sub kg/m²
- *Next Steps*
  - ULSOC Workshop to collect innovations
  - Initiate technology investments FY99?
  - Successful AMSD partnership
    - Mirror technology for NGST

NGST Driven Mirror Technology



Optics Innovations are Required

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