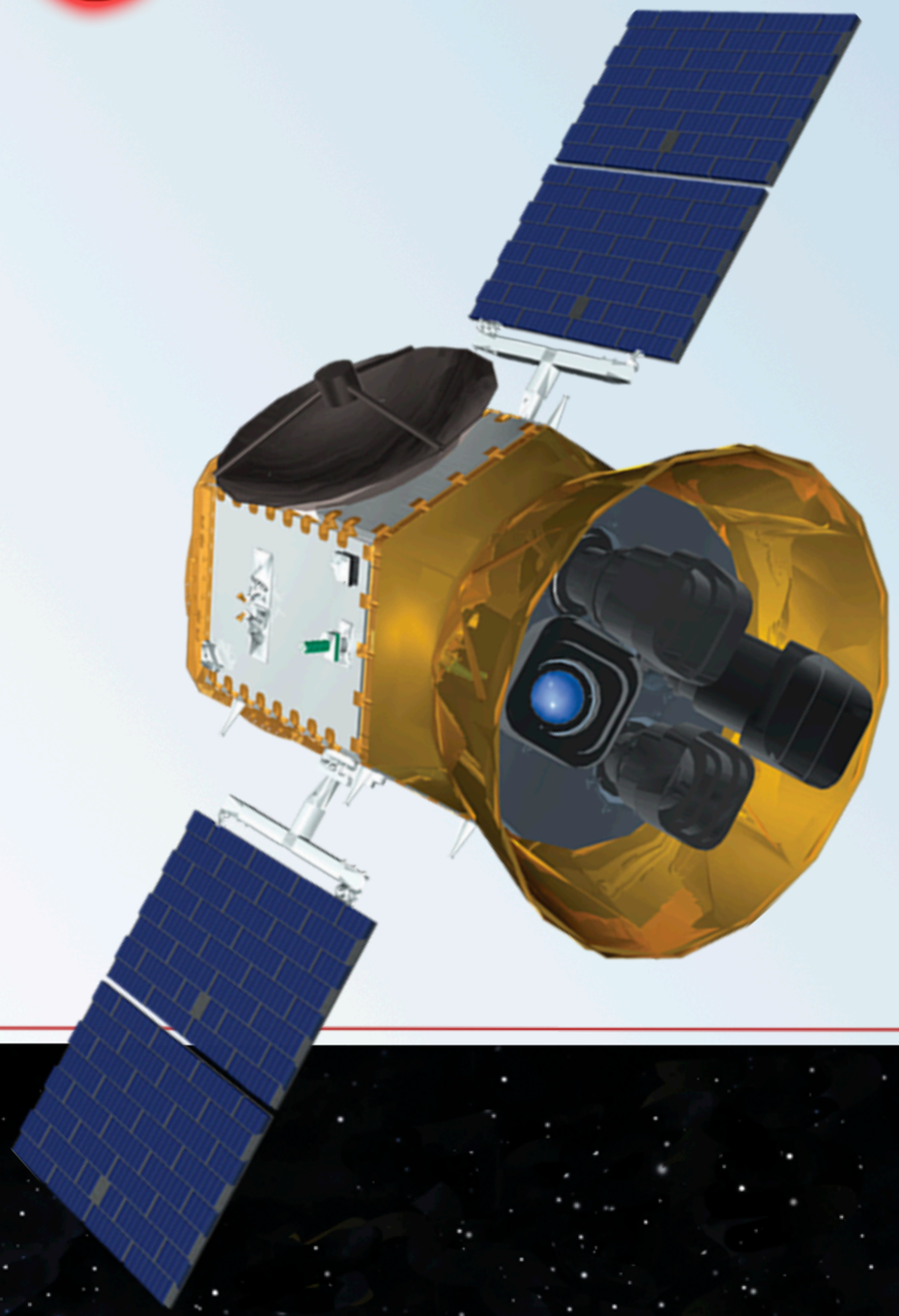
Transiting Exoplanet Survey Satellite



TESS Mission Status

George Ricker (MIT)

17 April 2013

Imagine Finding a New Earth-sized Planet Every Month…

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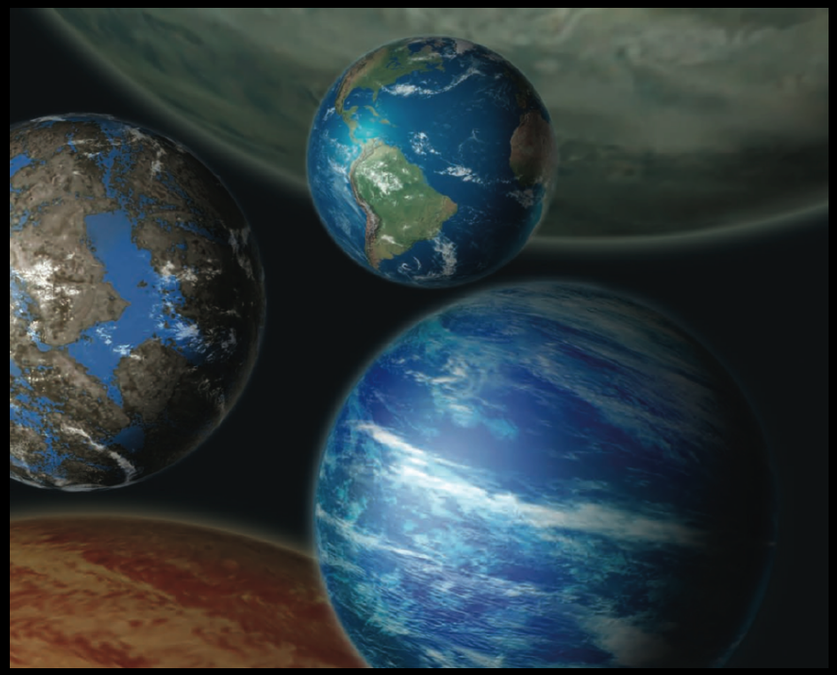

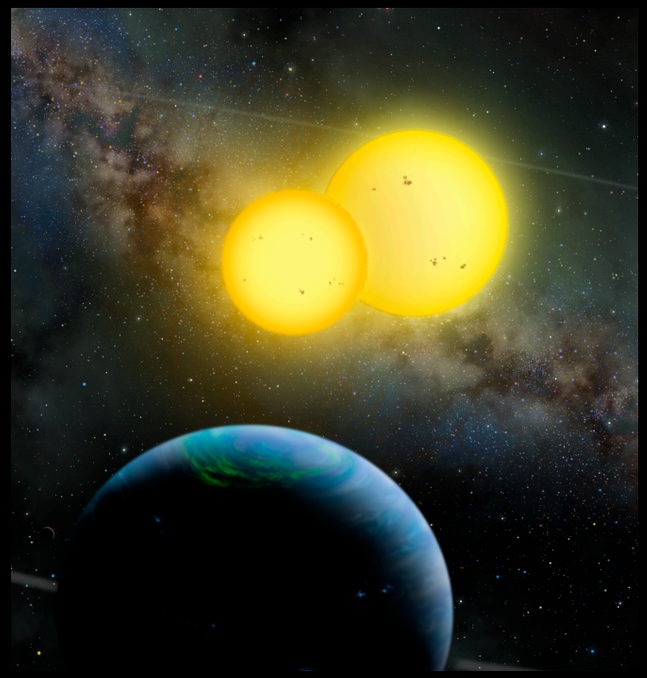

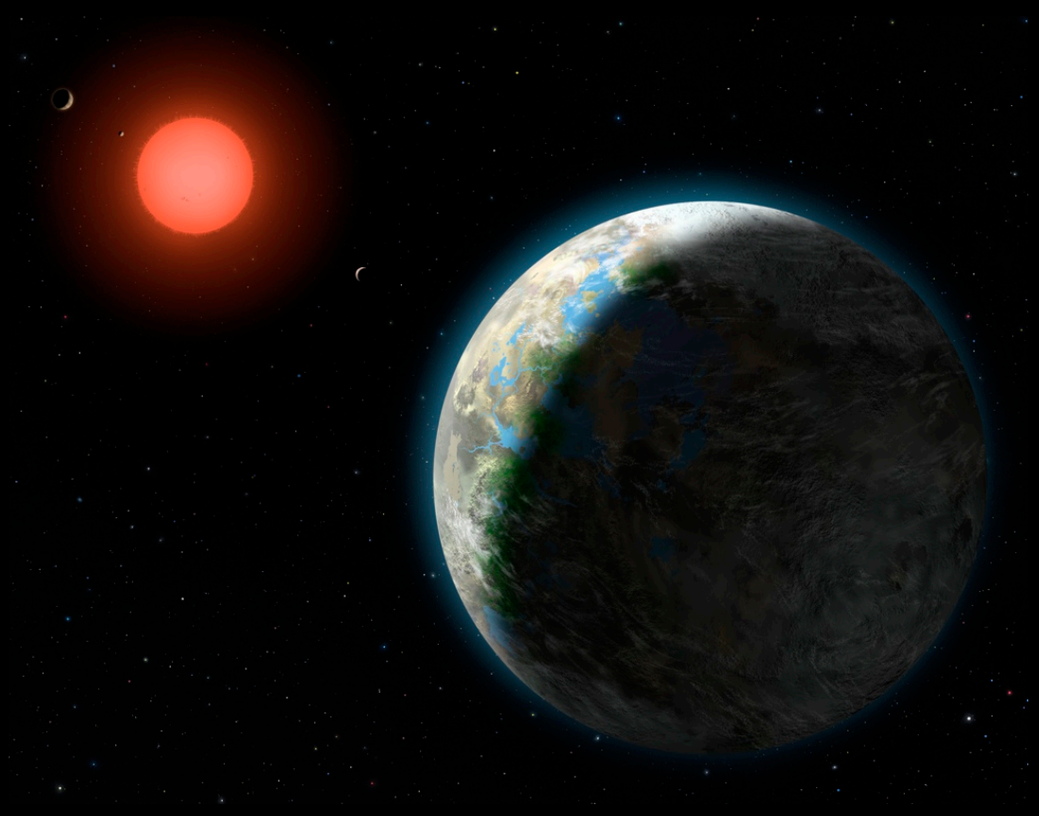

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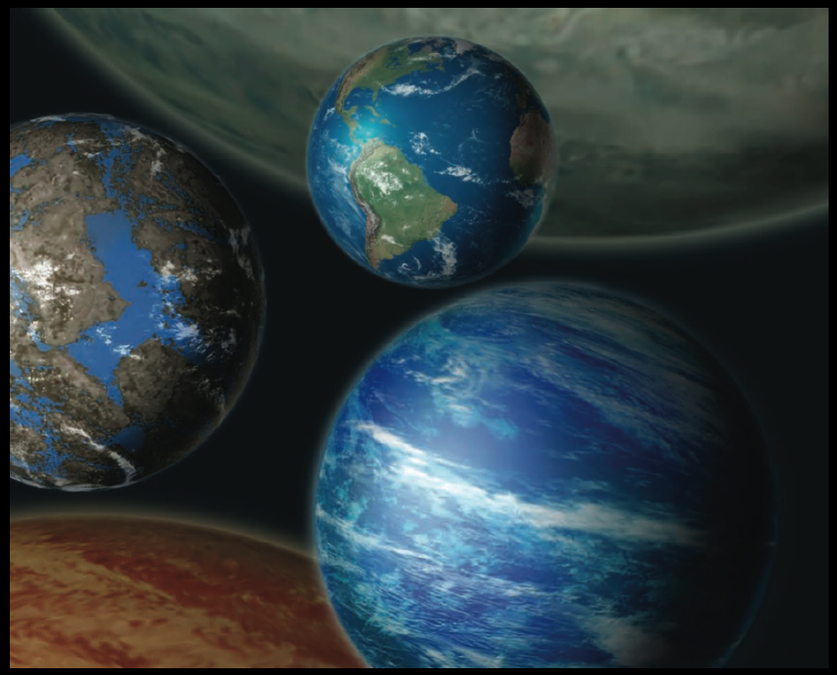
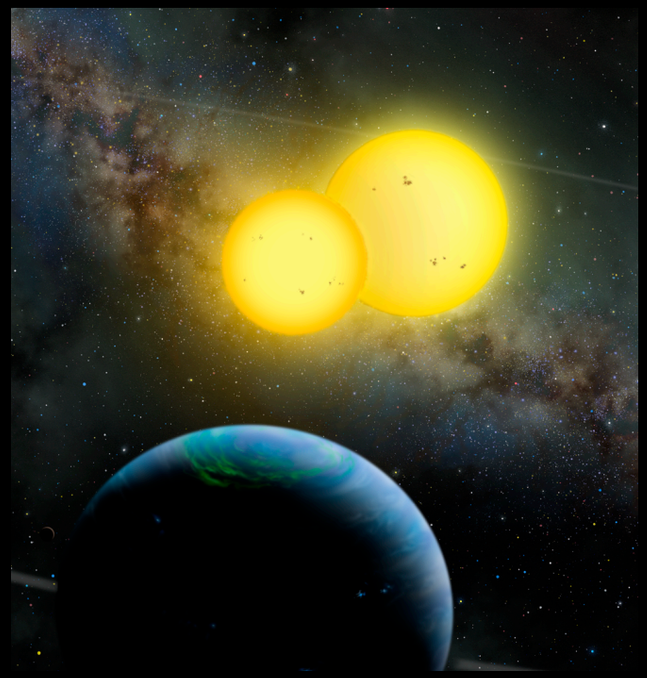
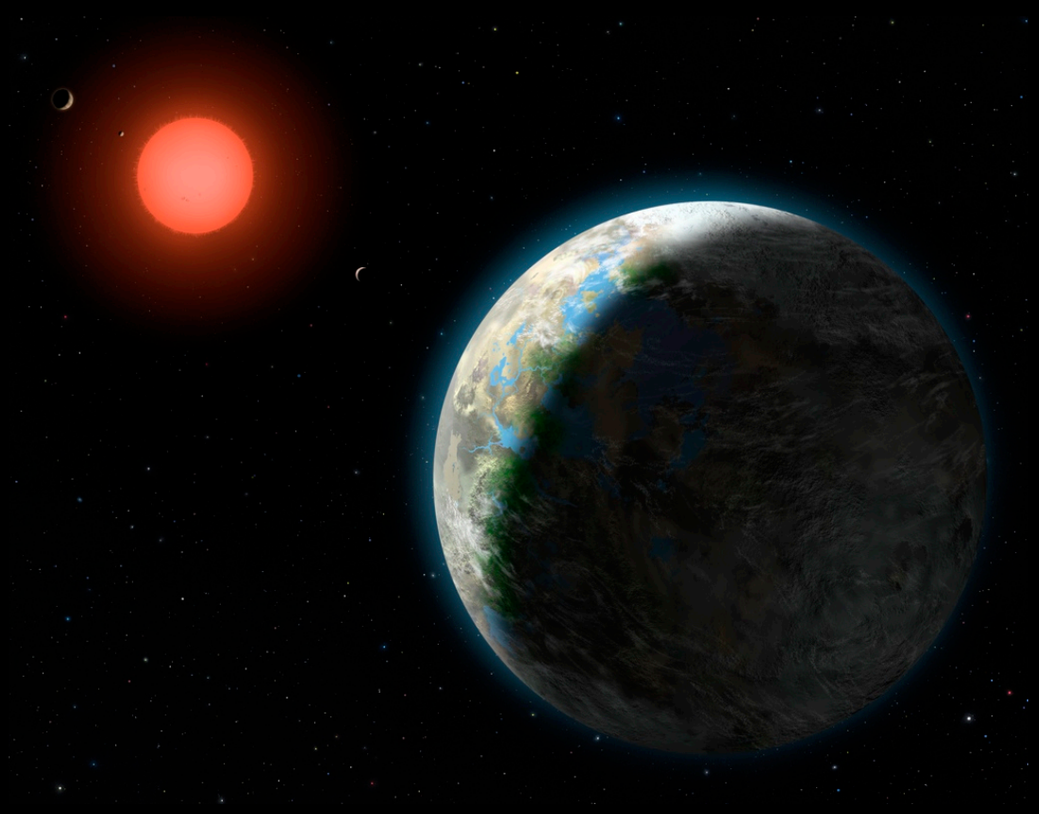






TESS:
The “People’s Telescope”

TESS Partnerships

MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MKI + LL)

PI, Payload, Science Center

NASA'S GODDARD SPACE FLIGHT CENTER

Mission Management, Engineering, Safety & Mission Assurance, E/PO

ORBITAL SCIENCES CORPORATION

Spacecraft Bus, Observatory I&T, Mission Operations Center

NASA AMES

Data Pipeline

SAO

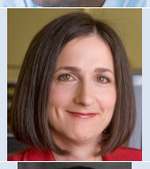
Follow-Up Program, Science Center

STScI

Archive, E/PO

Contributors include: SAO, MPIA-Germany, Las Cumbres Observatory, Geneva Observatory, OHP-France, University of Florida, Aarhus University-Denmark, Harvard College Observatory, STScI, and Vanderbilt University. There are no mission hardware contributions.

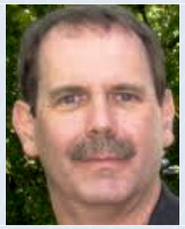
TESS Science Team

	G. Ricker (MIT-PI)			R. Vanderspek (MIT-DPI)	
	D. Latham (CfA)			J. Doty (Noqsi/MIT)		J. Lissauer (ARC)
	J. Winn (MIT)			T. Dunham (Lowell Obs.)		P. McCullough (STScI)
	J. Villasenor (MIT)			M. Holman (CfA)		S. Rinehart (GSFC)
	G. Bakos (Princeton)			J. Jenkins (ARC/SETI)		D. Sasselov (CfA)
	T. Brown (LCOGT)			G. Jernigan (Espace/UCB)		S. Seager (MIT)
	D. Charbonneau (CfA)			L. Kaltenegger (MPIA)		K. Stassun (Vanderbilt)
	J. Christensen-Dalsgaard (DN)			G. Laughlin (UCSC)		A. Szentgyorgyi (CfA)
	M. Clampin (GSFC)			A. Levine (MIT)		G. Torres (CfA)
	D. Deming (UMd)			D. Lin (UCSC)		S. Udry (Geneva Obs.)

TESS Team Includes Prime Kepler Members

D. Latham
(CfA)

J. Winn
(MIT)



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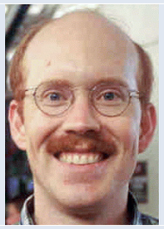

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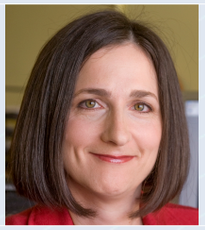

S. Seager
(MIT)

G. Torres
(CfA)

G. Marcy
(Collab. at UCB)

TESS's Seven Year History

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- **2006**: Conceived as a Privately-Funded Small Mission
  - *Kavli Foundation Support*
  - *Google Seed Funding*
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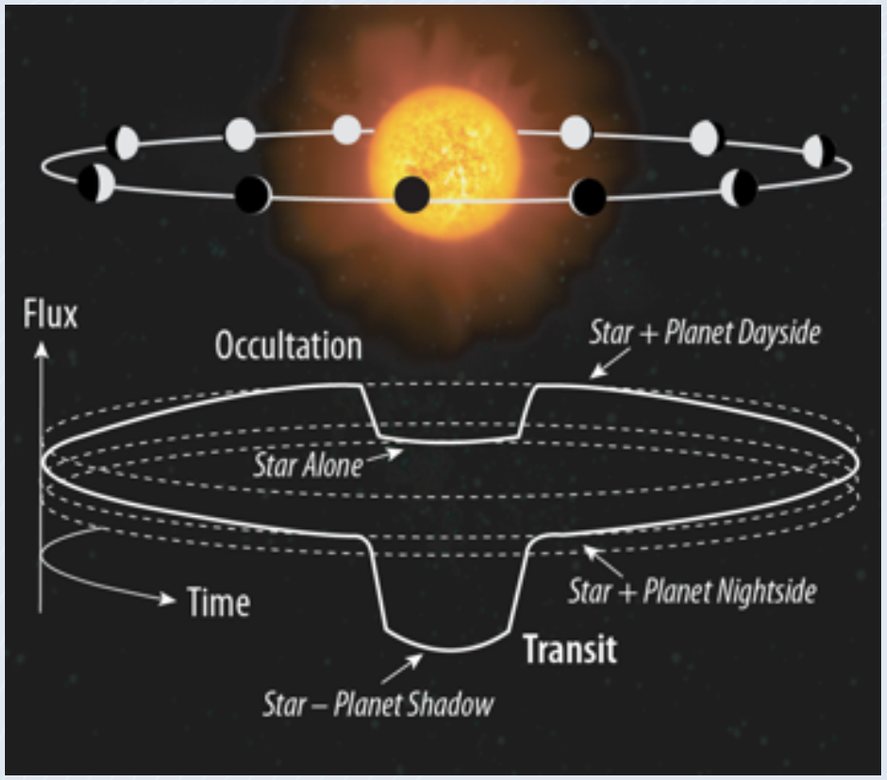
- **2013**: Selected for Implementation (April 5, 2013)
  - *Launch Ready in May 2017*

TESS Science Goals and Drivers



- Discover Transiting Earths and Super-Earths Orbiting Bright, Nearby Stars
  - *Rocky Planets & Water Worlds*
  - *Habitable Planets*
- Discover the "Best" ~1000 **Small** Exoplanets
  - *"Best" Means "Readily Characterizable"*
    - *Bright Host Stars*
    - *Measurable Mass & Atmospheric Properties*
  - *Only 2 small transiting exoplanets orbiting bright hosts are known*

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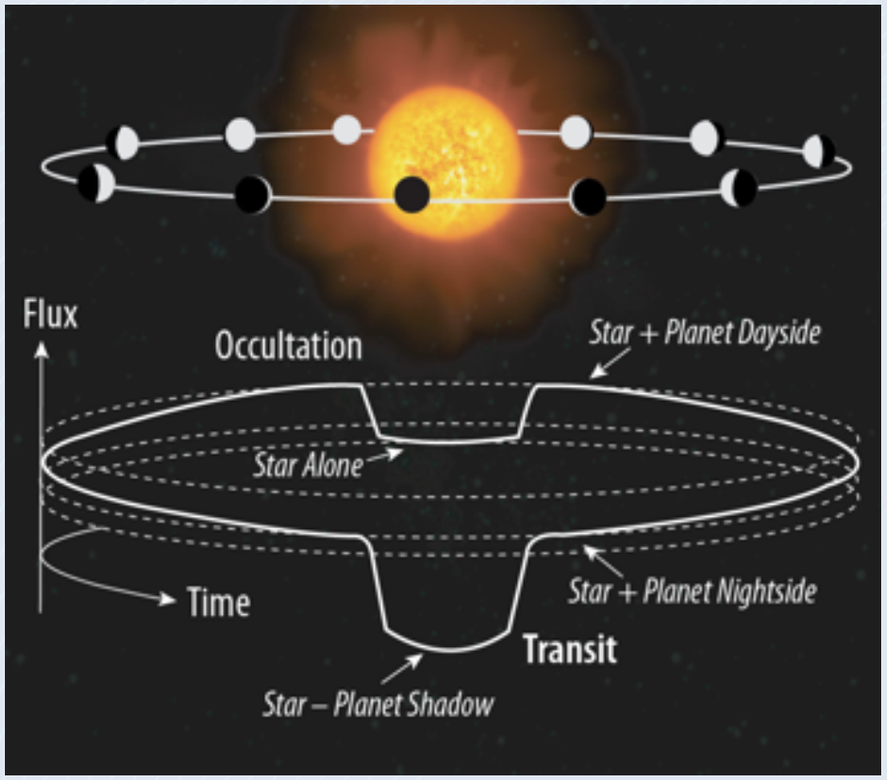

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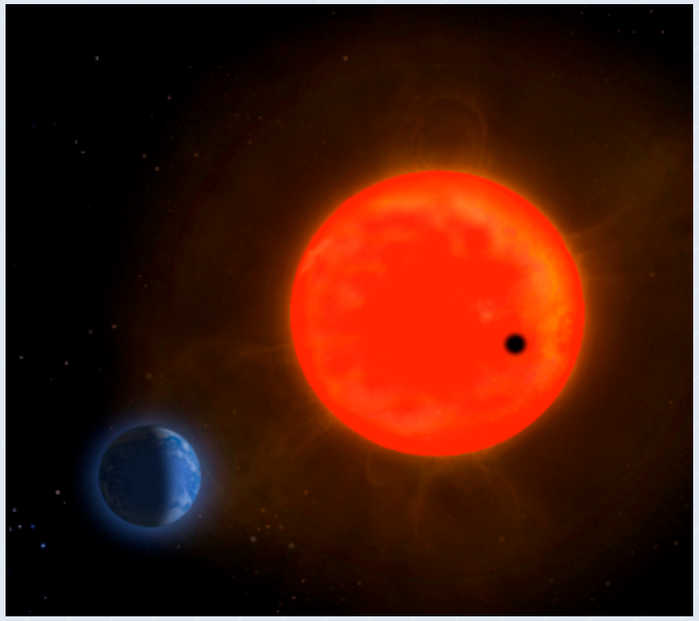
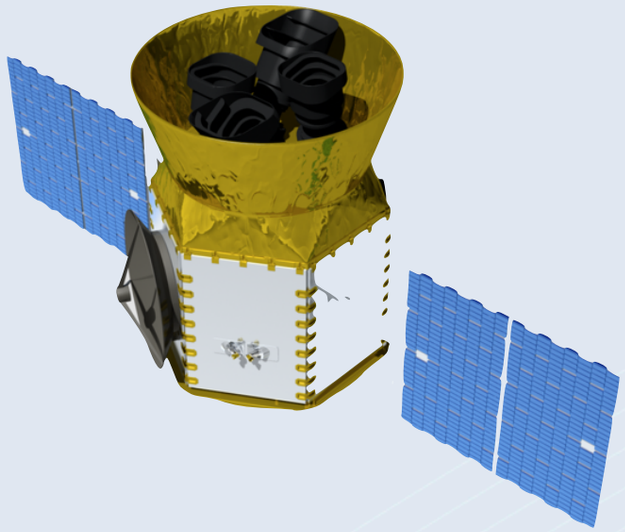
  - *Only 2 small transiting exoplanets orbiting bright hosts are known*
- All Sky Survey of Bright Stars
  - *F, G, K dwarfs: +4 to +12 magnitude*
  - *M dwarfs known within ~200 light-years*
  - *500,000 target stars in two years*



TESS and Kepler Answer Different Questions

- **TESS:**

  Where are the nearest transiting rocky planets?



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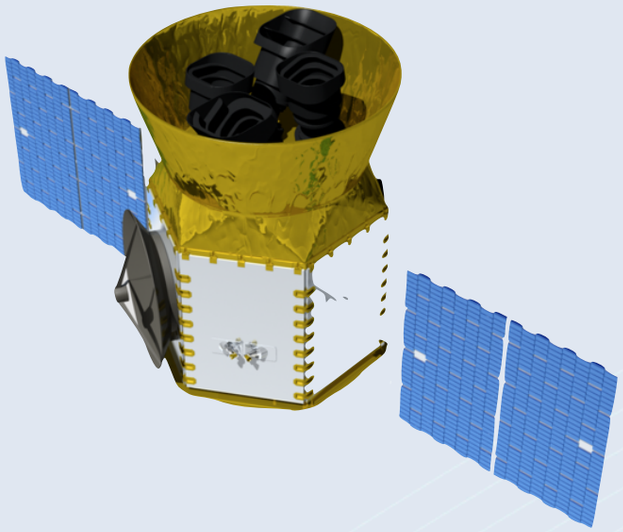
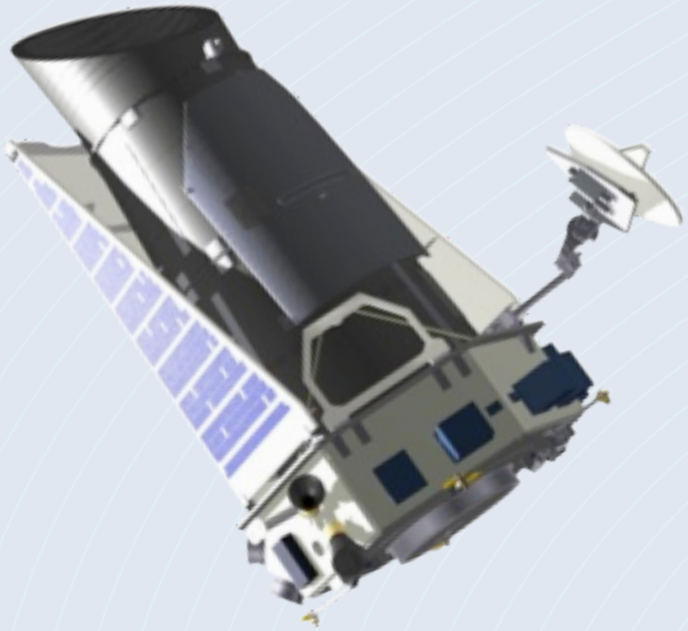


- **Kepler:**

  How common are true Earth analogs?



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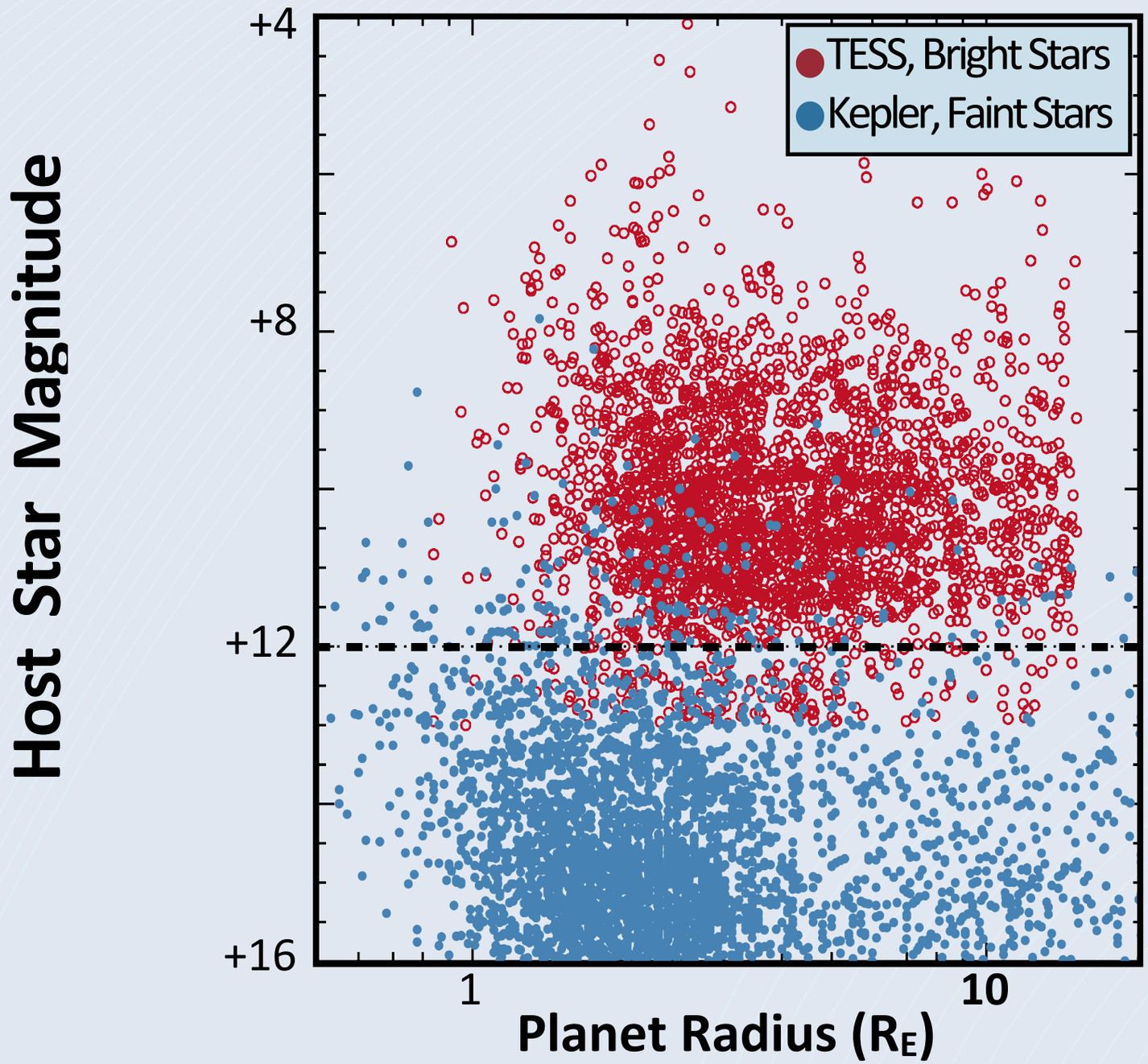
$1/R^2$ dependence means TESS stars are ~100 times brighter on average

Comparison of Host Star Brightness



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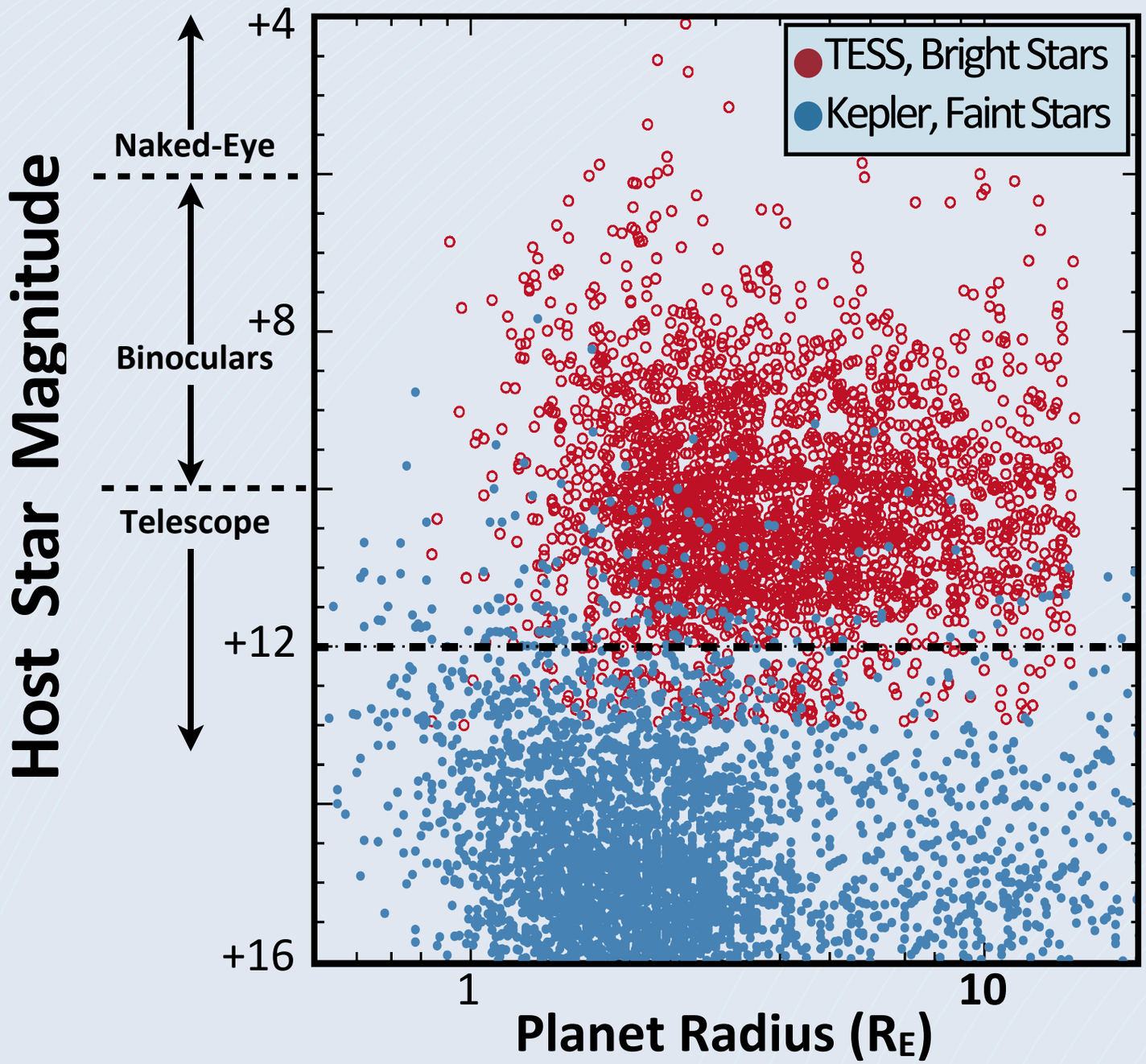

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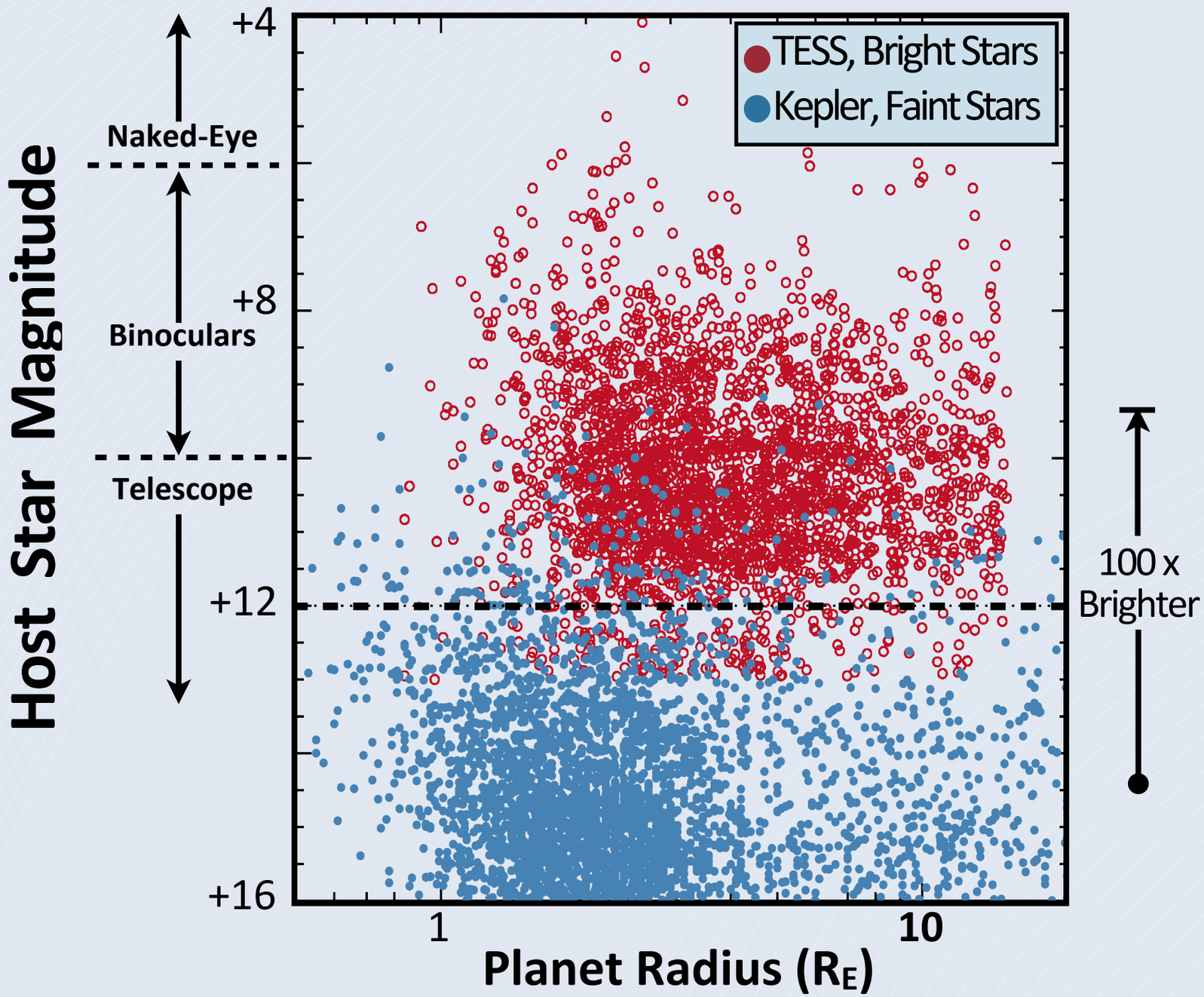

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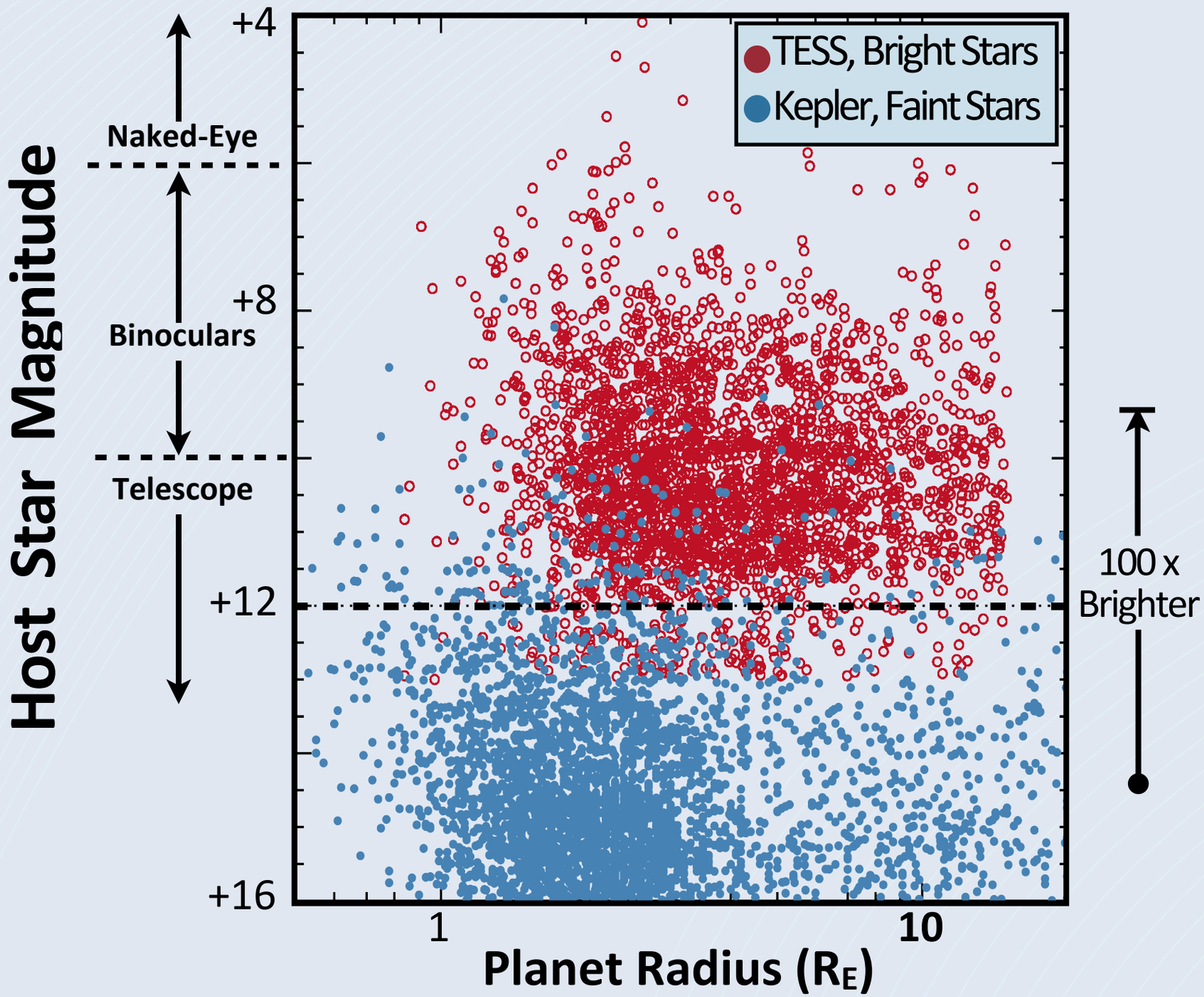

TESS Planets:
Easier to Followup

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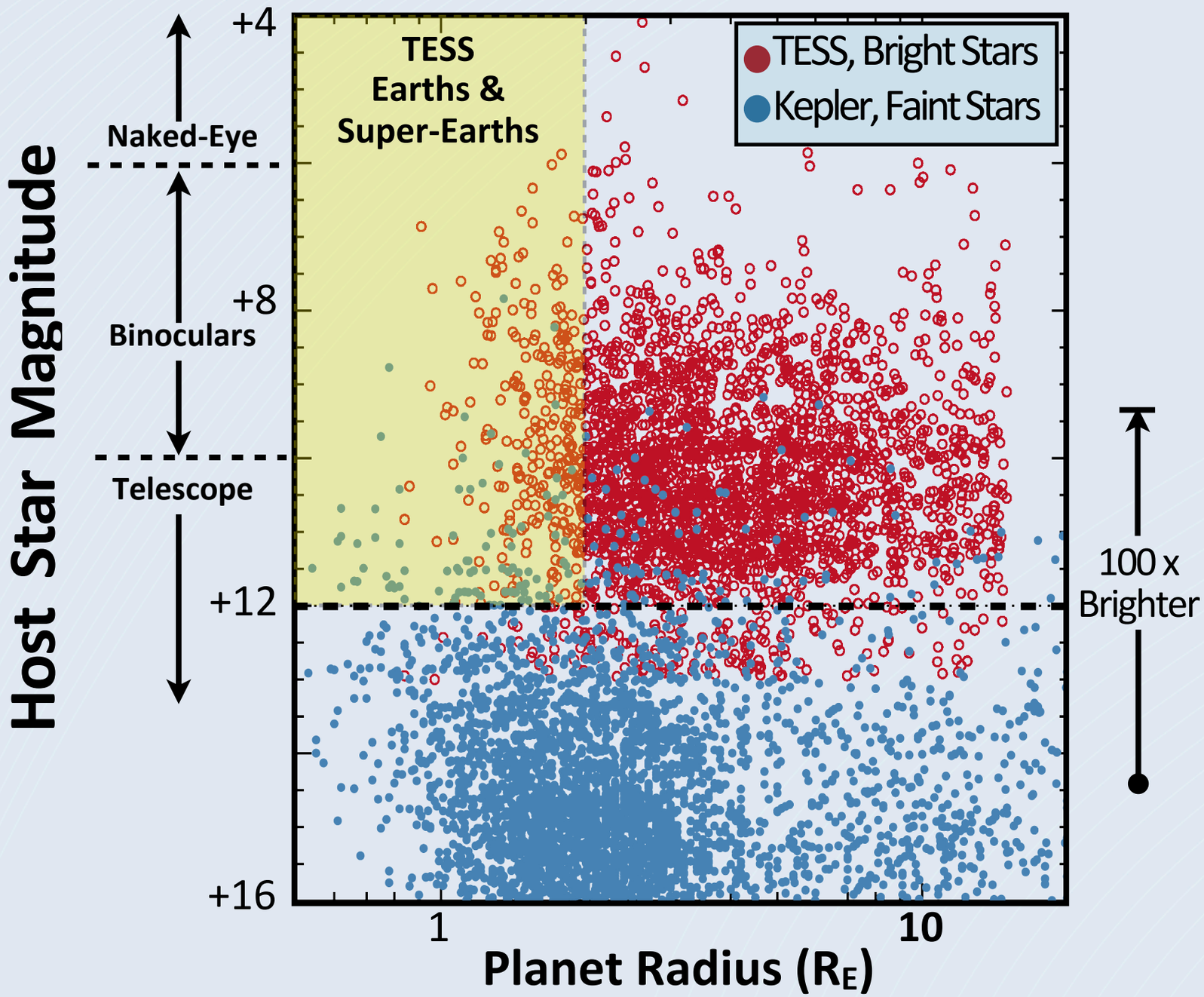

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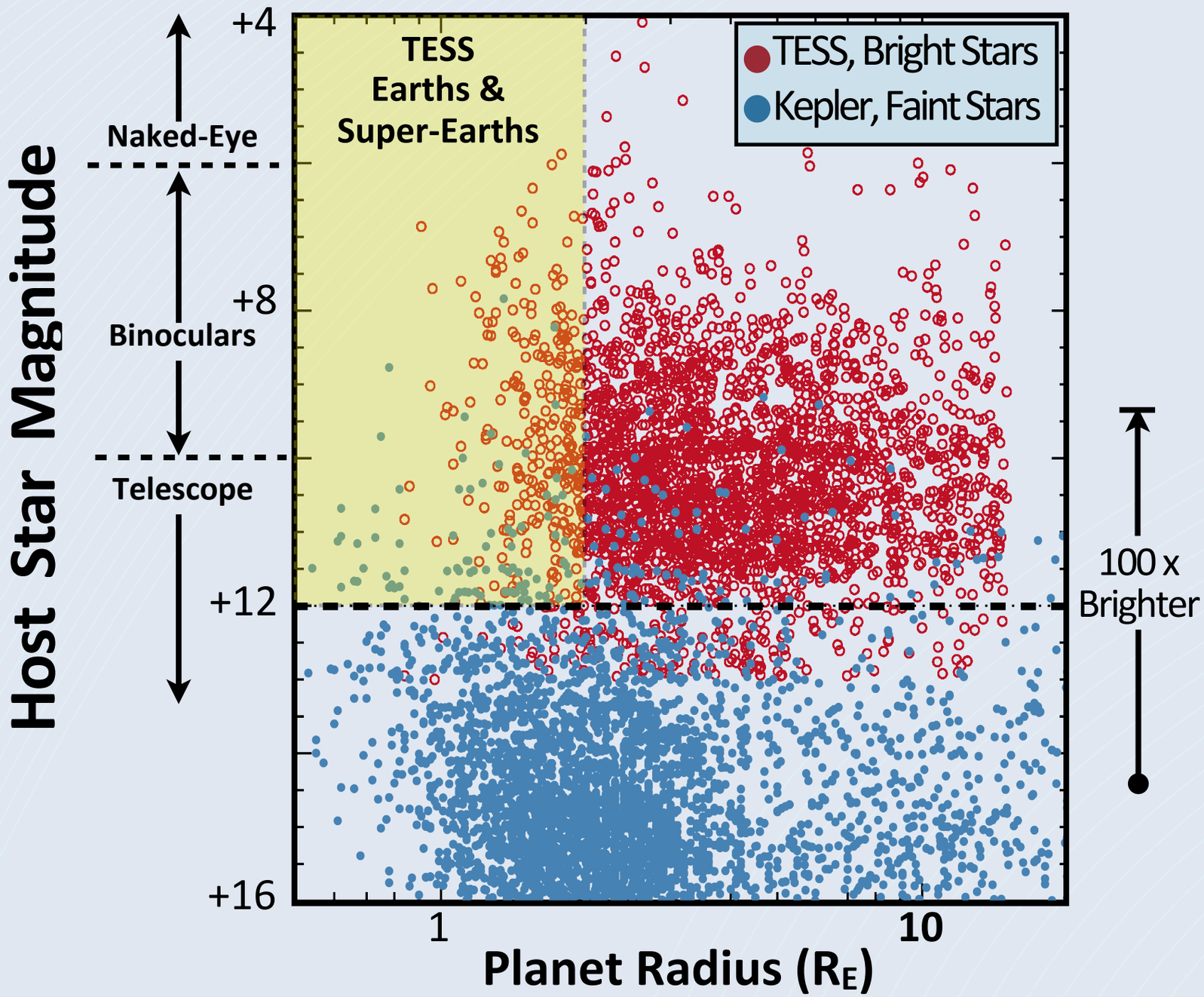

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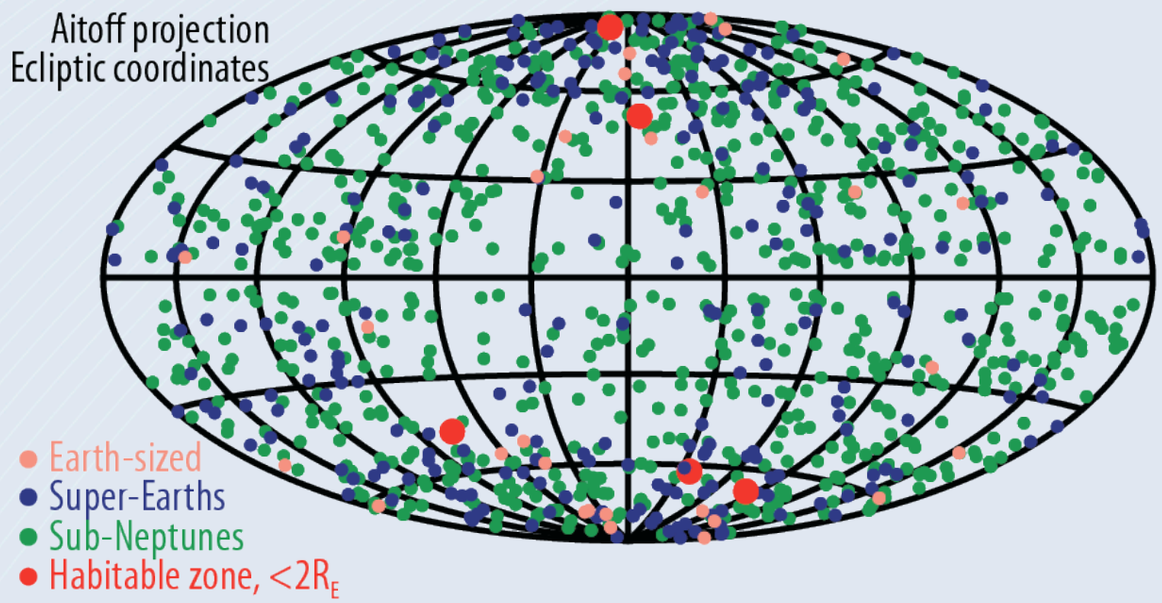
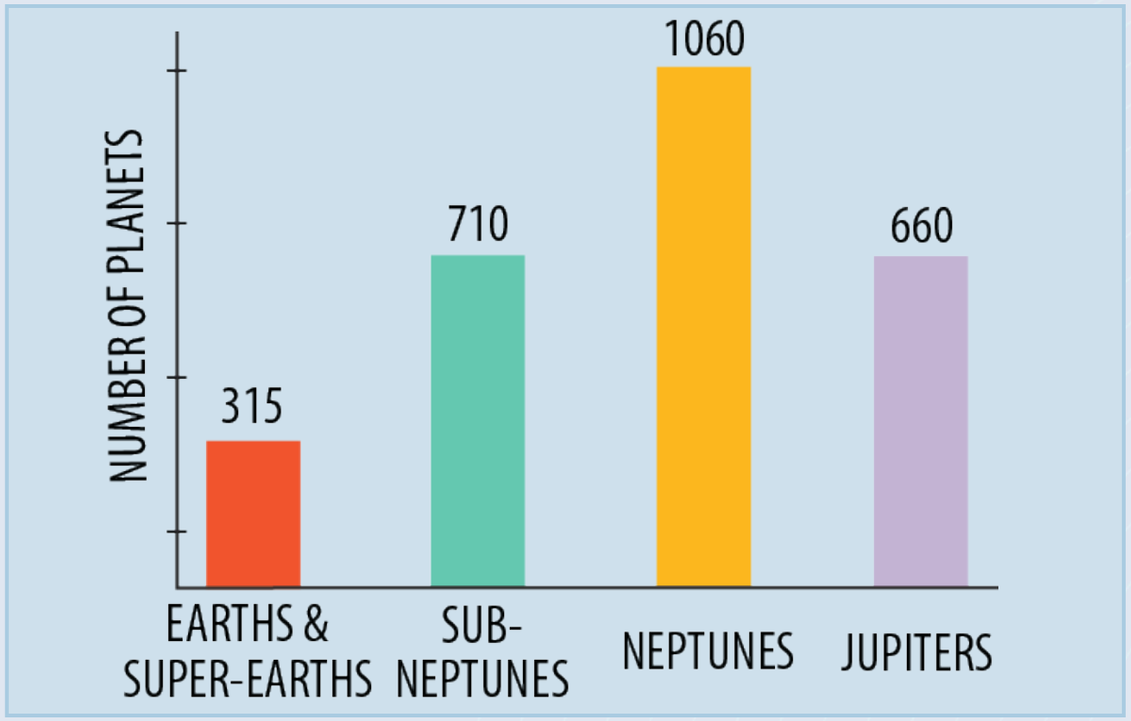
TESS Will Discover Earths & Super-Earths Orbiting Bright Stars

Predicted Science Yield from TESS Mission





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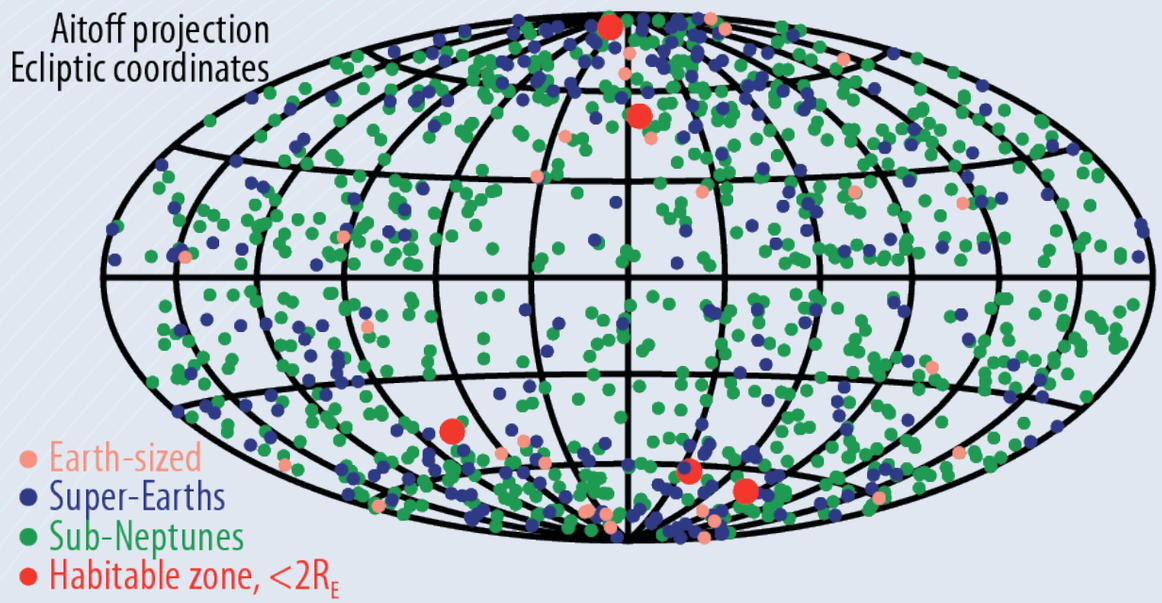
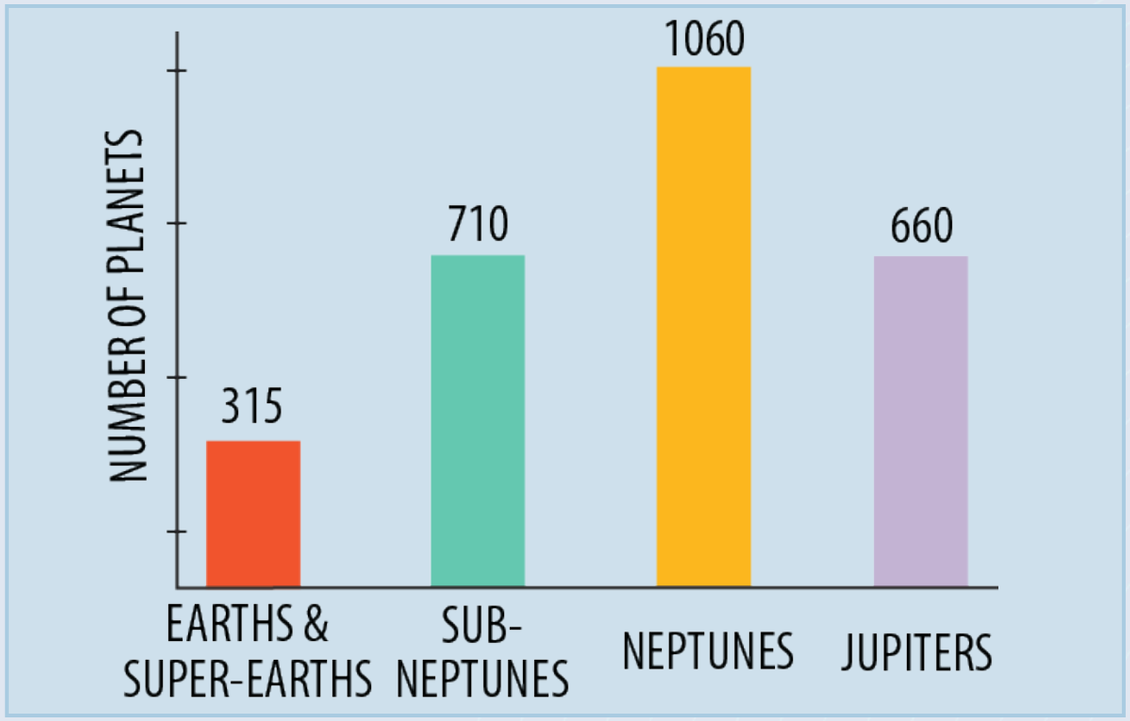
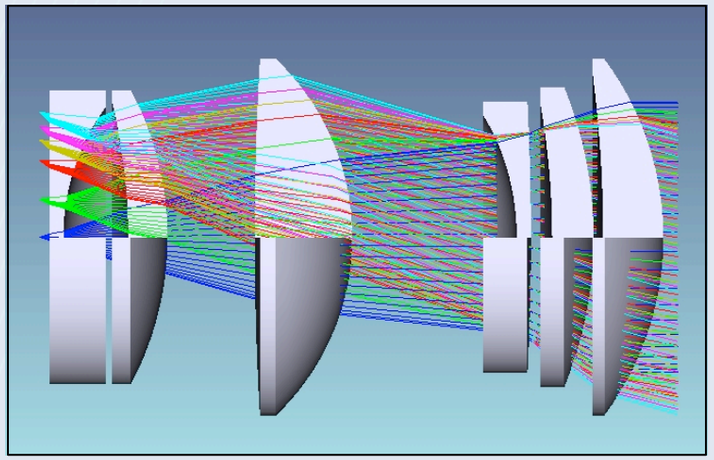


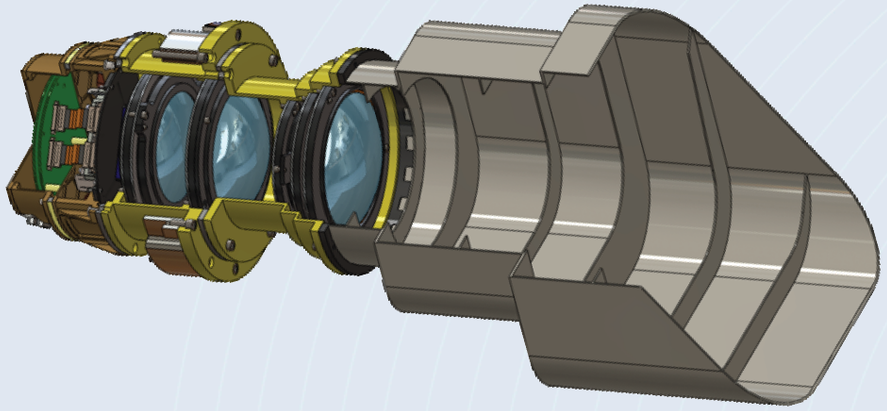


TESS Will Discover ~300 Earths & Super-Earths

Payload Overview

- Four identical wide-field CCD imaging cameras
  - *Straightforward optical design*
  - *Cameras passively cooled in a stable thermal environment*
  - *Heritage MIT/LL focal plane array*





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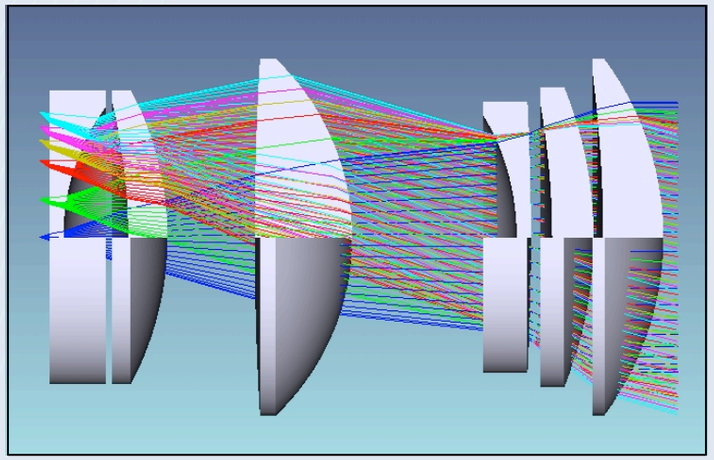
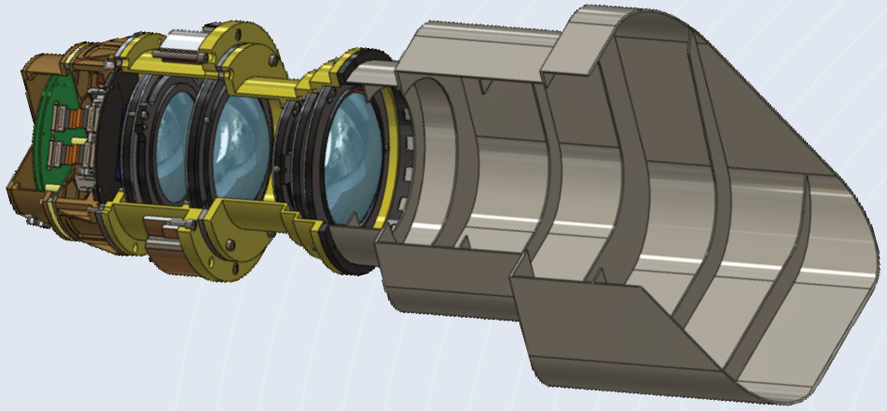
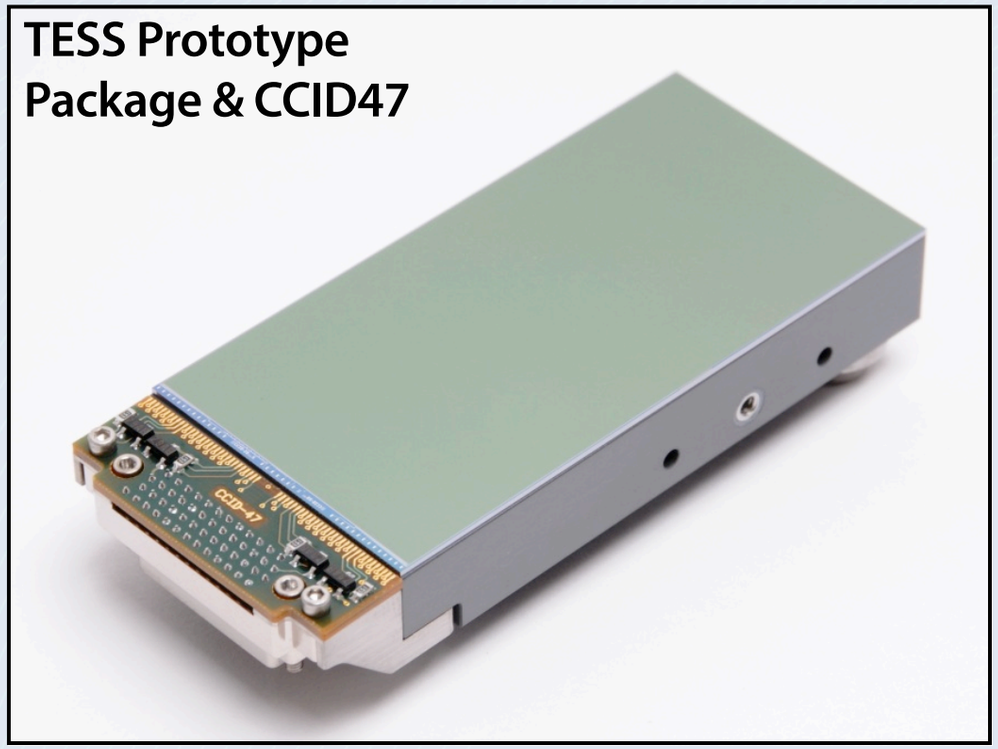
- SEAKR Data Handling Unit (DHU)
  - *FPGA front-end processors select & stack "postage stamps" around target stars*





TESS Wide FOV CCD Camera

CCD Package & Focal Plane Array Photos



- TESS CCD package derived from qualified designs:
  - *NASA WFIRST*
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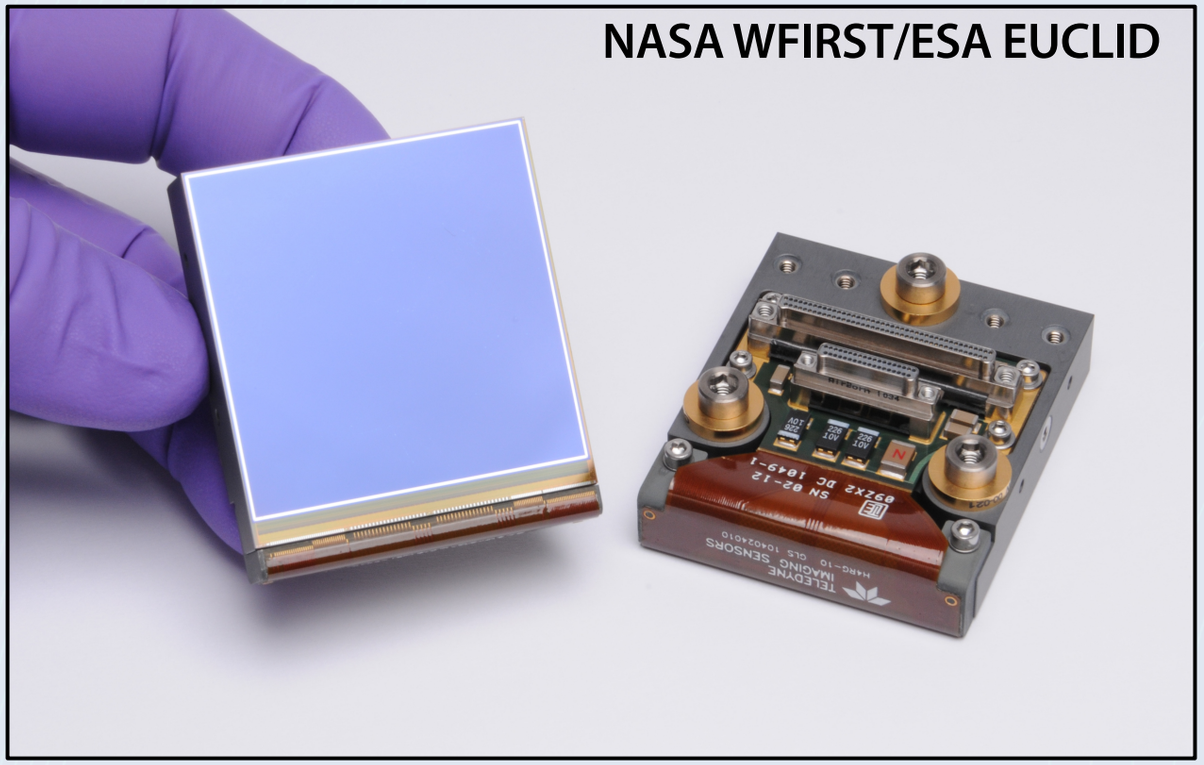

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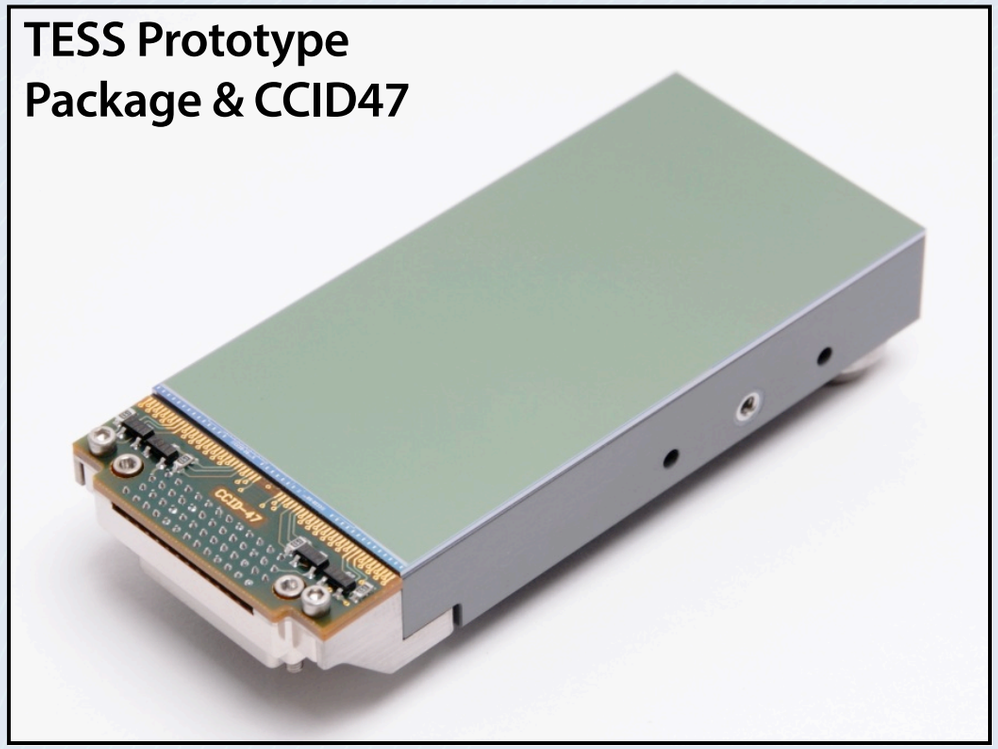

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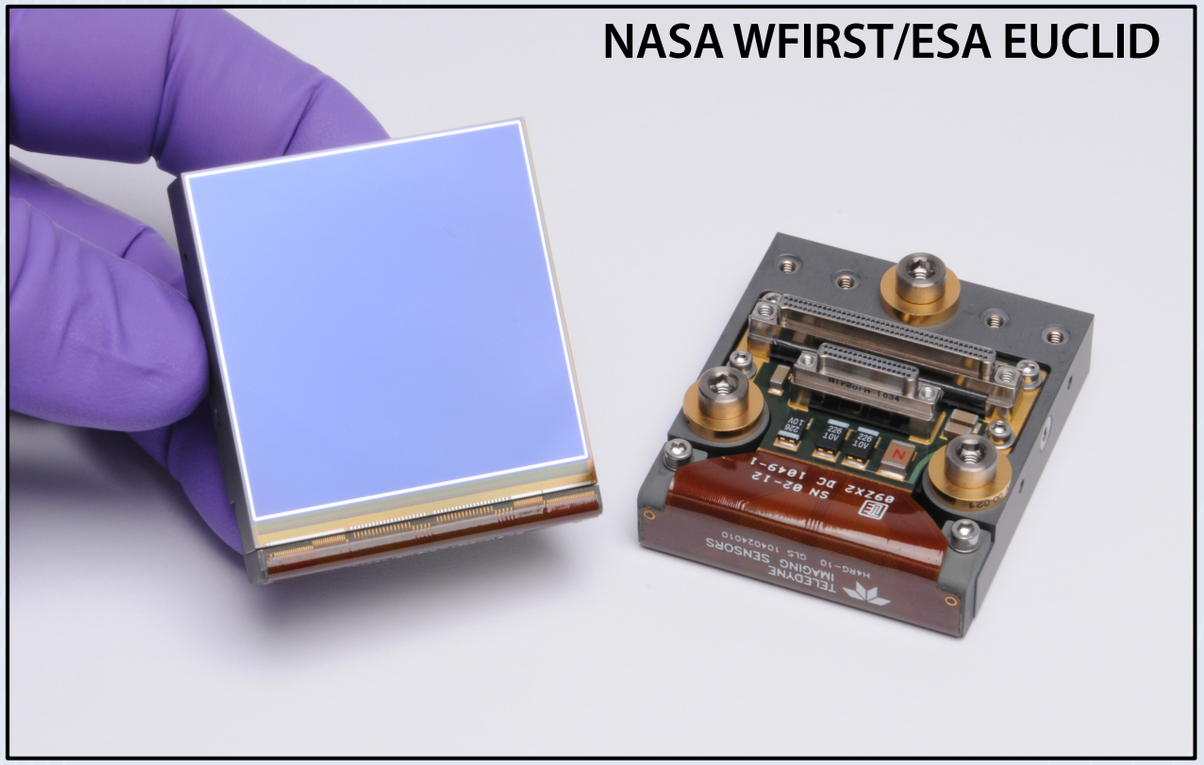
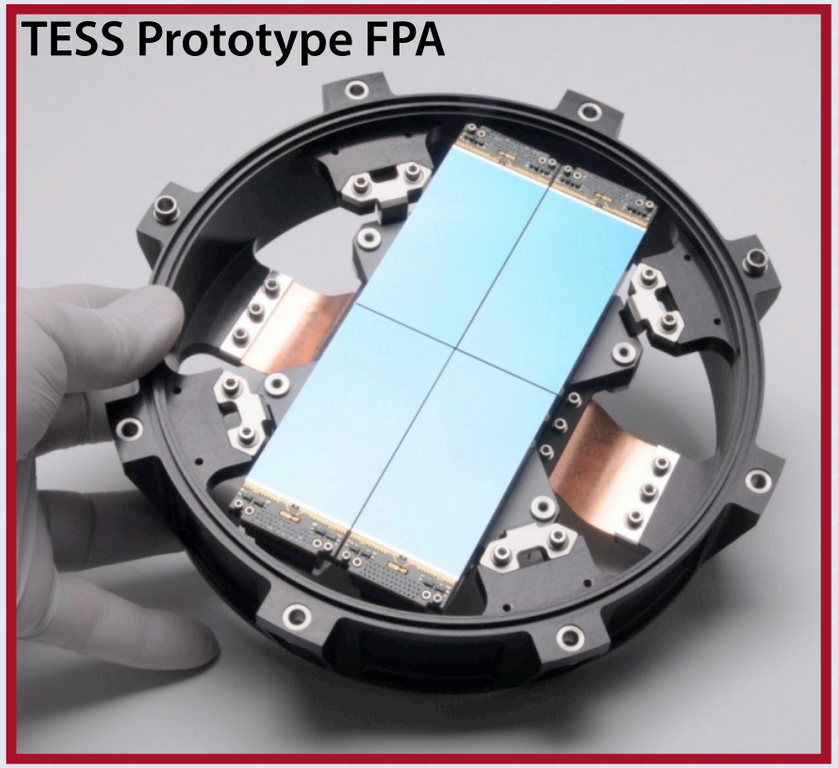
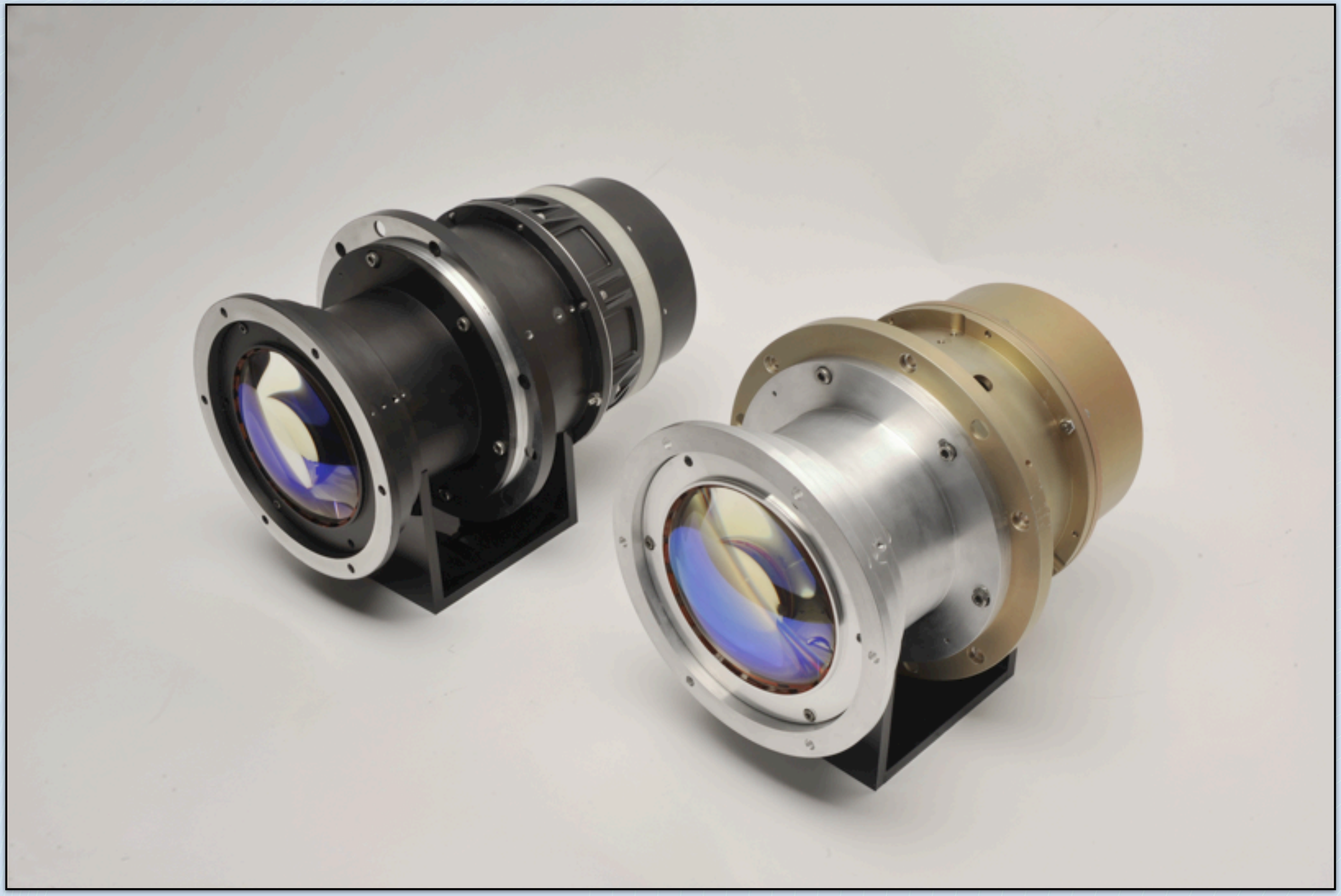
- Prototype FPA identical to flight FPA
  - *Identical SiC material and vendor*





TESS Prototype Cameras

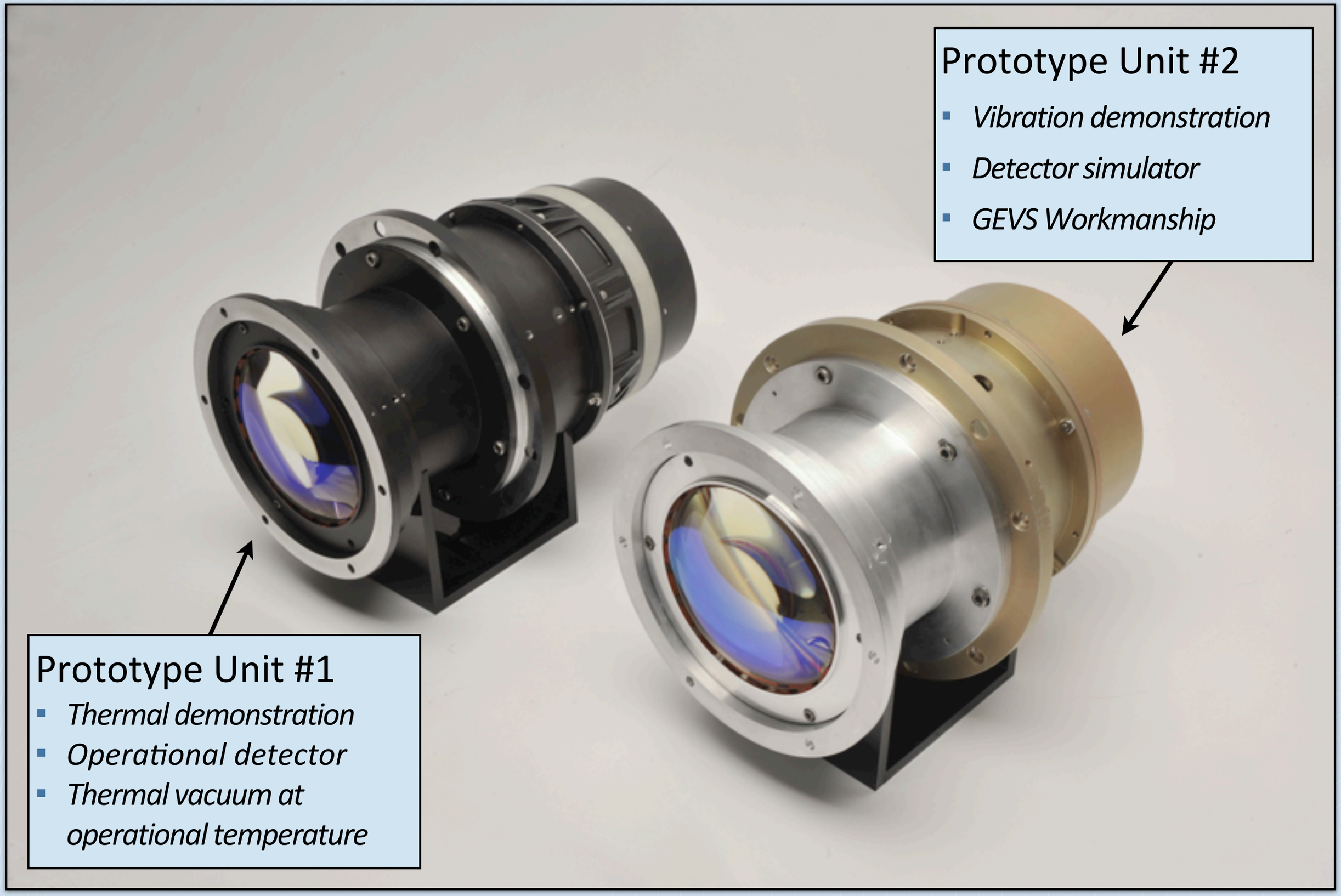


TESS Prototype Cameras

Prototype Unit #1

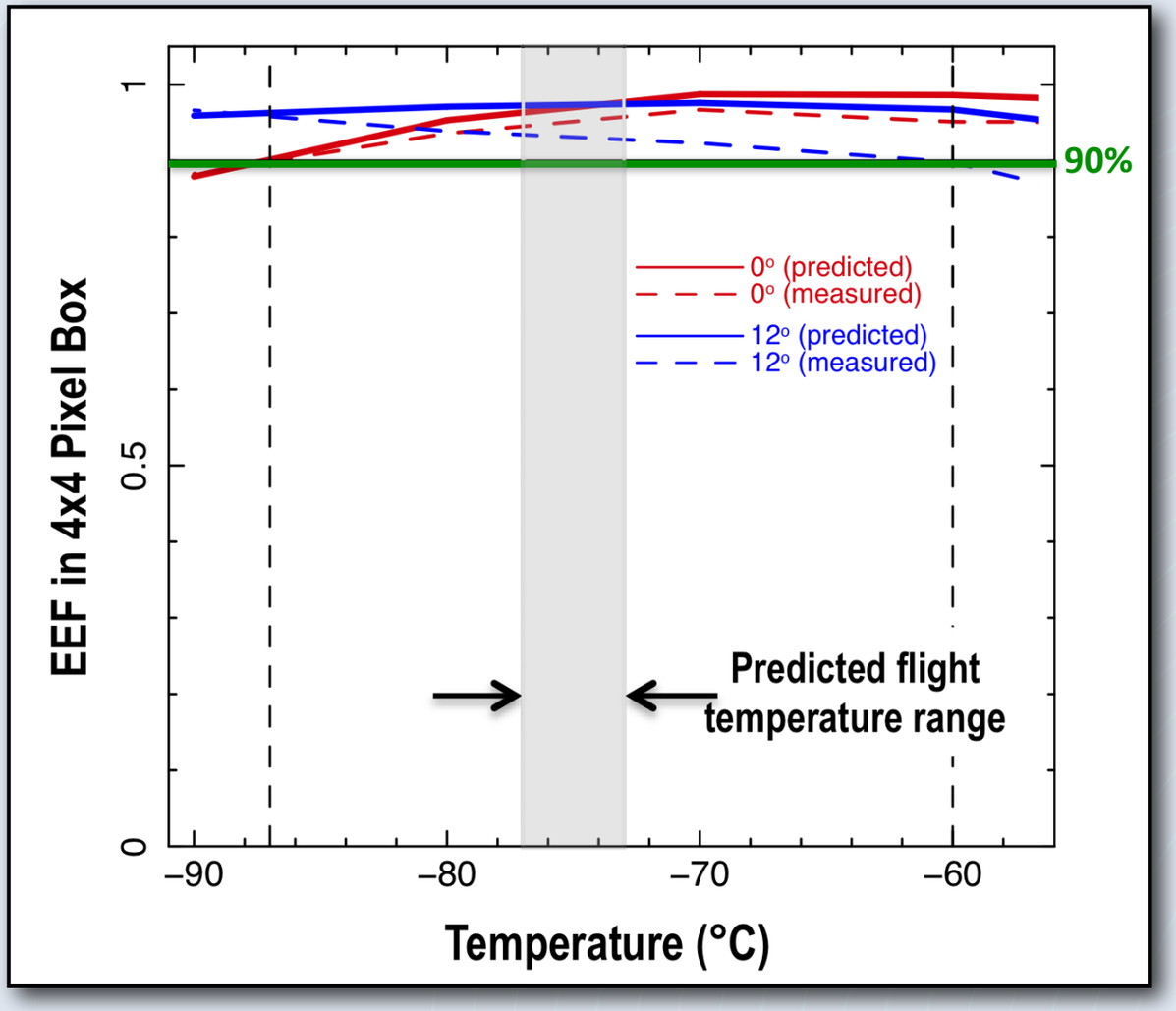
- *Thermal demonstration*
- *Operational detector*
- *Thermal vacuum at operational temperature*

TESS Prototype Cameras



TESS Prototype Optical Performance

- Polychromatic EEF was measured over temperature
  - *Measurements compare well with predictions*
  - *EEF meets specification over >25°C range*
  - *Predicted lens temperature excursion in flight is ± 2°C*

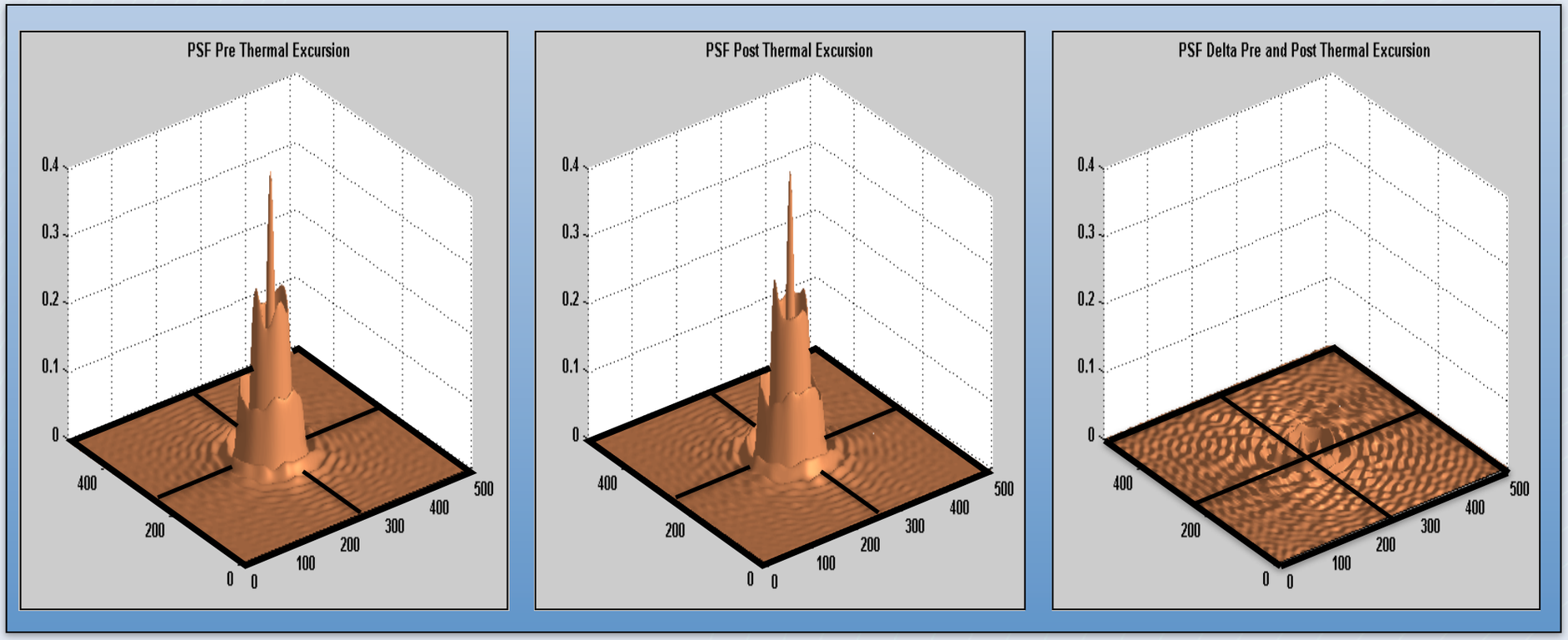


EEF = Ensquared Energy Fraction

Optical Alignment Stability of Prototype Cameras

- Optical properties measured interferometrically:
  - *Before and after 10 thermal cycles from ambient to -90°C*
  - *Before and after vibration at GEVS workmanship levels*
  - *No discernible difference identified after cycling*

Pre-Thermal **Post-Thermal** **Difference**



Scales on X & Y Axes: 500 units = 30 microns

Optical Alignment is Stable Over Thermal and Vibration Cycling

Full Size Replica of TESS

How TESS Gets Launch Ready By 2017…

- Simple Mission Design
  - *HEO assures stable instrument operation*
    - *Anti-sun, fixed inertial pointing*
    - *Infrequent maneuvers*
  - *All cooling is passive*
  - *Solar panels are the only deployable*
- Four Identical Cameras
  - *Modest aperture*

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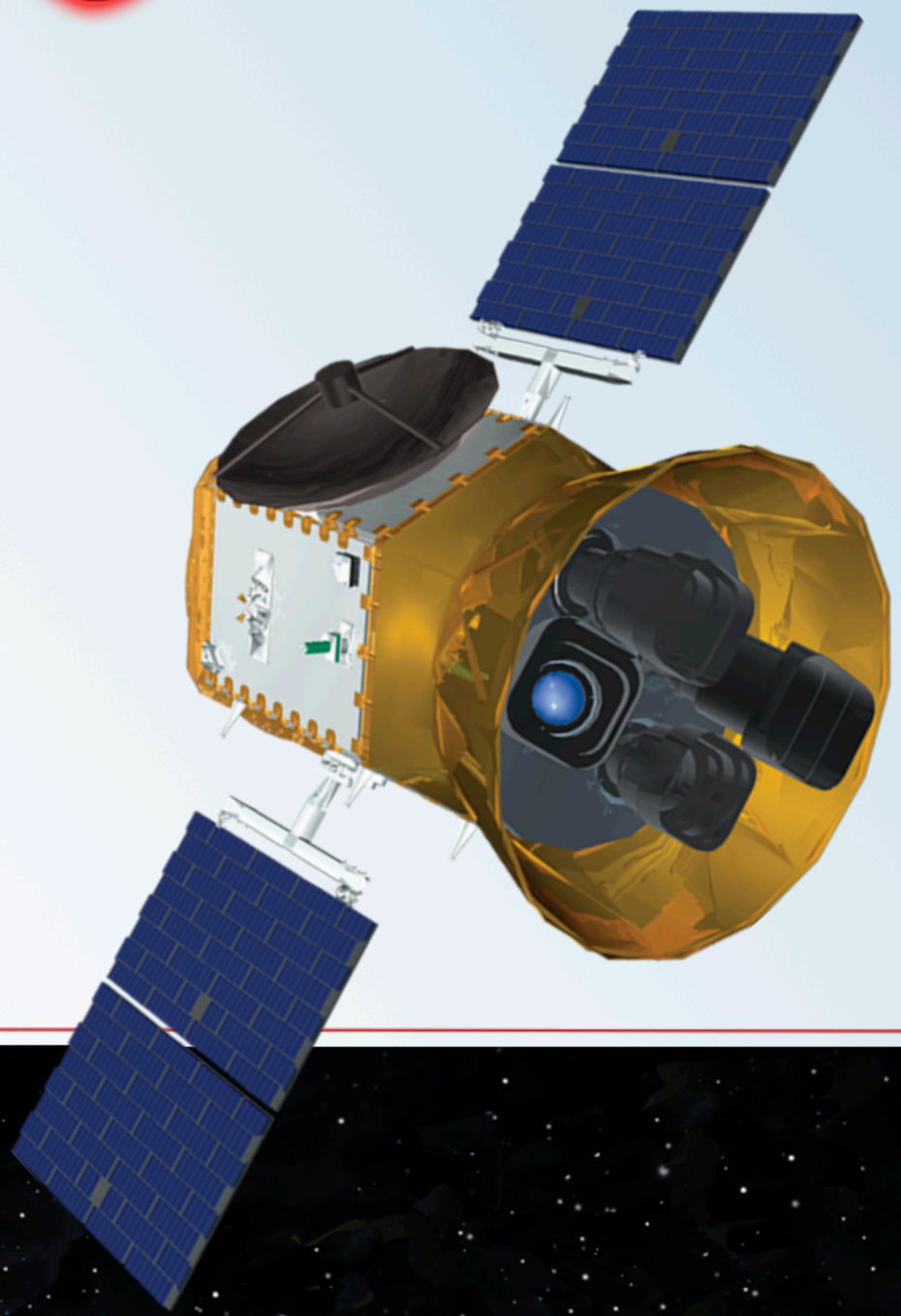
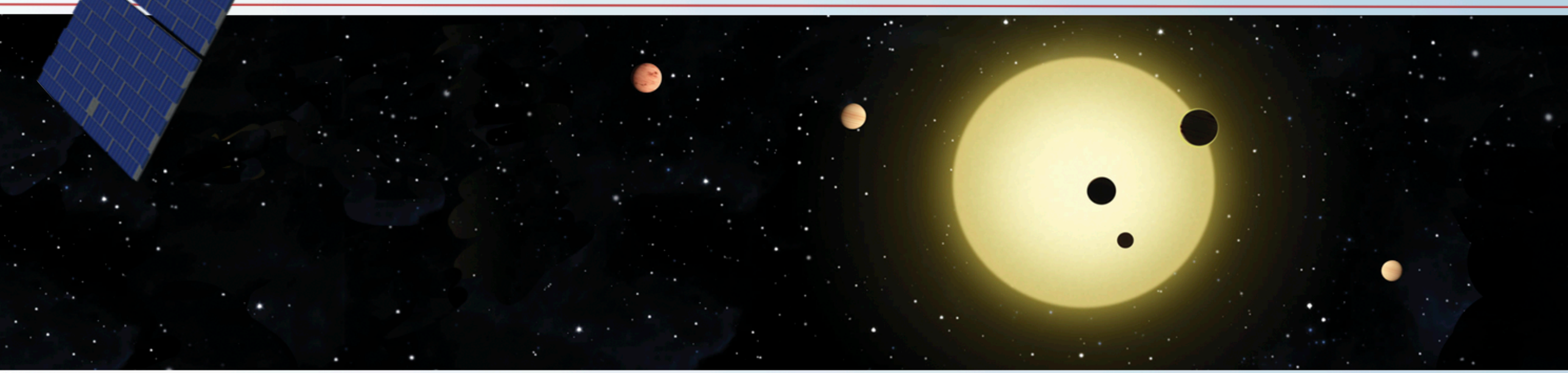
    - *Infrequent maneuvers*
  - *All cooling is passive*
  - *Solar panels are the only deployable*

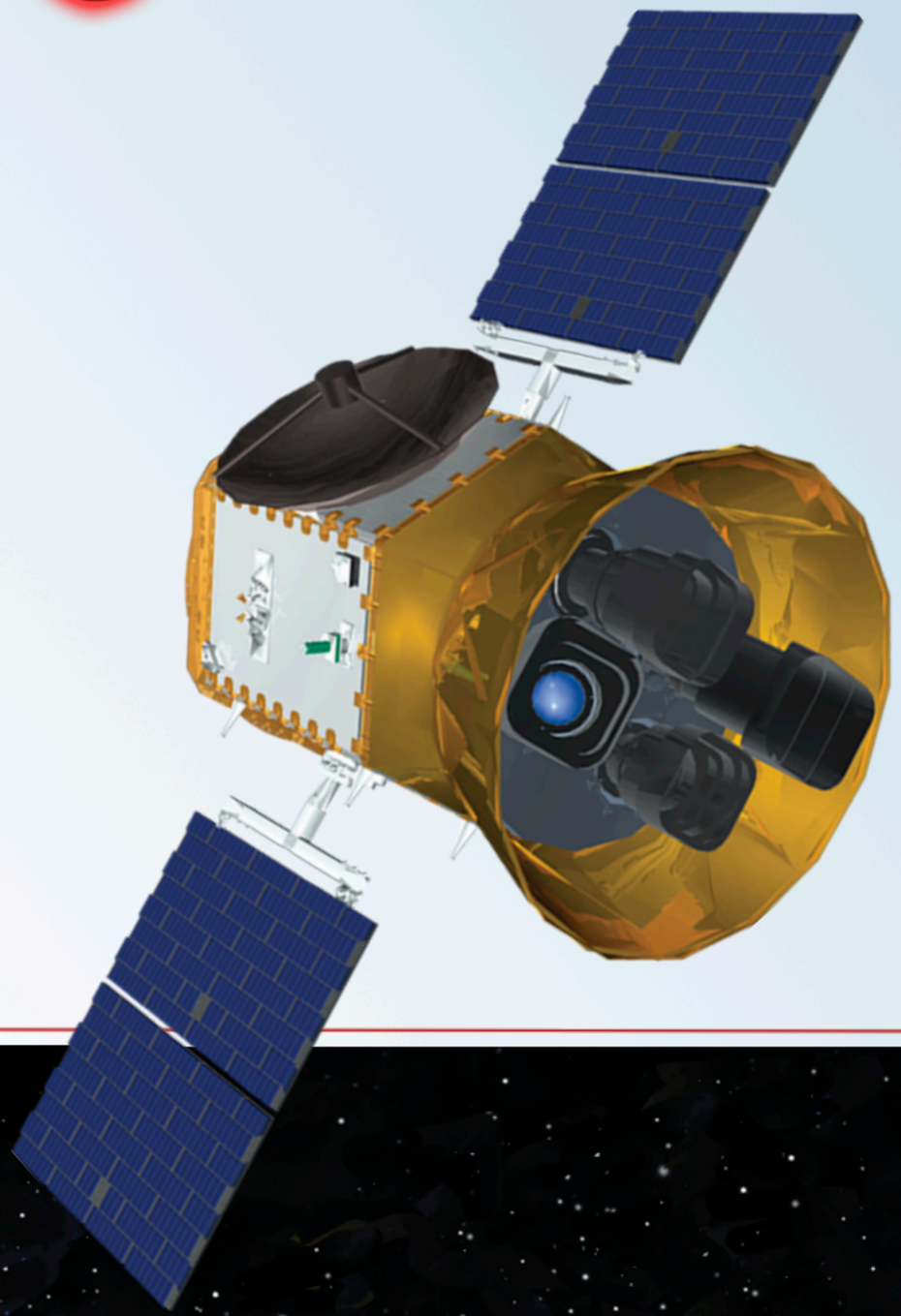
- Four Identical Cameras
  - *Modest aperture*
- Simple Payload Interface to Orbital's Heritage Bus
  - *Cameras bolt in place with no critical alignments*



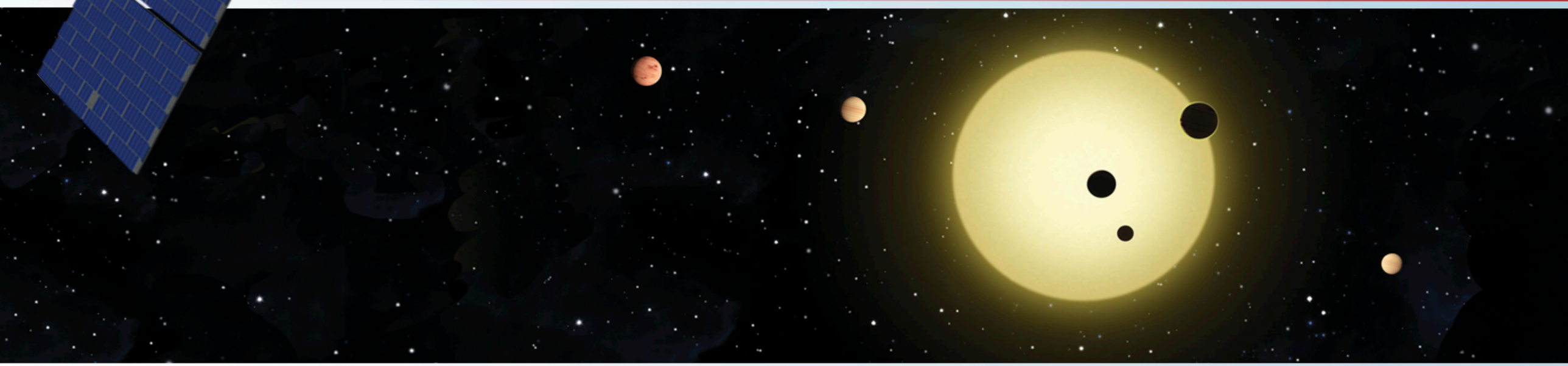
TESS Mission Video

http://www.youtube.com/watch?v=mpViVEO-ymc



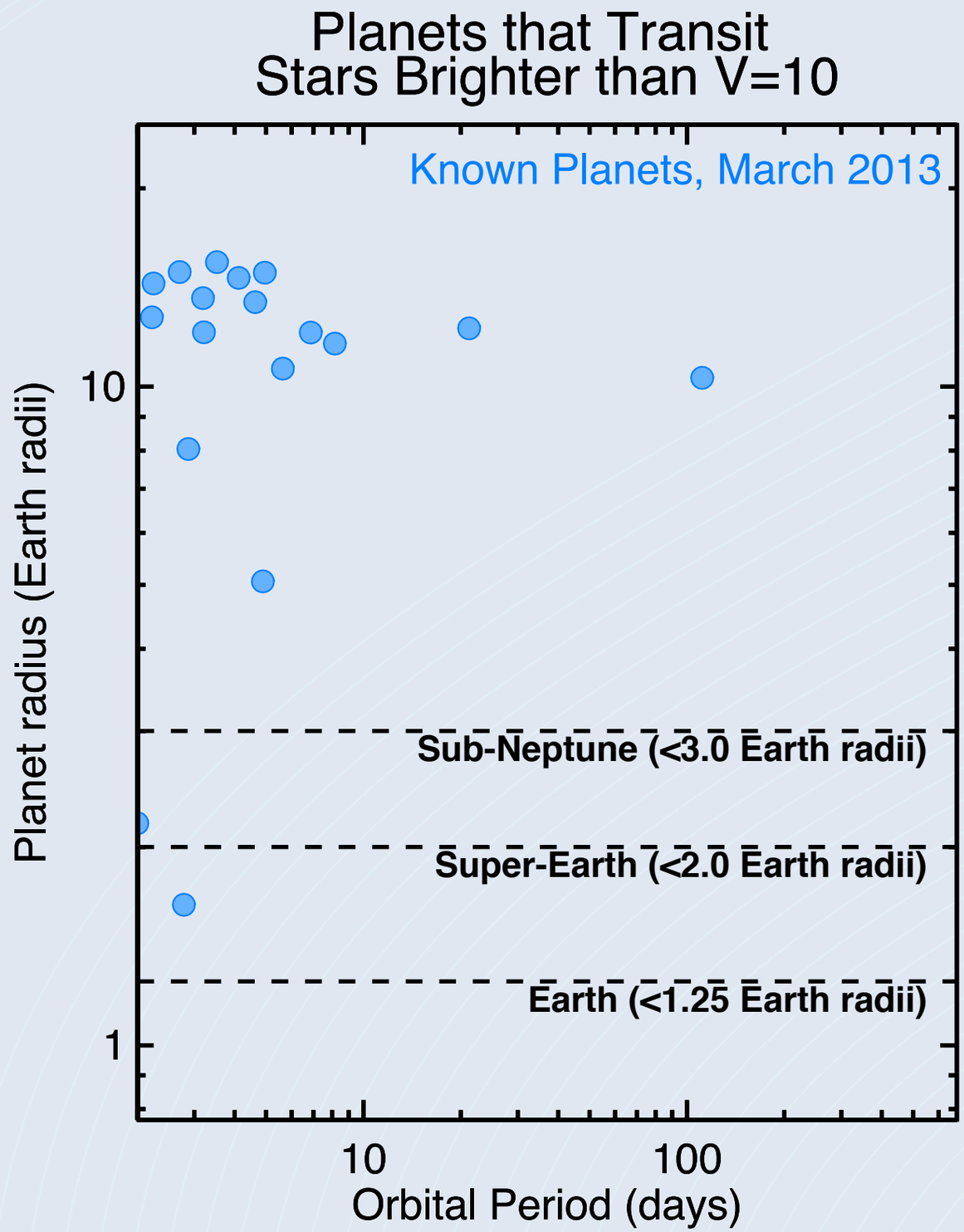


Why TESS?
Why Now?



Small Planets and Bright Stars

- ***Kepler:*** The most common members of the exoplanet family are Earths and Super-Earths
- Population of characterizable Earths and Super-Earths is extremely impoverished
- Two smallest transiting exoplanets with bright hosts were discovered from space:
  - *Kepler-21b: Kepler Team*
  - *55 Cnc e: Co-I Josh Winn*



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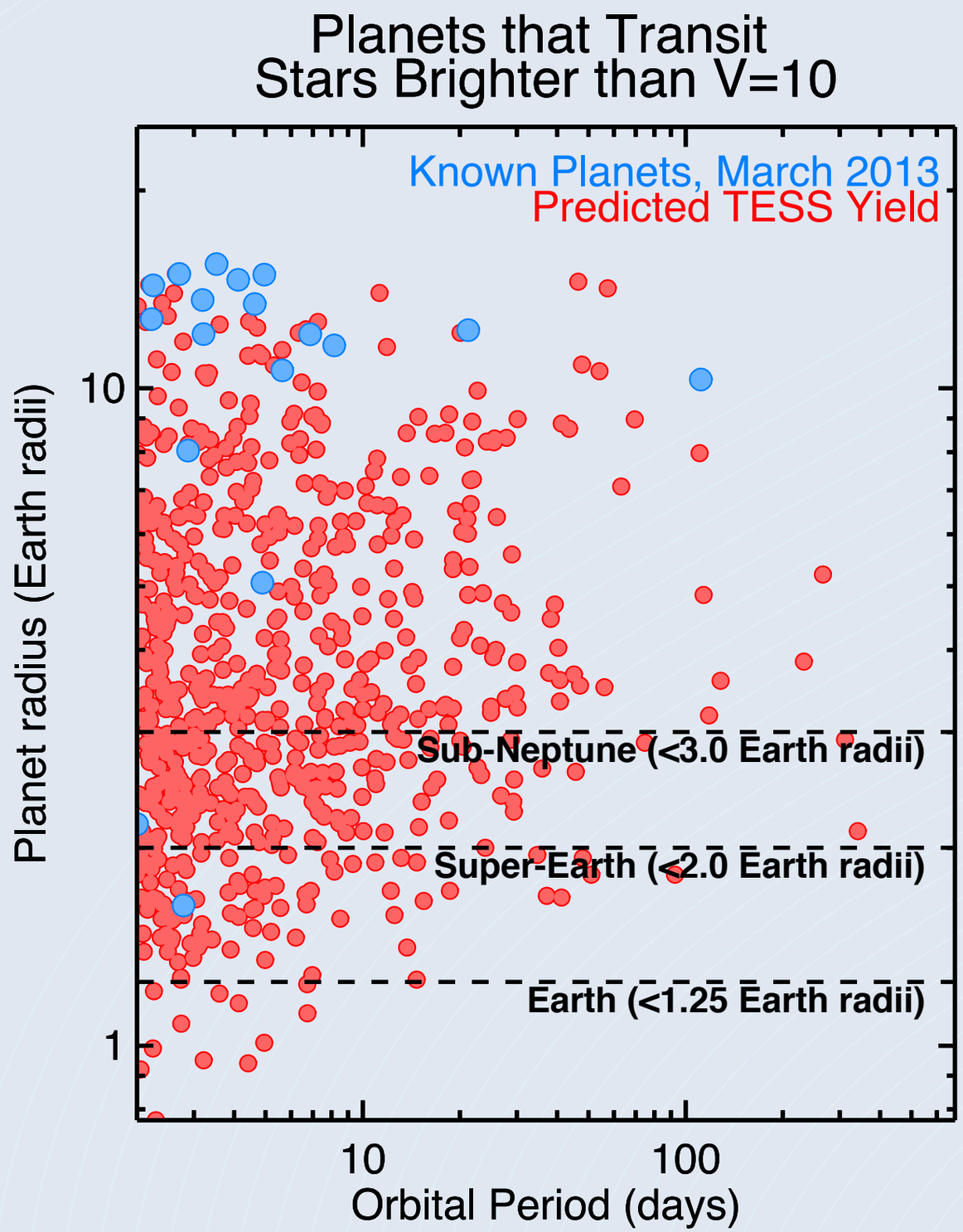

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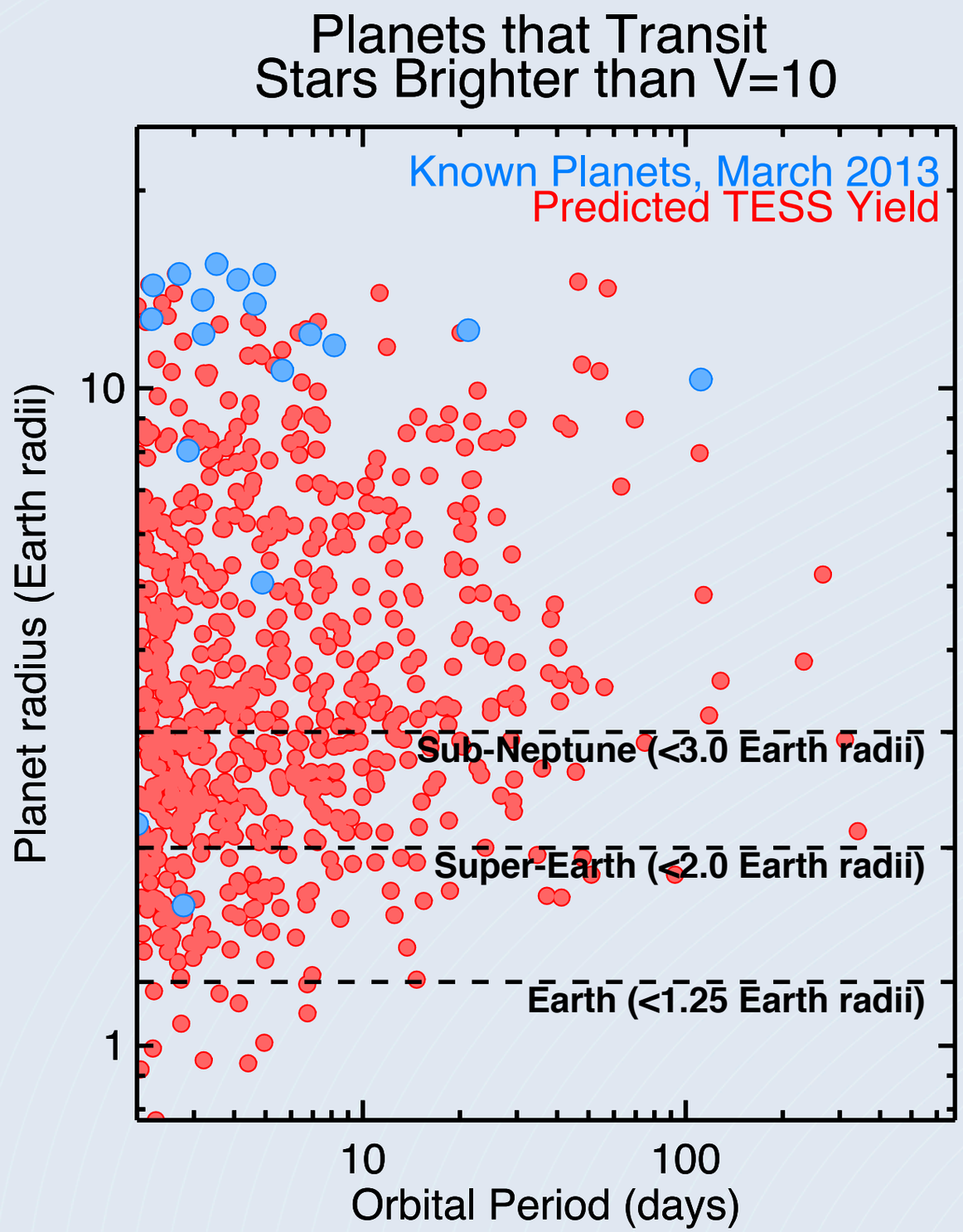
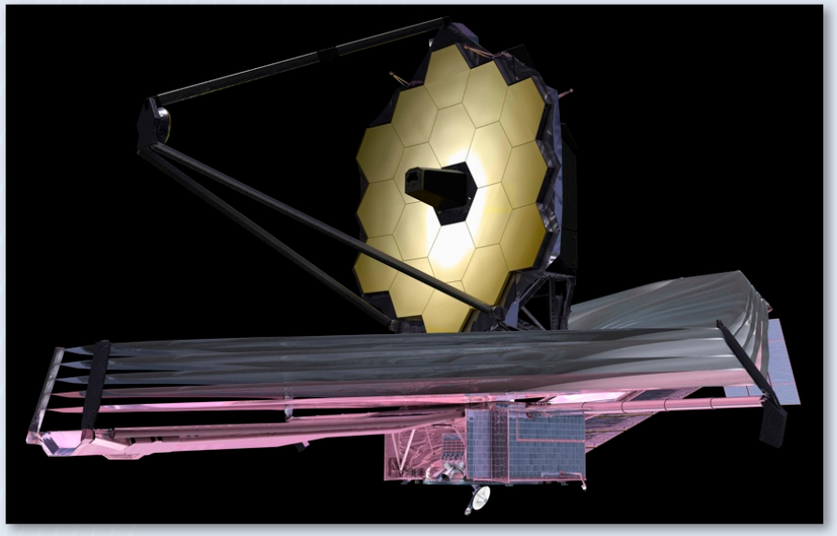
Only TESS Can Discover the Earths and Super-Earths Transiting the Brightest Stars



TESS Enables Atmospheric Characterization

- TESS will identify the **best and smallest** exoplanet targets for characterization of atmospheres using:
  - *JWST*
  - *Extremely Large Telescopes (ELTs)*
  - *Future Exoplanet Explorers, Probes, and Large Missions*



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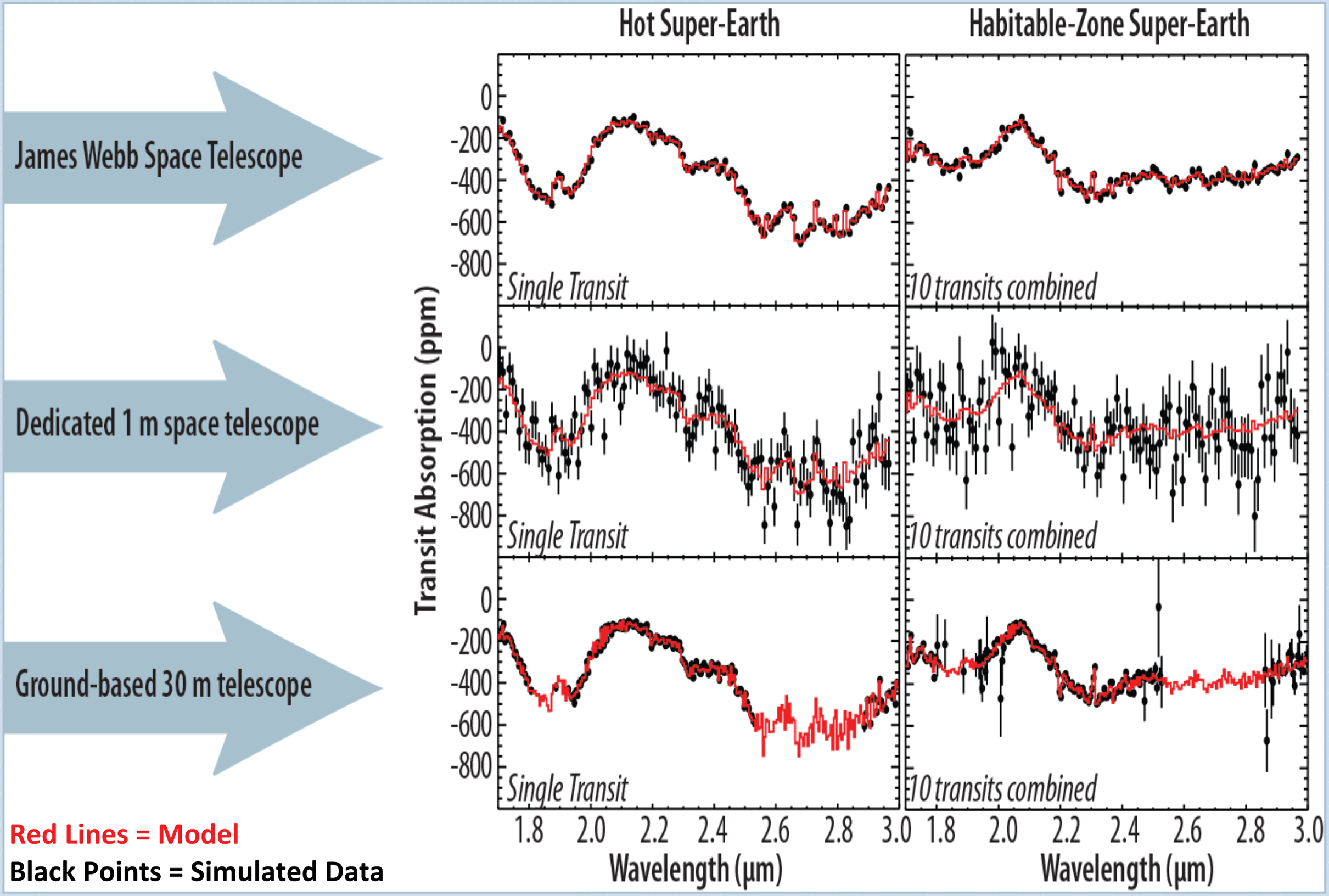
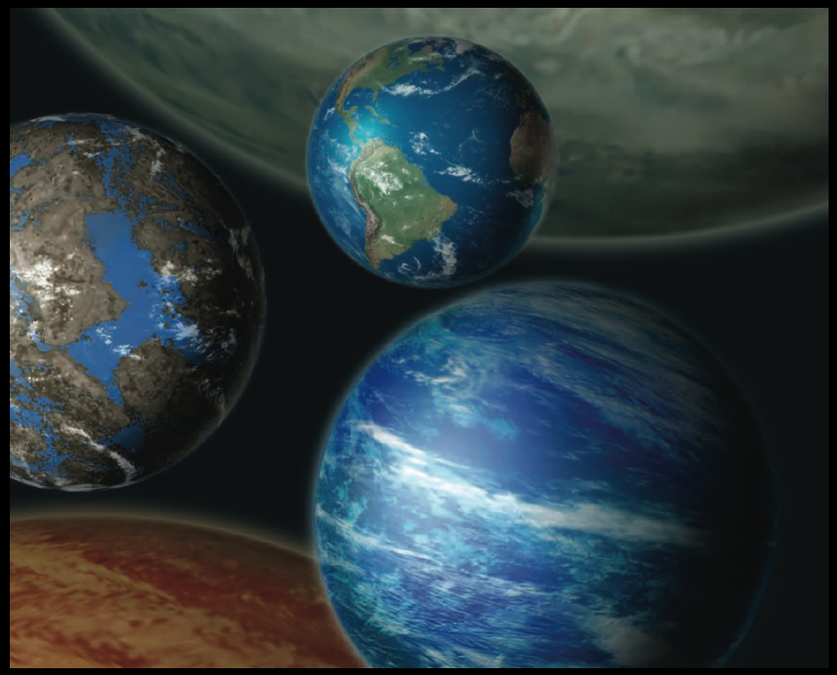
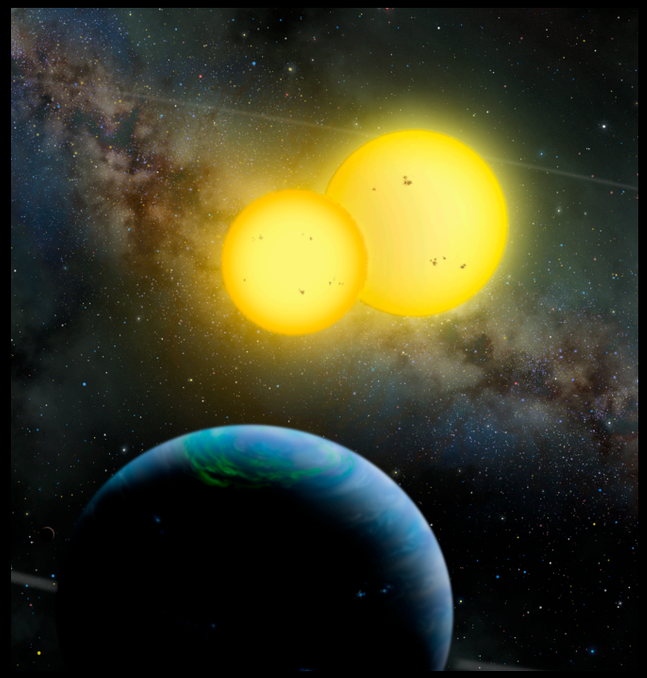


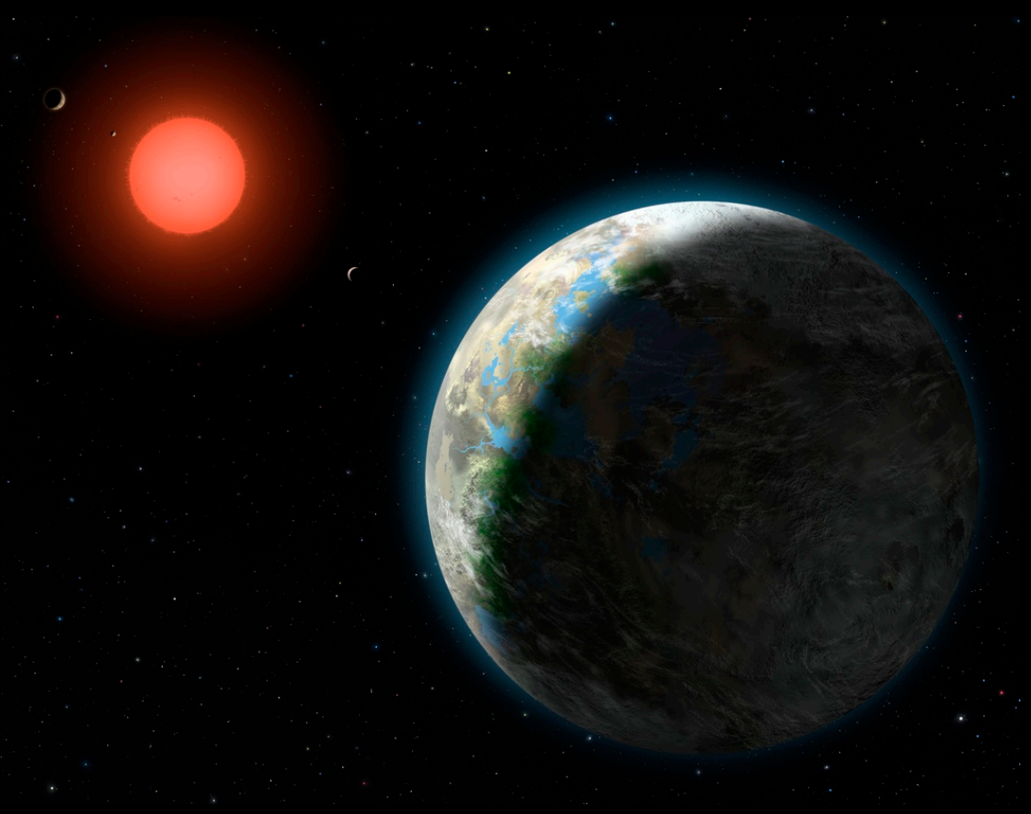
Red Lines = Model

Black Points = Simulated Data

Imagine TESS Has Found 30 New Earth-sized Planets...







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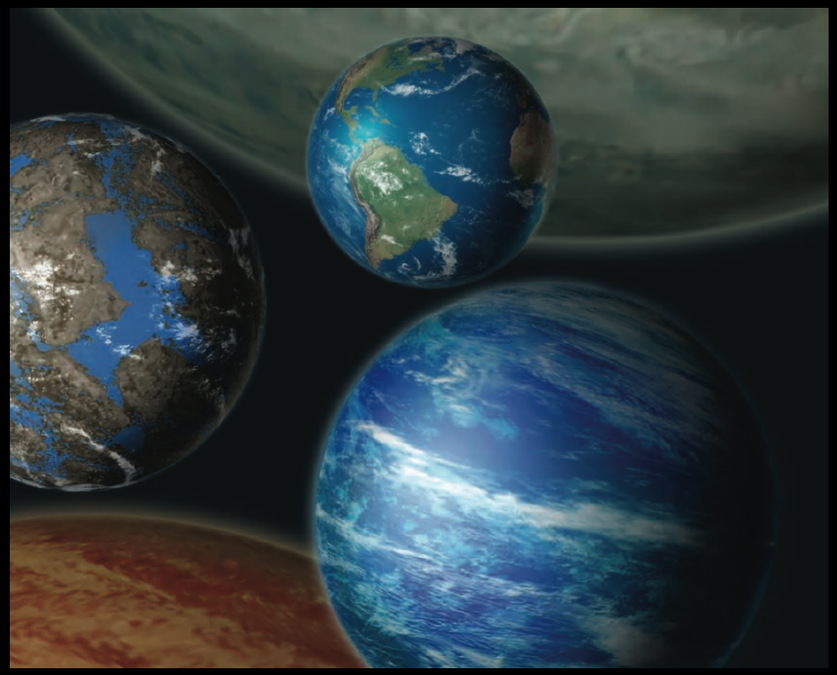
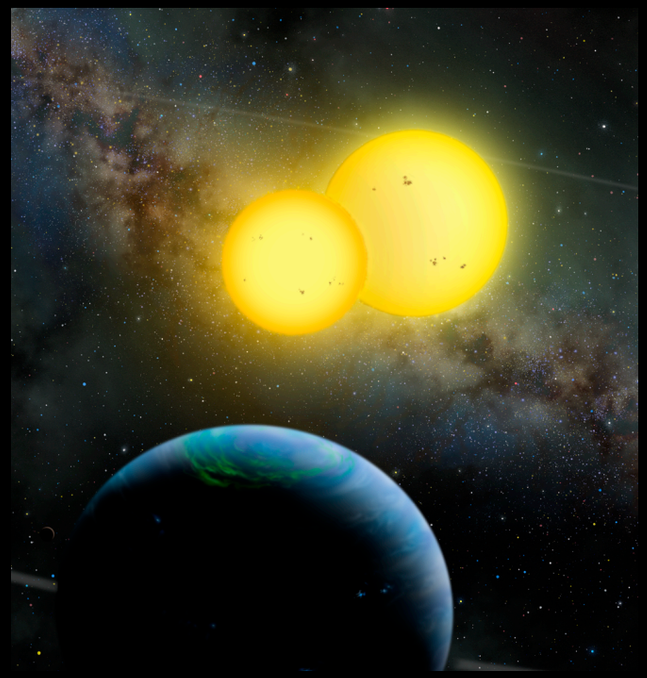
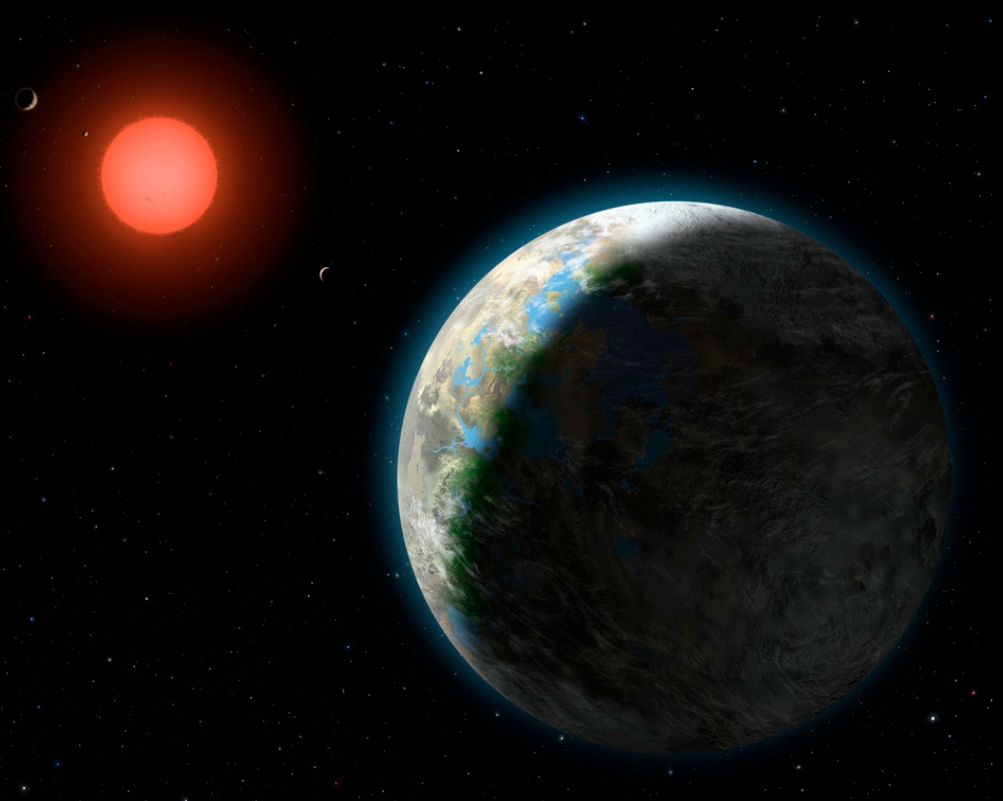






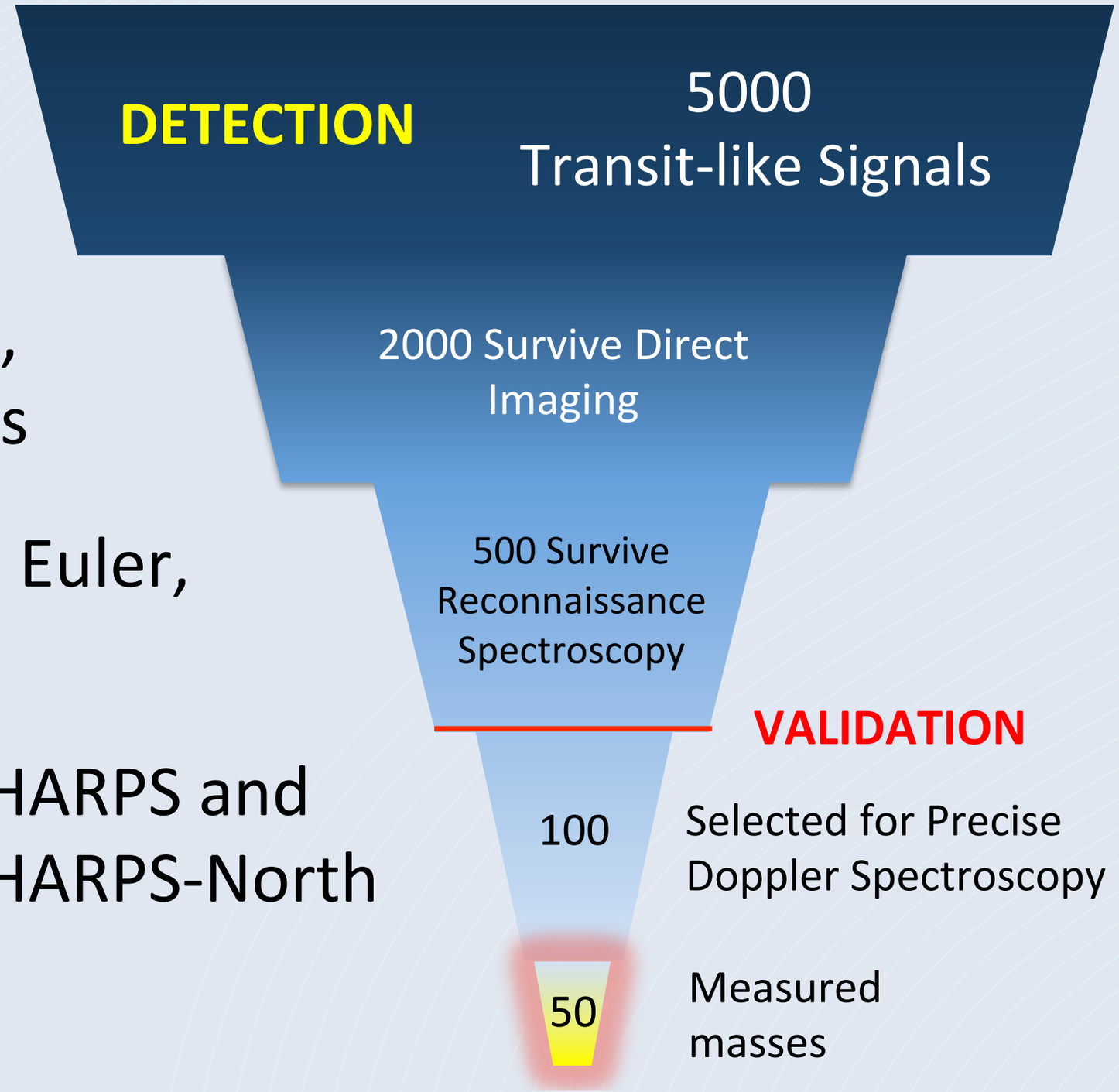
> 100x More Characterizable Earths and Super-Earths Than Known Today...

Thank You

Extra Slides

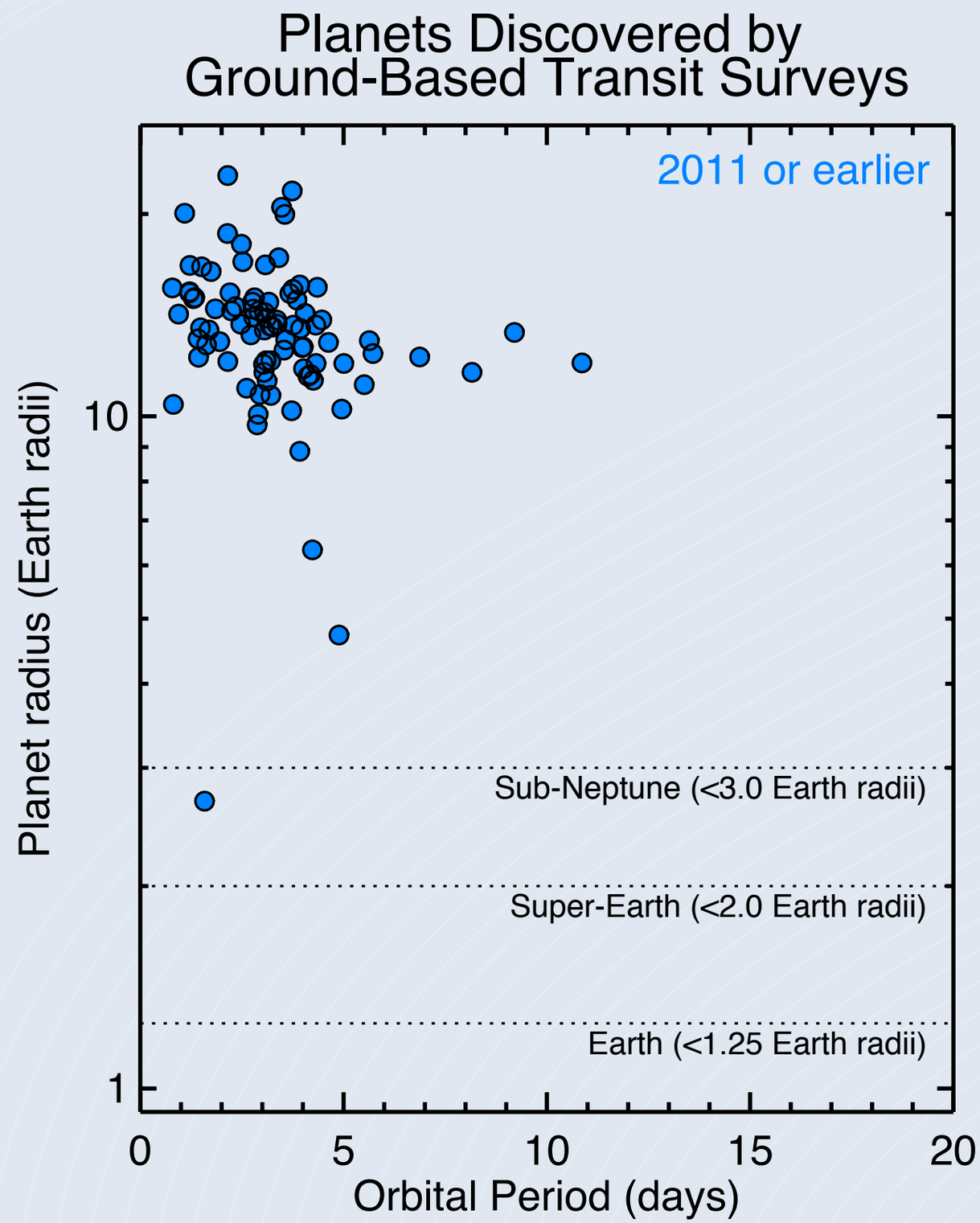
TESS Planet Validation and Mass Measurement

- TESS spacecraft data
  - LCOGT, MEarth, Euler telescopes
    - LCOGT, Euler, OHP
      - HARPS and HARPS-North



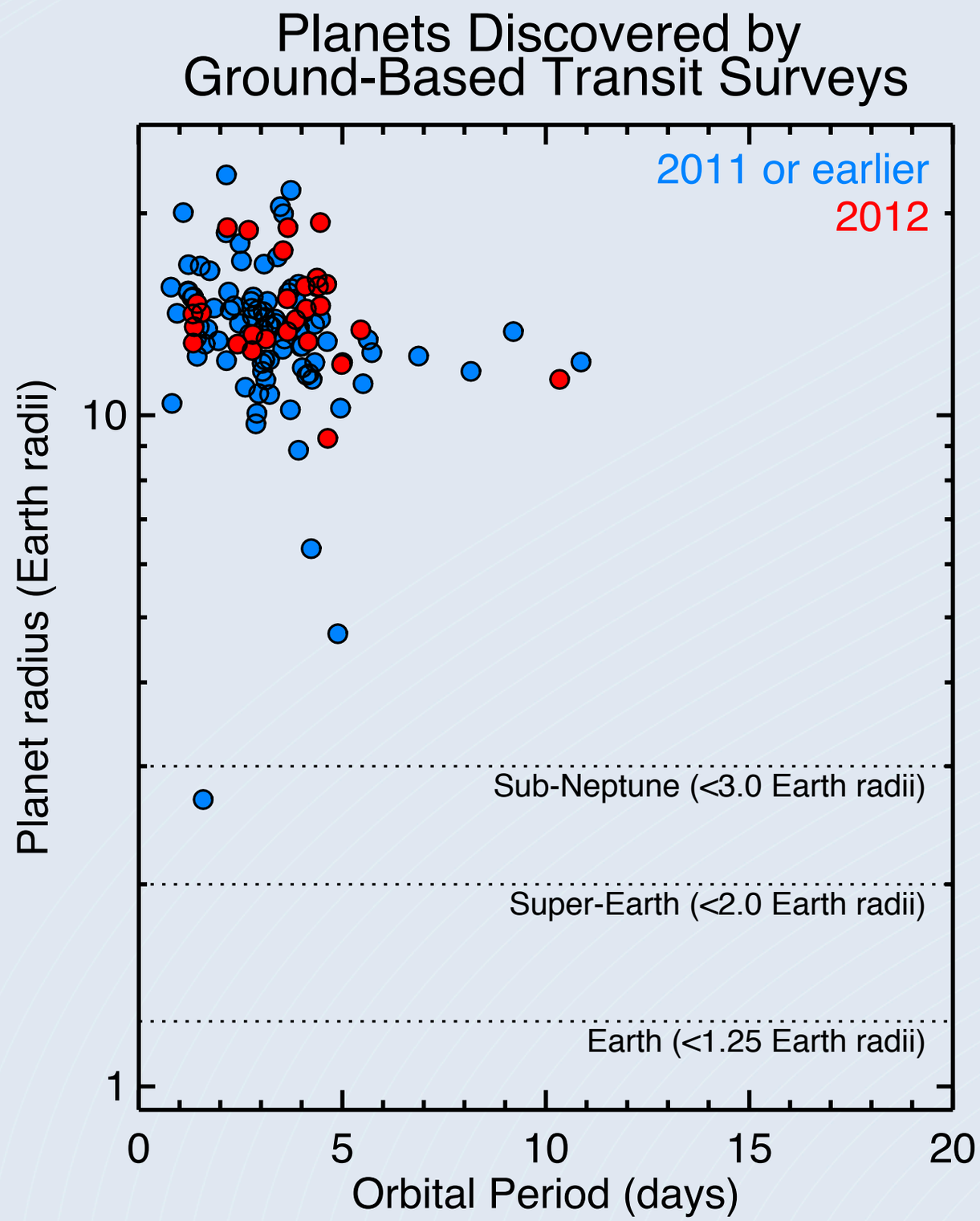
Ground-Based Surveys Through 2011

- Current ground surveys are mature
  - *>4 years in service*
  - *85 Hot Jupiters*
  - *1 Neptune*
  - *1 Sub-Neptune*



Ground-based Discoveries in 2012

- 29 new hot Jupiters
- No new Neptunes
- No smaller planets
- Discovery rate of Neptunes is 1 every several years



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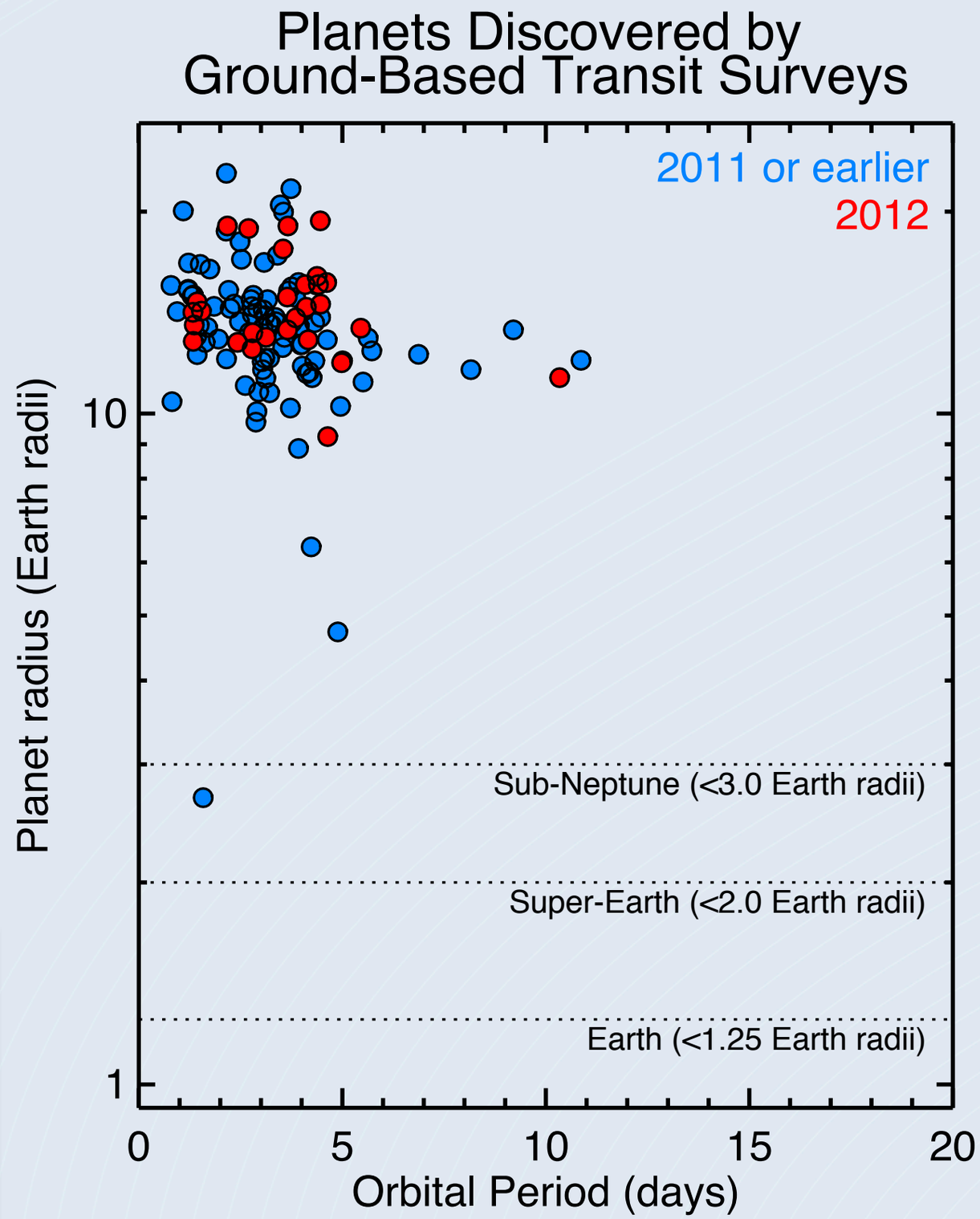

No Super-Earth or Earth Has Ever Been Detected by a Ground-based Transit Survey

Ground-based Survey Limitations

- Fundamental Limitation of Ground-Based Surveys is the Noise Floor from the Earth's Atmosphere
  - *Smallest Signal Detected is 3500 ppm (HAT-P-11)*
  - *This is 35X the Smallest Signals TESS Will Detect (100 ppm)*
  - *Earth is 80 – 330 ppm; Super-Earth is 330 – 1300 ppm*

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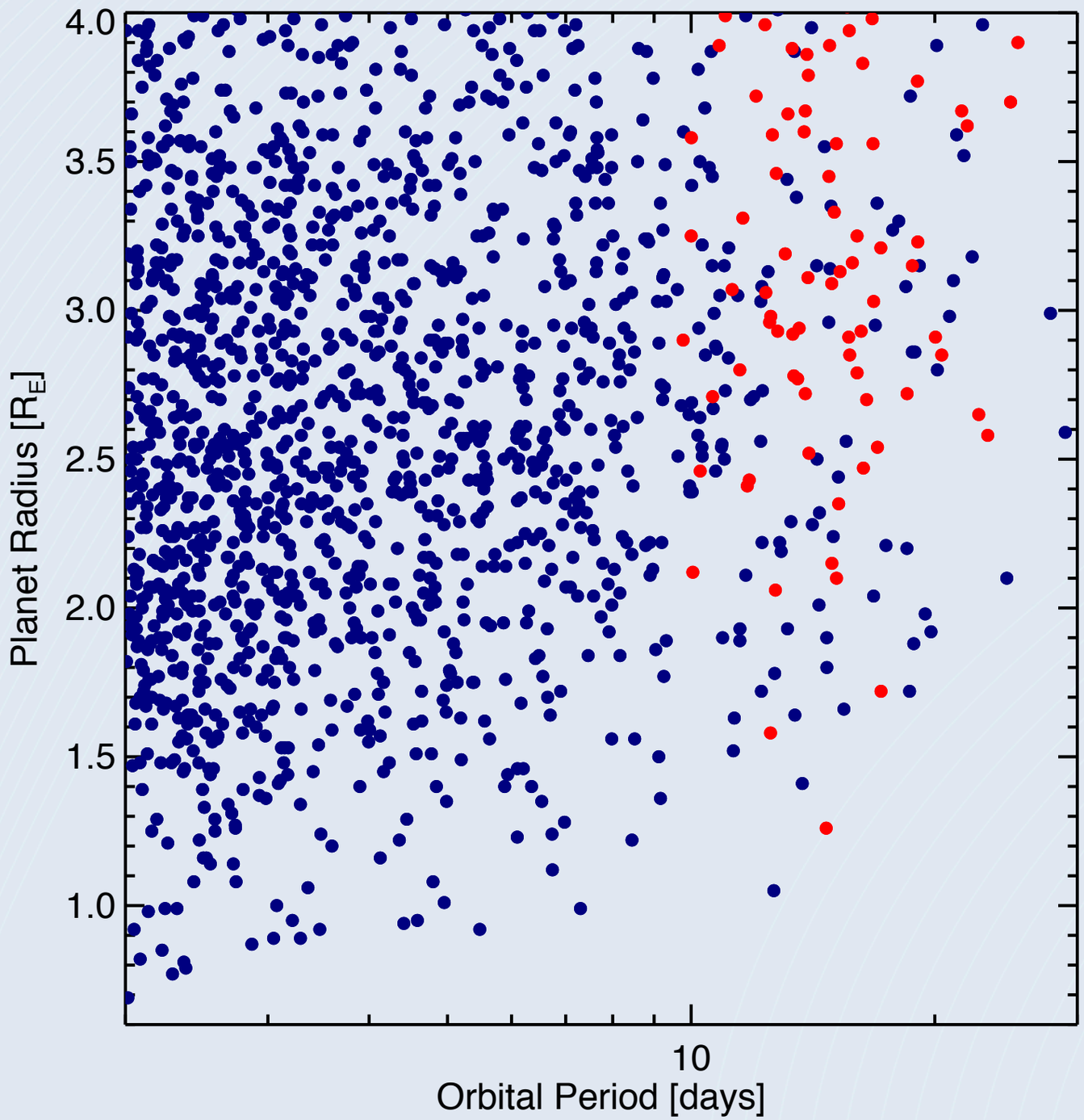
Ground-based Surveys Cannot Discover Earths and Super-Earths Limited to sub-Neptunes only for the very smallest stars (M5-M8)

TESS Will Discover Earths and Super-Earths for a Wide Range of Stars (F, G, K, & M)

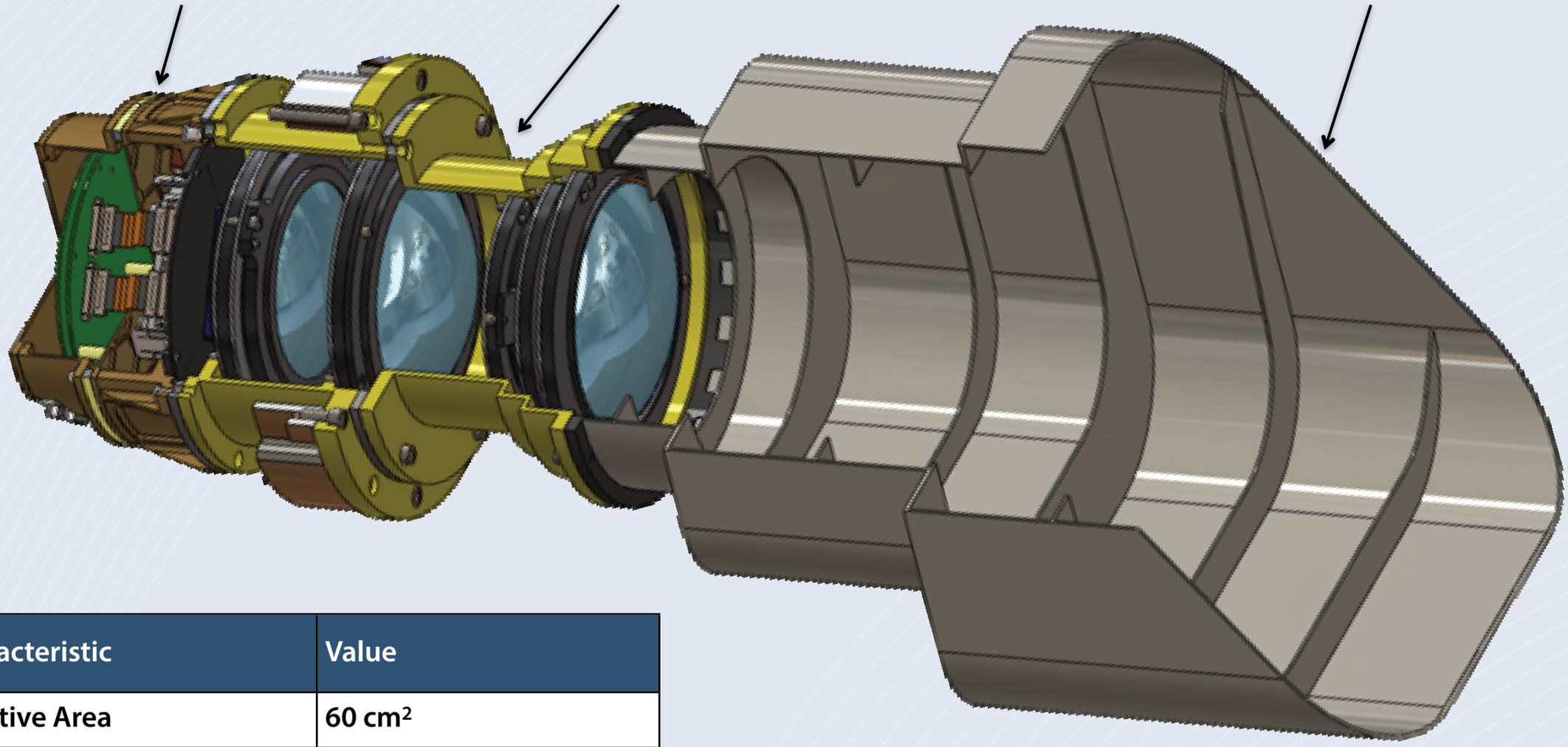
Planet Radius vs Orbit Period for TESS Planets



Blue = 3+ transits

Red = 2 transits

TESS Wide FOV CCD Camera



Characteristic	Value
Effective Area	60 cm^2
Lens Focal Ratio	1.6
CCD Focal Plane Array (Frame Store Mode)	4 @ 2K x 2K pixels 15 µm/pixel
Lens Focal Length	154 mm
Camera FOV	23° x 23°

Photometry Noise Budget for TESS

- Noise and systematic errors managed through
  - *Tests (e.g., photometric stability)*
  - *Measurement of key characteristics*
  - *Simulation (ETEM)*
  - *Analysis*
- TESS has significant margin on systematic errors
  - *Allocated as needed over lifecycle*

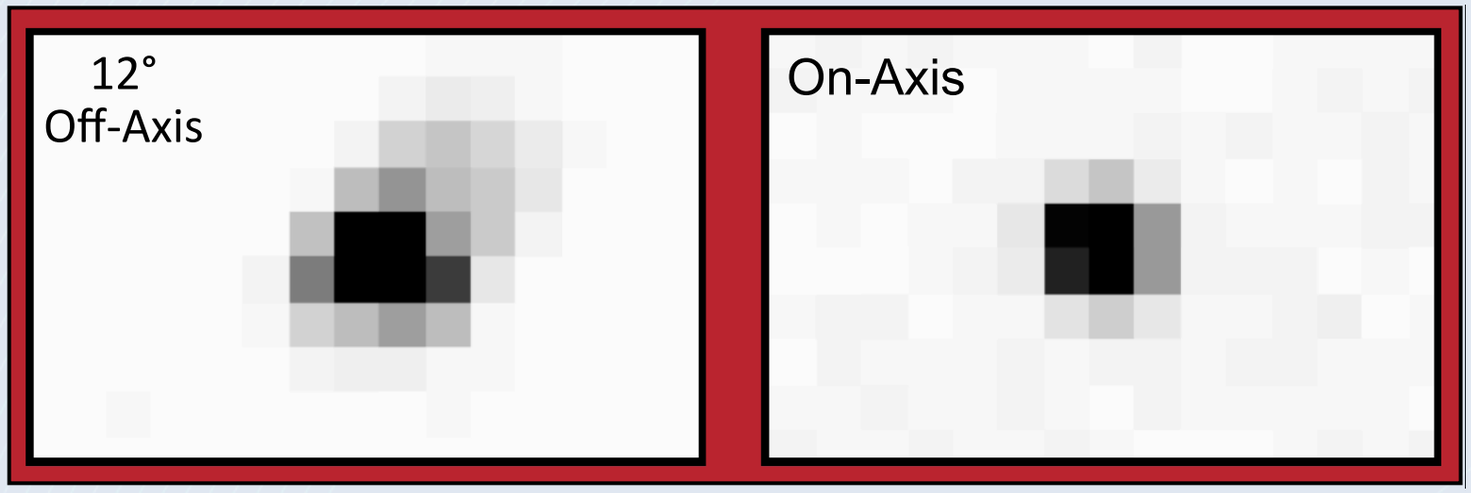
Table F-11: Systematic error capability of S/C bus and payload.

Component	Allocation	Capability (ppm in One Hour)		
		Eclipse	Start of HASO	Majority of HASO
Total PPM	60 ppm			
Quasi-static	0 arc-sec	0	0	0
Slow (**Table F-10**)	22 ppm	13.1	4.7	4.2
Fast (**Table G-30**)	31 ppm	10.1	14.8	6.1
Total RSS	**38 ppm**	**16.5**	**15.5**	**7.4**
Unallocated	46 ppm	57.7	58.0	59.5

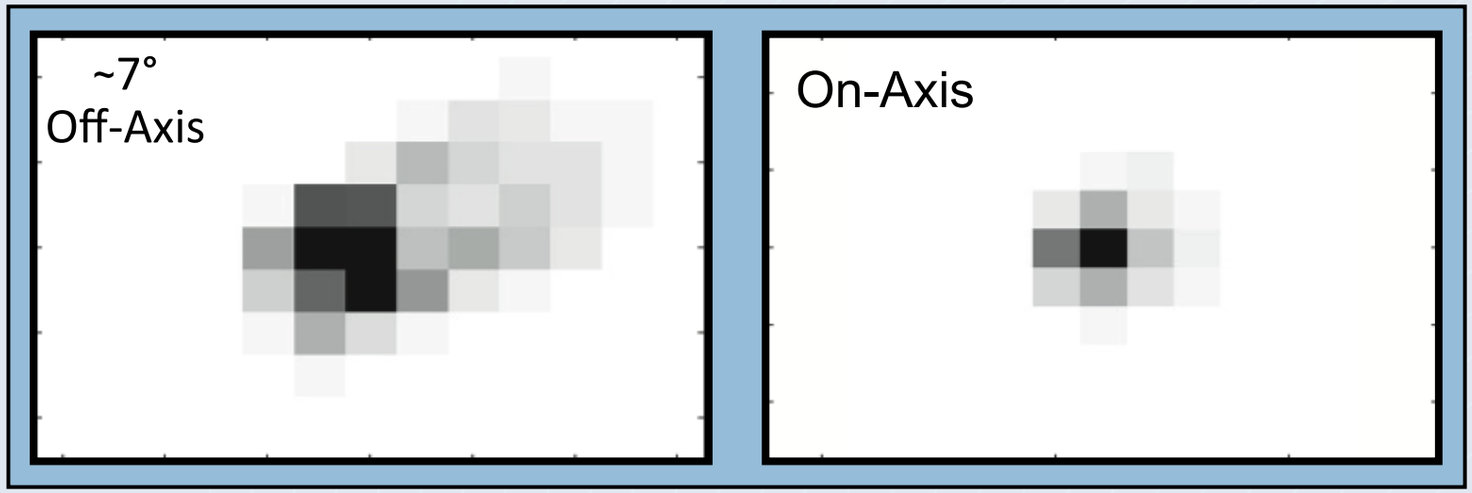
Polychromatic TESS and Kepler PSFs Compared

- **Measured** TESS and Kepler PSFs over FOV are comparable

TESS PSFs @ -75°C (Prototype Lens + CCDs)



Kepler PSFs (Flight Optics & CCDs)



PSF = Point Spread Function