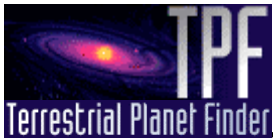


TRW Space & Electronics Group

TPF Requirements

Suzanne Casement

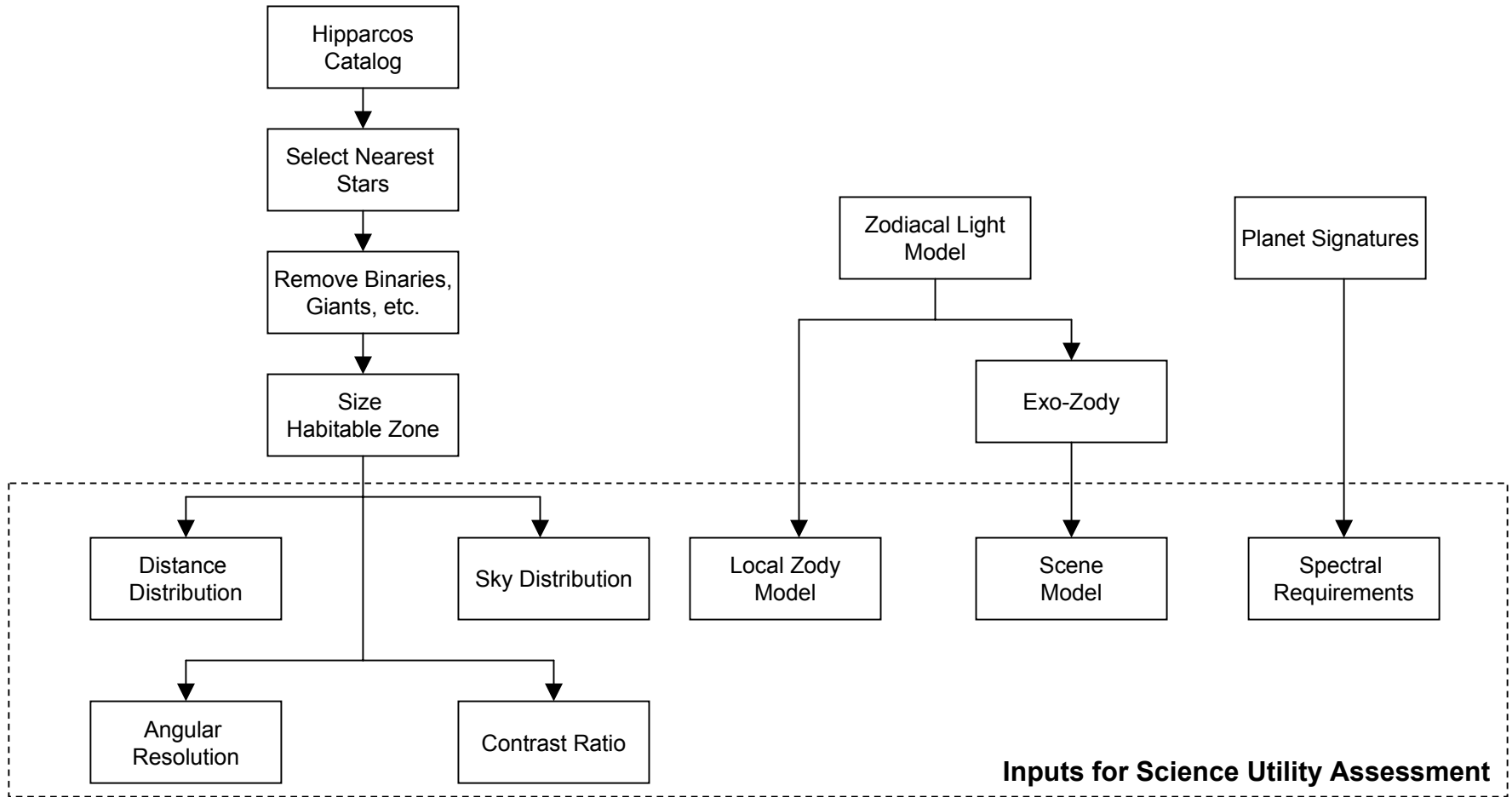


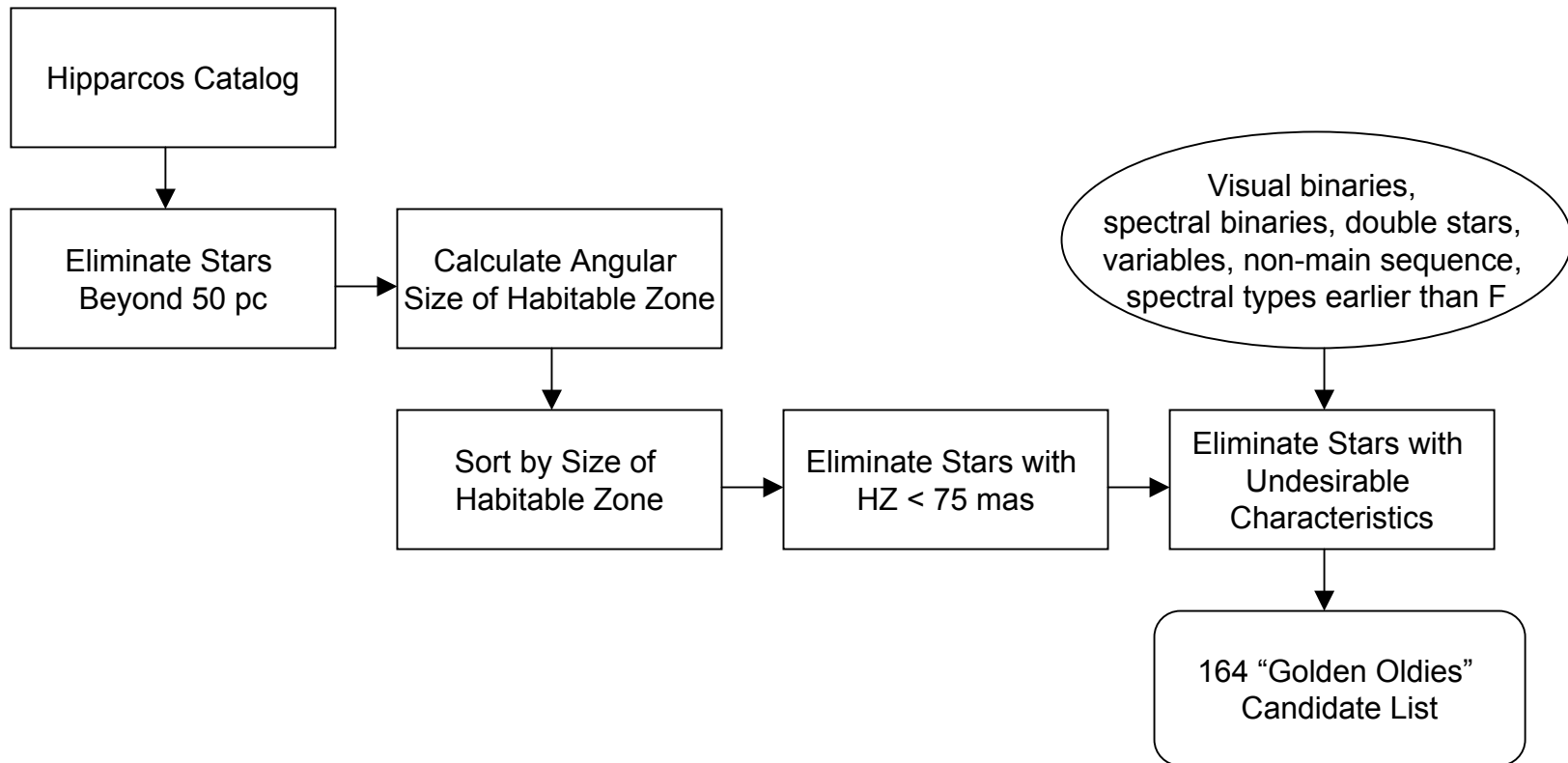
We Based Our Requirements on Three Sources

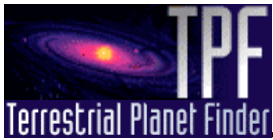
TRW

- Exhibit II from the TPF RFP
 - Mission duration, allocations between planet detection/characterization and astrophysics, number of planet detection targets
- Star catalog investigations
 - Angular resolution, sensitivity, sky coverage
- TPF Science Working Group Meetings
 - Number and frequency of revisits
 - Characteristics and number of TPF targets

- Requirement (Exhibit II) is to observe >150 stars
 - 2 revisits per star for detection at $R=3$ to 5, $SNR=5$
- Approximately 30 sources are then required to be characterized (assuming positive detection)
 - 4 additional revisits per star for orbit determination ($R=3$ to 5, $SNR=5$)
 - 1 visit for spectral characterization
 - 30 for CO_2 / H_2O detection ($R=20$, $SNR=10$)
 - $\sim 16x$ detection integration time when SNR limited by Endo-zody as is the case in the thermal IR
 - 5 for CH_4 / O_3 detection ($R=20$, $SNR=25$)
 - $\sim 100x$ detection integration time when Endo-zody limited
 - Assume these 5 are among the 30 above
- This implies a total detection observation time of <16 hours, including slew, settle, and acquisition to achieve mission in the allotted 2.5 years
 - Allocate ~ 30 calibration observations (1/month) in the 2.5 years



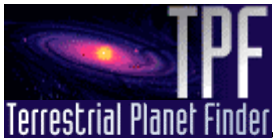




Goal of Statistical Investigation Were To Derive Set of ≥ 150 Target Stars

TRW

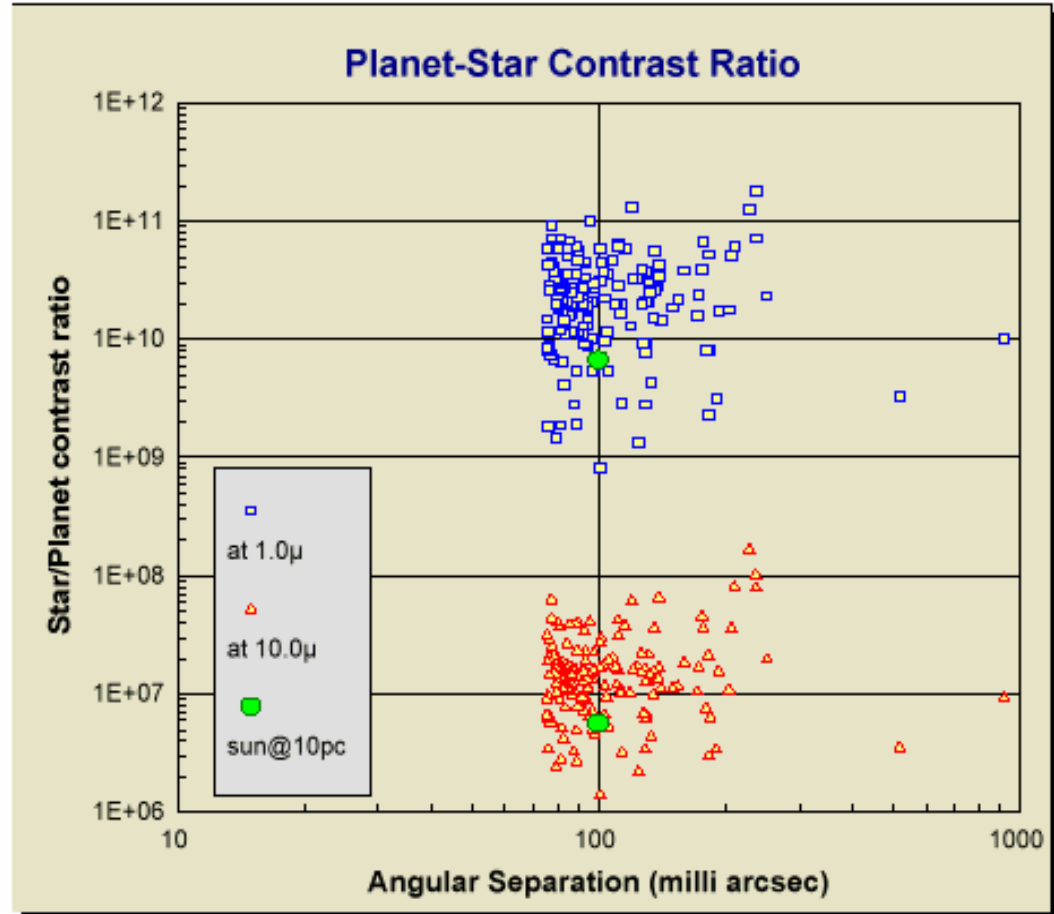
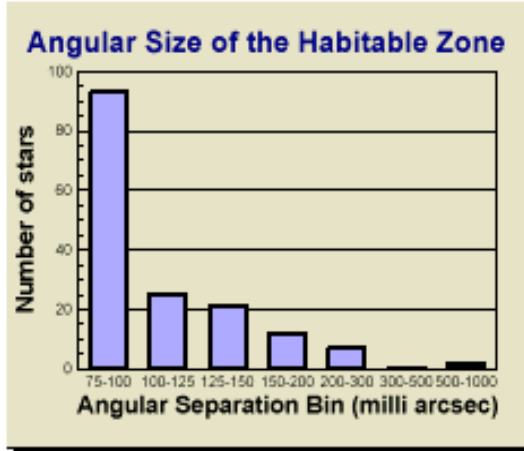
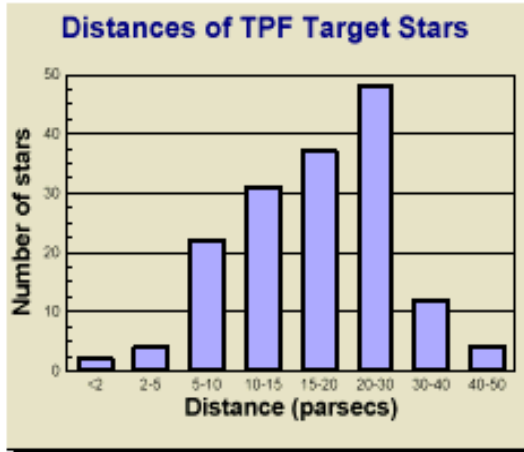
- Habitable zone cutoff of > 75 mas selected arbitrarily to achieve desired sample size
 - Smaller HZ would result in more candidate targets but would increase angular resolution required by system
 - Larger cutoff would not provide enough targets
- “Undesirable” characteristics were those that would tend to preclude habitability
 - Short stellar lifetimes of early type stars
 - Non-main sequence stars where the stable lifetimes are very short
- Also excluded close binary stars
 - Techniques explored could not handle second bright source in or near the field of view to achieve required starlight suppression



Statistical Analysis Provided Surprises About the Target Characteristics

TRW

- To get >150 targets, volume of space required is much higher than expected
 - Targets out to ~50 pc
 - Requires higher system sensitivity than for canonical system of Solar System at 10 pc
- Contrast ratios varied by almost factor of 100
 - Better than 10^7 star suppression may be required in IR
 - Better than 10^{10} star suppression may be required in visible
- As expected, sources nearly uniformly distributed
 - Slight under-representation near the ecliptic may be due to selection effect in catalog used (due to local zody)
 - Requires nearly 4π steradian sky coverage unless architecture is sensitive to smaller angular separations

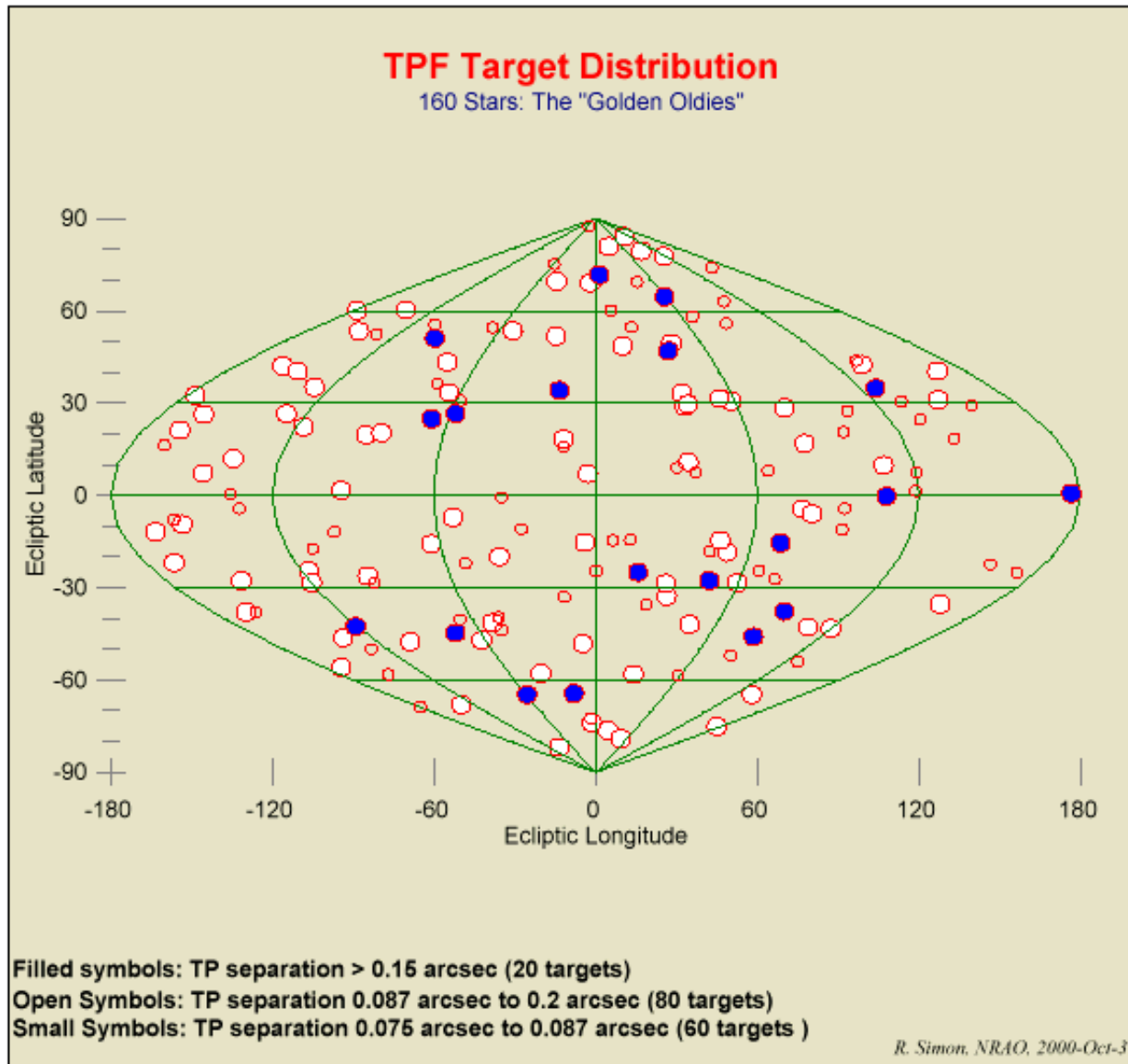


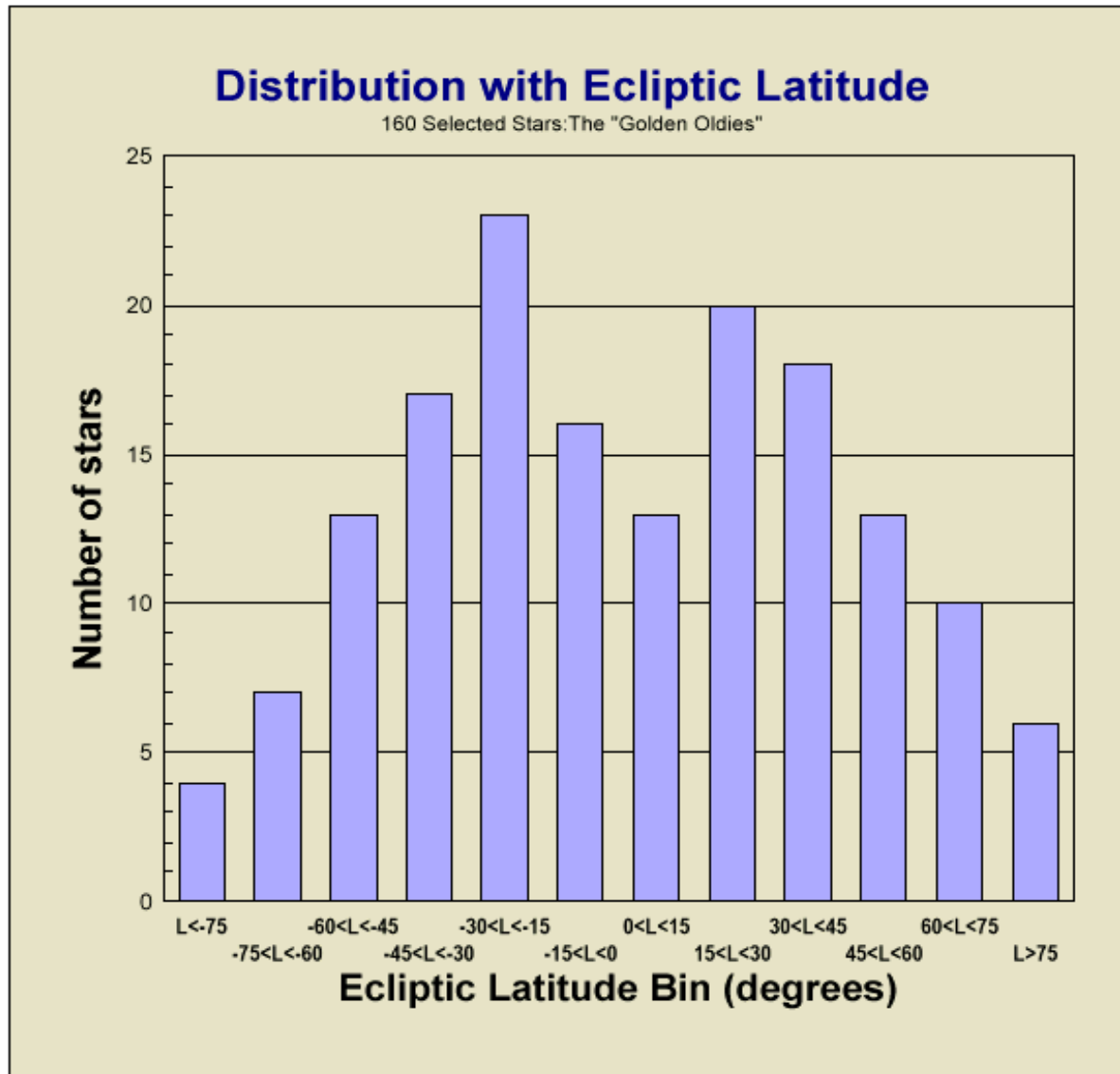
Target Star Selection:

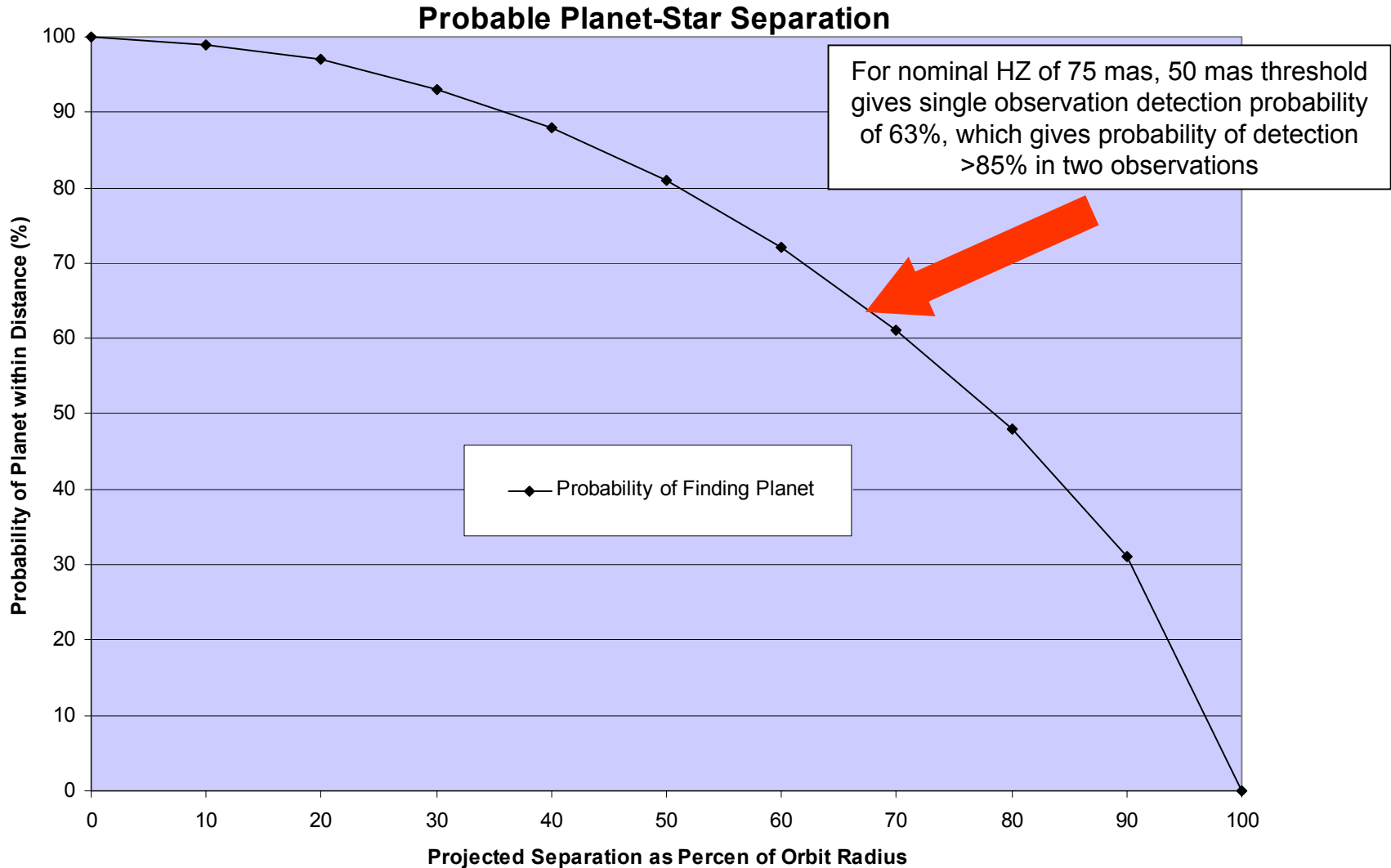
- HIP Stars with "Habitable Zone" > 75 mas
- Suspected binary stars <math>< 10''</math> or Spec Bin. <math>< 5</math>yrs excluded
- Stars with Spectral type A or earlier excluded
- Giants (Lum Class III, II, or I) excluded
- Known RS CVn's, W Uma's, Algols, roAp's, or A2CVn's excluded

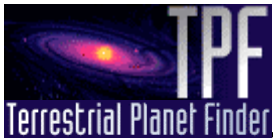
Planet Characteristics:

- "Planet" is an Earth-Analogue:
- Equilibrium Temp. = 293K
- Earth-like albedo and radius





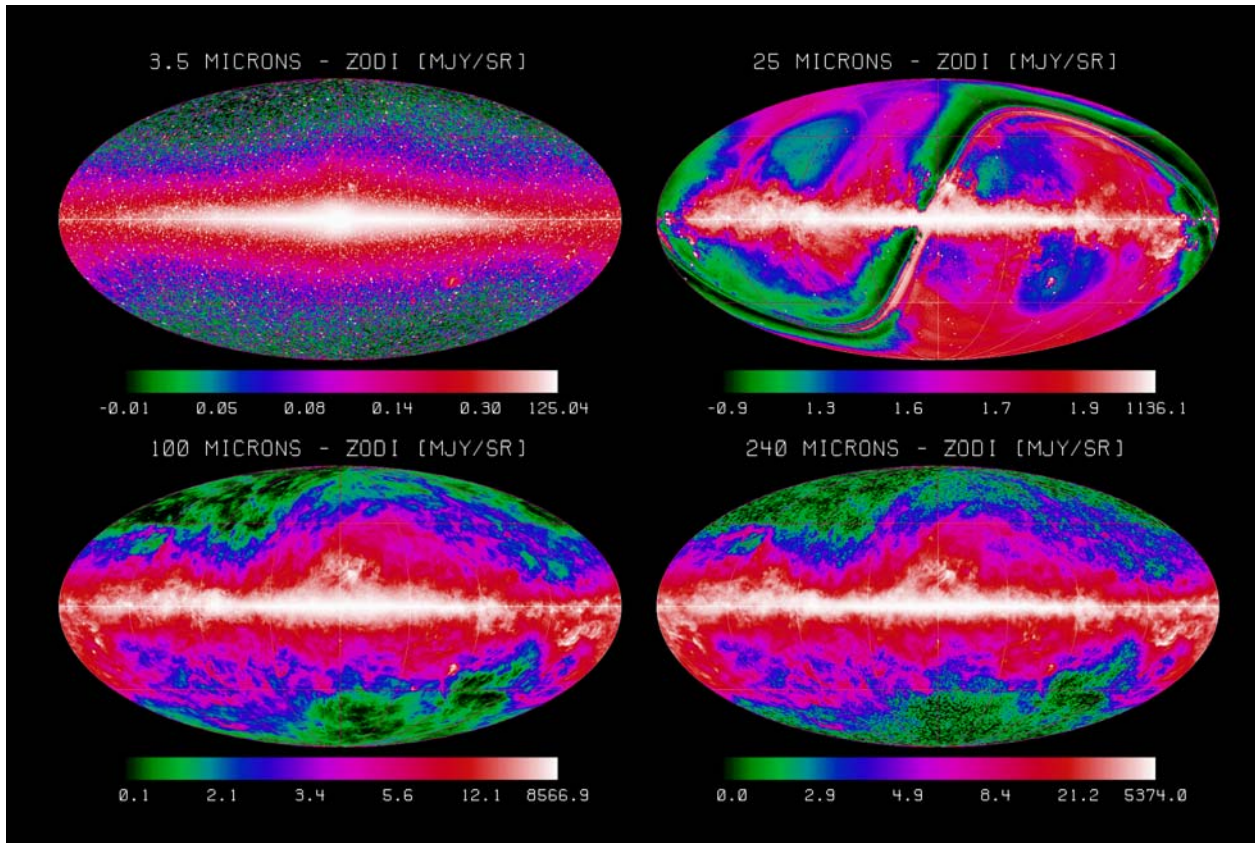




TRW Team Selected Two Sample Targets for Performance Estimations

TRW

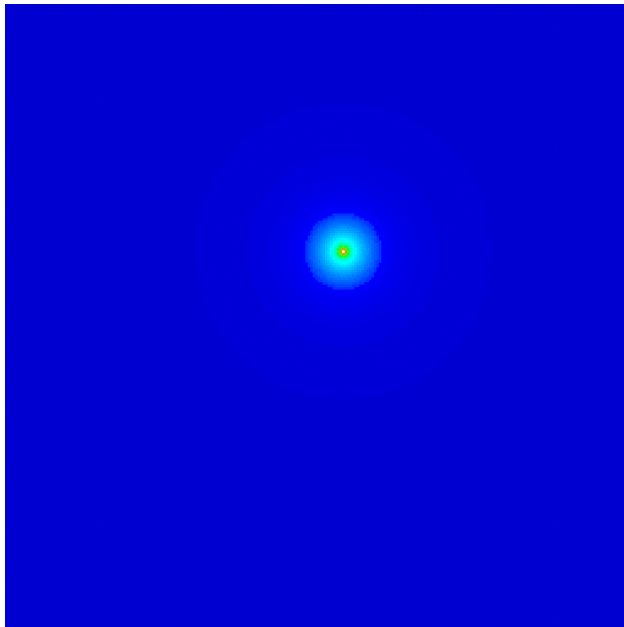
- Sun - Earth system at 10 pc
 - Provides reasonable, well-understood target baseline
- Additional system chosen to reflect median of Golden Oldies List
 - Phi2Pav, F8 star
 - HZ approximately 2 AU
 - Distance 24 pc
- Earth spectra used for characterization performance estimates



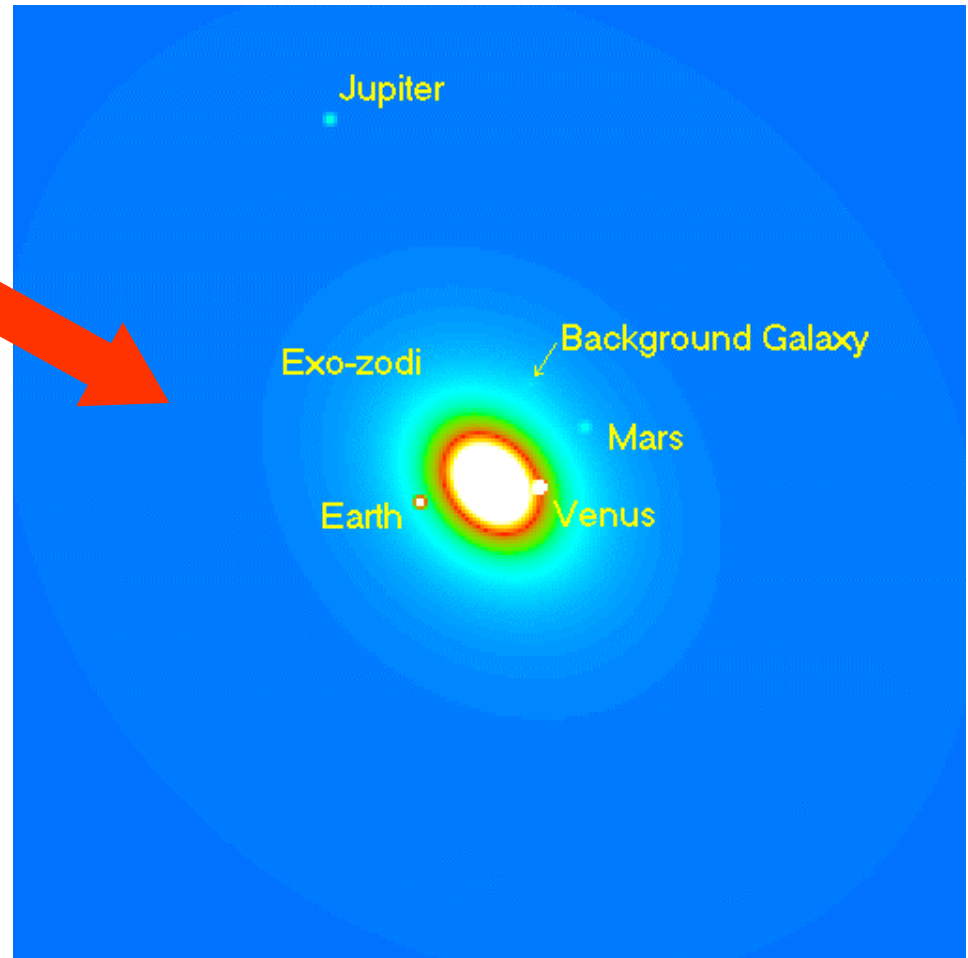
Analytical model is fitted within these parameters provided by DIRBE data:

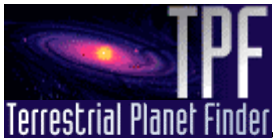
- 1.25 to 240 μm
- 64 to 124 degrees from the Sun
- 1 AU from the Sun

DIRBE data with known sources removed



Background galaxy modeled for $z=1$ at $10\ \mu\text{m}$. Total flux is $0.5\ \mu\text{Jy}$, roughly equal to Earth at $10\ \text{pc}$.





Galaxies Not a Significant Source of Confusion for TPF

TRW

- Confusion from background galaxies cannot be ruled out by surface density alone
- Characteristics of these objects can be used to distinguish them from planets
 - Majority of these objects will be resolved by TPF
 - Spectral data will show they are not planets
- Proper motion can also be used to distinguish background objects

Target	Objective	Max K mag	Log (res in mas)	Log (contrast)	Image Types	Time Constraints
Near-Earth Object	Structure	15	0	0	Complex	Tracking
Kuiper Belt Object	Composition	15	0	0	Complex	Tracking
Cometary Core	Structure	15	0	0	Complex	Tracking
Jovian Planet	Atmosphere	$7/\text{sec}^2$	0	1-3	Complex	Tracking
Protostellar Disk	Structure	$5/\text{sec}^2$	-1, 1	1-3	Complex	-
Young Planet	Structure	22-26	-3	5-7	Spread	-
Planetary System	Motion	22-26	0-2	5-7	Points	-
Brown Dwarf	Weather	15	-1	1-3	Complex	-
Binary Brown Dwarf	Evolution	15	0	0	Points	-
X-ray Binary	Mass	18	-2	0	Points	-
Supergiant Star	Atmosphere	$-7/\text{sec}^2$	0	1-3	Complex	-
Planetary Nebula	Binary Nuclei	5	-2, -1	0	Points	-
Globular Cluster	Population	21-25	0	4-5	Points	Years
Cluster's Core	Structure	21-25	0	4-5	Points	-
MACHO	Population	18,26	0	5	Points	Months
AGN	Disk, Cluster	21	0	2-5	Complex	-
Starburst	Structure	25-26	0	1-3	Complex	-
Supernova Envelope	Distance	13-16	-3	0	Spread	Weeks
g-ray Burst	Environment	22-26	0	1-3	Complex	-
g-ray Burst	Afterglow, light echo	>22	-2	2	Spread	2 Days

Parameter	Requirement	Source
Mission duration	5 year requirement; 10 year goal	RFP
Investigation allocation	50% Planet detection/characterization, 50% Astrophysics	RFP
Number of targets	At least 150 for detection, at least 20 for characterization	RFP
Detection criteria	SNR = 5	TRW
Angular threshold	50 milli-arcseconds	TRW
Sky coverage	4π steradian	TRW
Integration time	<24 hours for detection; <2 weeks for characterization	RFP/TRW
Wavelength range	VIS: 0.5 – 1.5 microns (TBR); IR: 7 - 17 microns	RFP/TRW
Spectral resolution	VIS: at least R = 100 (TBR); IR: at least R = 20	RFP/TRW
Characterization performance	SNR = 5 for spectral lines	TRW/SWG
Number of revisits	2 for detection, 7 total (including characterization)	SWG
Revisit frequency	No less than 1 month	SWG

RFP refers to Exhibit II in TPF RFP; TRW refers to requirements derived by the TRW Science TEAM; SWG refers to requirements derived at the September meeting of the TPF Science Working Group

- Goals list represents guidelines for defining and sizing systems
- Angular resolution will be different for different measurement techniques
 - Threshold represents distance beyond central star where useful measurements can be made
- SNR = 5 is bare minimum for detection
 - How to get to SNR = 10 study topic for Phase 2
- SWG stated SNR = 5 on line detection sufficient for characterization; trade space of resolution v. SNR still to be explored
 - Used RFP requirements for IR systems where spectral characteristics are better understood; may be relaxed during Phase 2
 - FFO did full spectral modeling to understand visible spectral performance and characterization

- Additional star catalog results
- Additional zodi model information
- Confusion discussion
- Proper motion analyses
- Simulated background galaxy
- General astrophysics investigations