Precursor

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Terrestrial Planet Finder (TPF)
Phase 1 Architecture Study Report
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Why Consider a Precursor?

- We have so little understanding of the frequency expected for terrestrial planets that we can neither justify a large cost nor a long delay.
- A mission that uses TPF expected technology to learn more about frequency also explores both technological barriers, and those unknown barriers associated with the nature of planetary systems (or other systems around nearby stars).
- A precursor may be able to using fewer technological developments. This can reduce the time to launch and cost to launch.

Science Requirements for Minimal TPF

- Detect giant planets (Jupiters and Saturns) in Solar System-like orbits in ~50 star systems out to ~13 pc
- Detect Earth-like planets in 10 star systems up to 8pc
- Detect CO_2, H_2O, and planet's temperature in 4 stars if Earths are found
- Paring down requirements to a minimum mission buildable within reasonable time/cost

Science Issues for a Pre-TPF

- Major role of Giant Planets in setting up the volatiles and collisional status of terrestrial planets.
- Frequency of Giant Planets with large orbits as in the solar system.
- Frequency of old planetary systems with planets in close orbits like Jupiter and Saturn. Not expected to be stable unless orbits are circular.
- Should be able to see and characterize for habitability any very close-by terrestrial planets.

Which Islands are Possible for Pre-TPF

- Cost analysis suggests that for minimal systems, free-flyer cost is a significant additional increment. So we eliminate islands 1,2 and 4.
- Options are:
  - *Island 3 small scale* ✔
  - *Island 5 small scale* ✘ *Tasks remain high and tech development will be prohibitive*

Island 5 small scale versions

Helpful changes

- Use smaller mirror (which would likely be round).

Remaining

- If habitability is to be established, spectroscopic capability is still needed, and seeing water vapor is not substantially easier than showing presence of oxygen.
- At any size, the $\sim 10^{10}$ reduction of the star is still needed, and so the requirements on AO and coating remain unchanged.

Pre-TPF and TPF

- A Pre-TPF would likely set the direction for TPF (assuming it was successful).
- Therefore Pre-TPF should be in an island that is of greatest science interest for a TPF.
- Minimally we would prefer it to be in the spectral region we want for TPF and testing out much TPF technology.
- This would select Island 3.

Island 3 small scale versions

Helpful changes

- Use non-adjustable small mirrors (e.g. SIRTF-size)
- Use small foldable truss (New, but easily/rapidly testable)
- Nulling needs only 1:1 ratio.
- (Picture on next viewgraph is for a 15m truss system in a SIRTF like rocket - we need about a 20m truss but otherwise similar system.)
- Astronaut assistance in assembly (Shuttle launch)

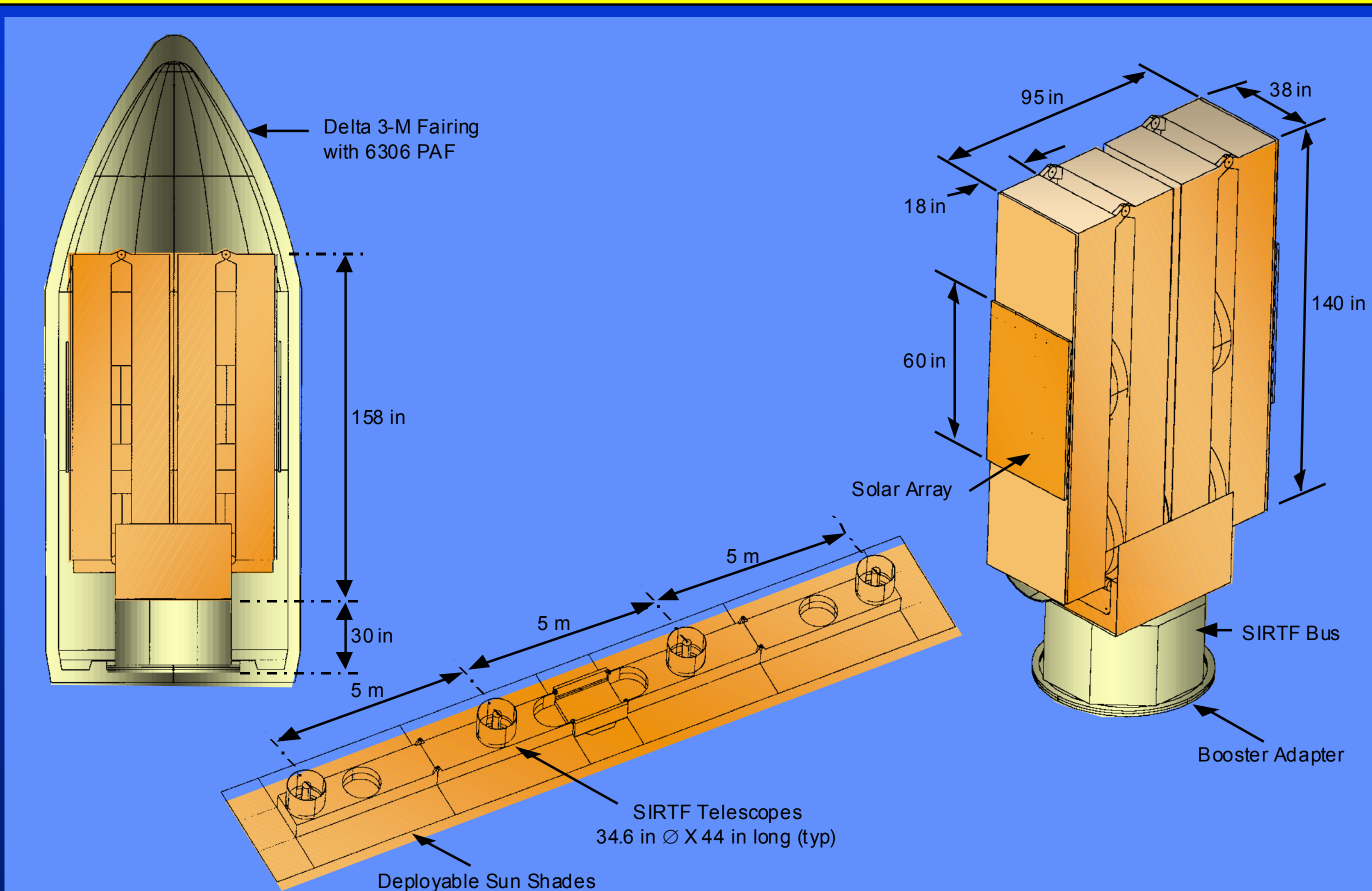
Remaining key technical requirement

- Sunshield required to produce 25-30K rather than 35K

Precursor Concept

Civil Space Programs

Planet Discovery Mission



Precursor Stars for Terrestrial Planets

Scaled to results in table 1.2 of TPF book

Planet @ Earth temperature, no closer than 0.13 arcseconds

Name	mbol	parallax	planet separation	Type	Detect Planet	Detect CO_2 & H_2O
1) ε Eri	3.50	.310	.18	K2V	5.09hrs	5.6 days
2) ε Indi	4.14	. 276	.13	K4-5V	8.1	9.0
3) τ Ceti	3.50	. 274	.18	G8V	8.34	9.27
4) 40 Eri	4.26	.198	.13	K1V	30.5	34
5) Altair	0.90	.194	.60	A7IV-V	33.2hrs	36.9days
6) η Cas	3.44	.168	.19	G0V	2.46day	9.4weeks
7) 82 Eri	4.25	.165	.13	G5V	2.64	10.0
8) δ P av	3.52	.164	.18	K2V?	2.7	10.3
9) Fomahault	1.26	.130	.50	A3V	6.9	26.1
10) Vega	0.03	.129	.90	A0V	6.9days	26.1weeks

Jupiters and Saturns with Precursor

- In the 20-27micron region, Jupiters will have a Signal/Noise 7x higher than an Earth-like planet achieves in the 12-14 micron region. Saturns are about 3x fainter in this wavelength region so to get Signal/Noise = 5 on Saturns, we must get Signal/Noise = 15 on Jupiters.
- Let us assume observations out to 13 pc with 50-60 stars expected to be accessible to the precursor.
- At 13pc, Jupiter will yield S/N = 5 in 27.4 hours. and will take 10.3 days to reach S/N 15 (giving Saturns S/N=5) If we have 50 objects and take 10 days each, we need ~500 days of observations or 1.4 years for this part of the program.
- The "Earths" part of the program is expected to last ~1 year if about 30% of stars have Earth-like planets. So the total required duration of the program is 2.5 years, and in a 5-year mission there are opportunities to make up for any unexpected sensitivity losses.

5 Year Precursor Mission

5 year precursor mission

	Year 1	Year 2	Year 3	Year 4	Year 5	Average
Cool down + setup	0.5	0	0	0	0	0.1
Object-to-object + object setup	0.025	0.05	0.05	0.05	0.05	0.045
10 systems within 8 pc	0.475	0.21	0.21	0.21	0.21	0.263
Added obs for spectra on 4 stars	0	0.2	0.2	0.2	0.2	0.16
40 systems within 13pc for Jupiters/Saturns	0	0.54	0.54	0.54	0.54	0.432

40 stars for Jupiters/Saturns only: 20 days of observations each, divided into 3 observations each system
6 stars for Earth-like planet orbits + Jupiter/Saturns: 48 days of observations each divided into 8 observations for each system.
4 stars for Earth spectra + planet orbits +Jupiters/Saturns : 120 days of observations each, divided into 8 observations per system
Time to L2 ~ 100 days. Additional time to cooldown + checkout = 80 days.
Time lost in moving object to object = 8 hours x 240 observations = 80 days through entire mission.