The Transiting Exoplanet Survey Satellite

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Overview

The Transiting Exoplanet Survey Satellite (TESS) is a space telescope which will conduct a nearly all-sky survey to discover small exoplanets orbiting bright, nearby stars. The Legacy of TESS will be a catalog of the nearest and brightest stars hosting (small) transiting exoplanets which will be the base for future investiagtions, e. g. with the James Webb Space Telescope.

Spacecraft and Payload

- **Payload**: 4 identical cameras with hoods, Data Handling Unit (DHU)
- **Spacecraft**: solar arrays, sunshield, thrusters, antenna
- TESS size: 1.5 x 1.2 x 3.9 m
- weight: 362 kg [1]

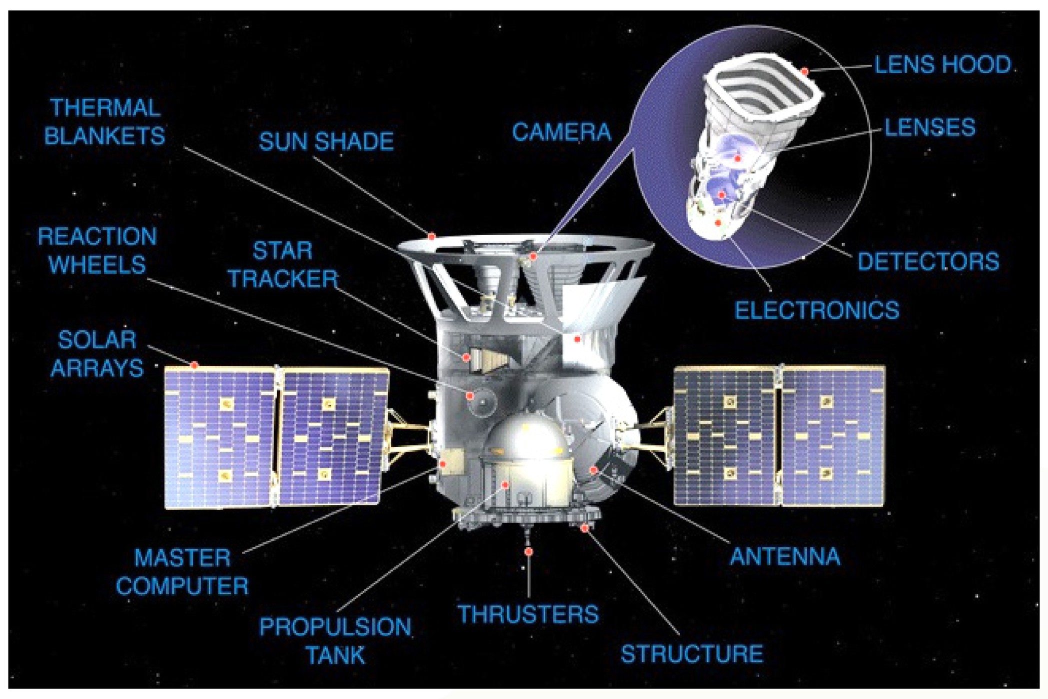


Fig 1: Transiting Exoplanets Survey Satellite Overview [2]

Cameras and Lenses

- 4 CCDs with FOV (field of view) of 24° x 24°, respectively -> combined **FOV of 24° x 96°**
- lens design (see Fig. 2) provides un-vignetted image on focal plane + consistant image spot size
- expected 50% ensquared-energy half-width: 15 µm (1 pixel)
- frame-transfer CCDs: back-illuminated MIT/Lincoln Laboratory CCID-80 with shutterless readout of 4ms
- detector resolution (4 CCDs): 4096 x 4096 px (62 x 62 mm)
- cameras attached to a common plate (see Fig. 2)

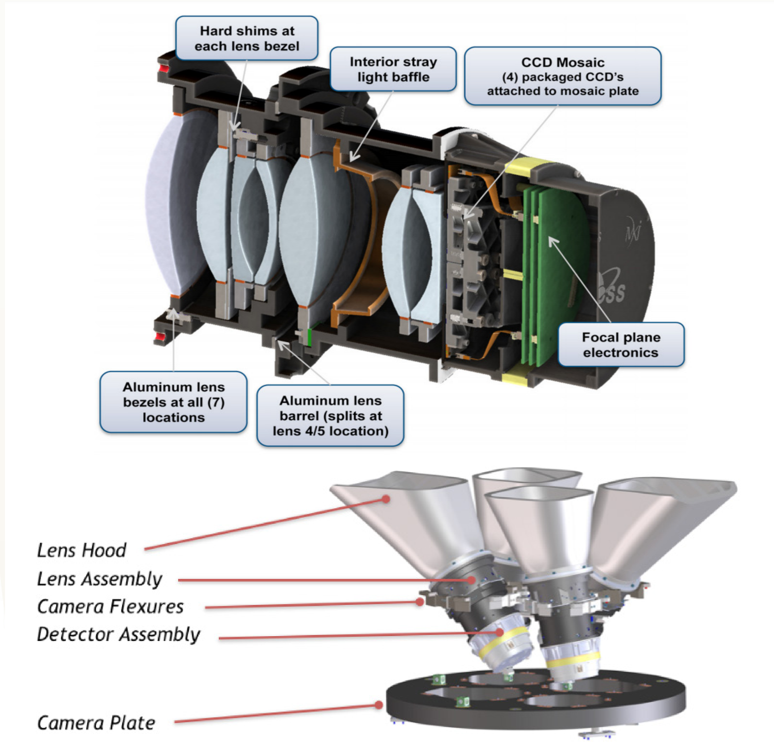


Fig 2: Lens and detector assembly (top) and location on common plate []

Bandpass

- range: **600 - 1000 nm**
- long-pass filter: cut-off at 600 nm
- upper limit: quantum efficiency of the CDDs
- low photon counting noise
- sensitive to the light of cool, red stars.
- combines Cousins I-band (I_C), R_C and Sloan Digital Sky Survey z filter (see Fig. 3) [3]

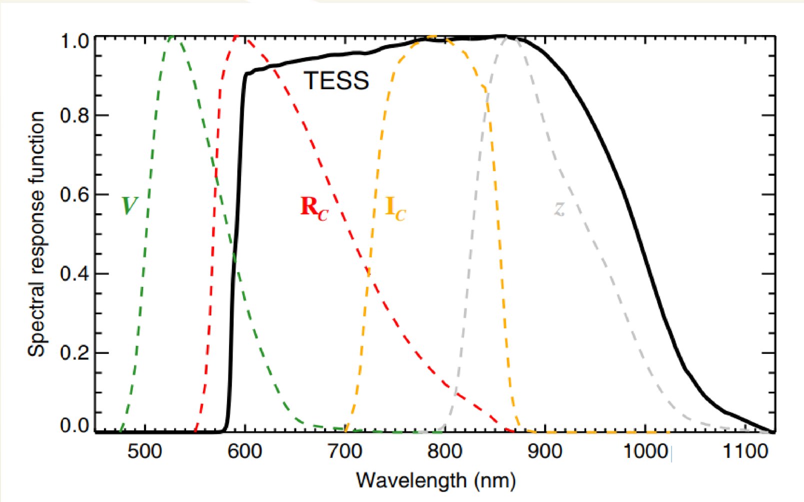


Fig 3: TESS detector spectral response function in comparision to other bandpasses [3]

Data Handling Unit (DHU)

- compressing and storing data (192 GB solid state recorder), spacecraft avionics and ground communications
- CCDs produce constant 2 sec exposures -> 2 kinds of pictures compressed in real time:
  -> 900 pictures are summed as **30-minute Full-Frame Images** (FFIs)
  -> 60 pictures summed as **2-minute exposures** -> **Postage Stamps**

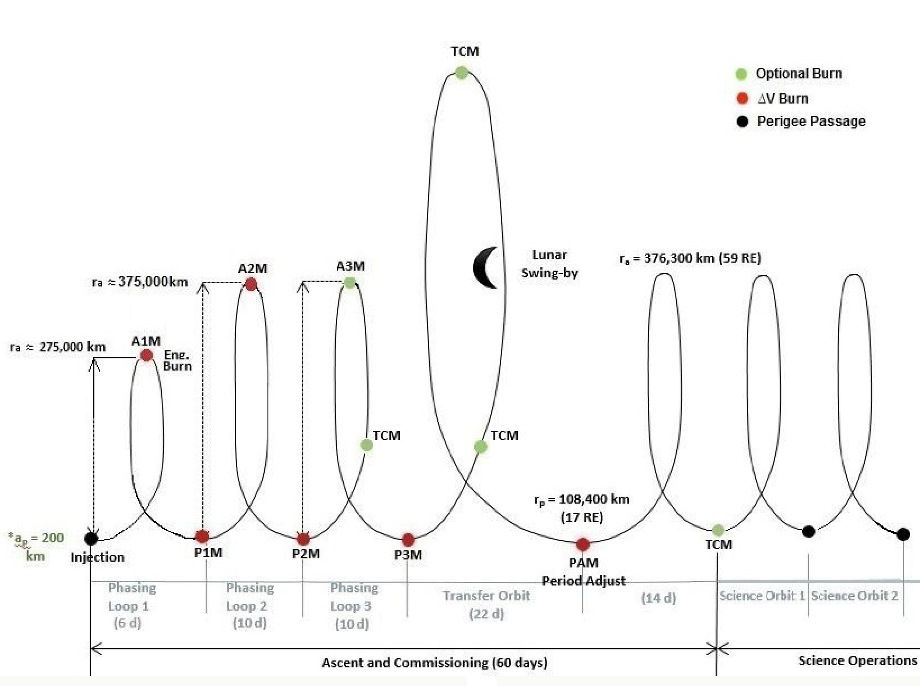
- Postage Stamps: nominally 10 x 10 pixels centered on preselected target stars
- per orbit >10 000 Postage Stamps and >600 FFIs are created by each camera
- ~ 200 guide stars traced by DHU to calculate offset quaternions for fine attitude pointing [4]

Spacecraft

- LEOStar-2 spacecraft bus (Orbital ATK)
- solar arrays produce up to 415 W (estimated total power needed: 290 W)
- every perigree: data from SSR is downlinked with K_a-band antenna dish (data rate up to 125 Mbs^{-1})
- **attitude control**: 4 reaction wheels (pointing accuracy <3.2"; stability 0.05"/h) and a Micro-Advanced Stellar Compass "µASC Star Tracker Unit" (accuracy: 2")
- **orbit controll**: hydrazine monopropellant propulsion system: 45 kg fuel -> delta-v budget of 268m/s (80% needed) [4]

Orbit Design

- Launch: April 18, 2018 at Cape Caneveral Air Force Station, Florida aboard a SpaceX Falcon 9 rocket
- highly eccentric orbit, inclined by 28.5°; apogee radius 59 R_E, perigee radius 17 R_E
- orbit period of 13.7 days, 2:1 resonance with the moon (see Fig. 4) [5]



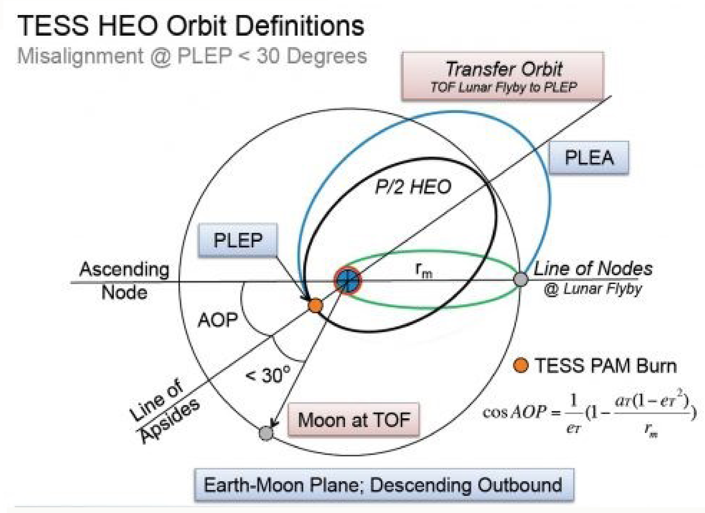


Fig 4: *left*: TESS trajectory events; *right*: TESS Orbit [5]
PLEP: Post-Lunar Encounter Apogee
PLEA: Post-Lunar Encounter Perigee
TOF: Time Of Flight
AOP: Argument of Periapsis

Observing Strategy

- main mission of TESS: observing northern and southern hemisphere for 1yr, respectively
- "stop and stare" method:
  2 orbits (27.4 days) for one sector then eastward rotation by 27.7° (see Fig. 6)
- all in all 26 sectors cover **90% of the sky**
- overlappig sectors create longer observation times
- all sectors anti-solar (see Fig. 5)
- sectors begin at 6° ecliptic lattitude to create a continuous viewing zone at the ecliptic poles [4]

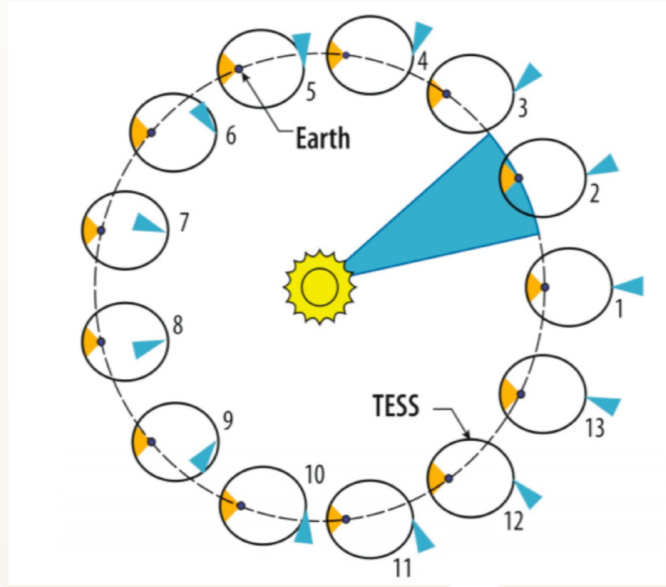


Fig 5: Schematic diagram of TESS orbit, observing orientation (blue; always anti-solar) and downlinking periods (orange) for 1 year [4]

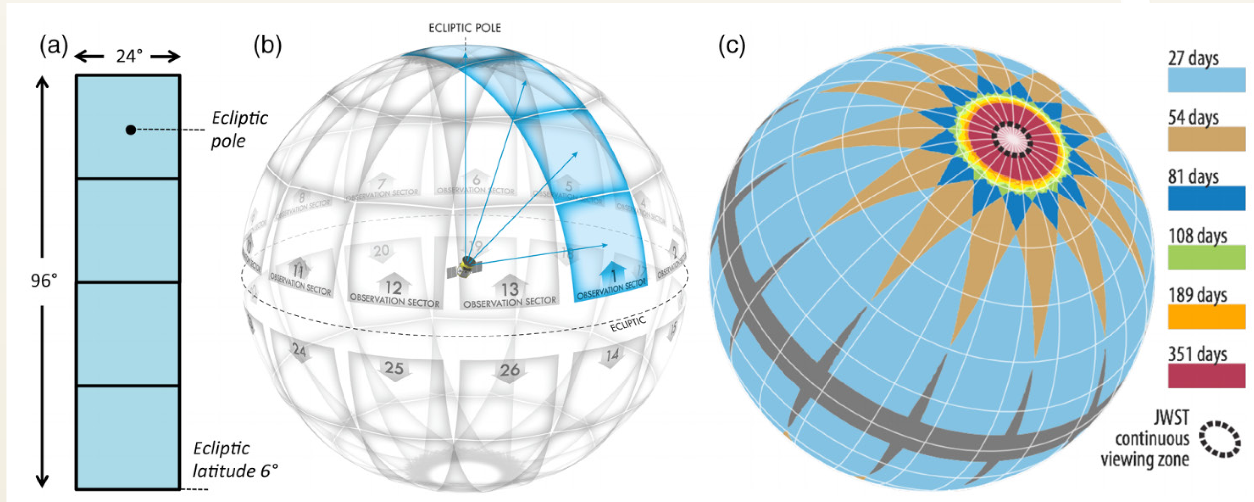


Fig 6: FOV of TESS with observing sectors of the 2 year mission; right: overlapping sectors [3]

Which stars will be observed?

- mainly stars of spectral types F5 - M5 -> allow finding small planets around them (also, 75% of solar neigborhood stars are M0 -M5) -> Follow Up
- **TESS Input Catalog (TIC)**: all sky catalog (created from Gaia, 2MASS etc.) of about $473x10^6$ objects
- TIC serves as base for the **Candidate Target List (CTL)**: contains about $3.8x10^6$ point sources for the selection of 2-min targets
- CTL ranked by priority and provides sky position, stellar radius, brightness, and contamination
- **demands for CTL** (see Fig. 6):
- prioritize 200 000 stars for planets (r<2.5 R_E) with orbital periods of <10 days
- 10 000 stars in ecliptic pole regions for planets (r <2.5 R_E) with orbital periods <120 days [6]

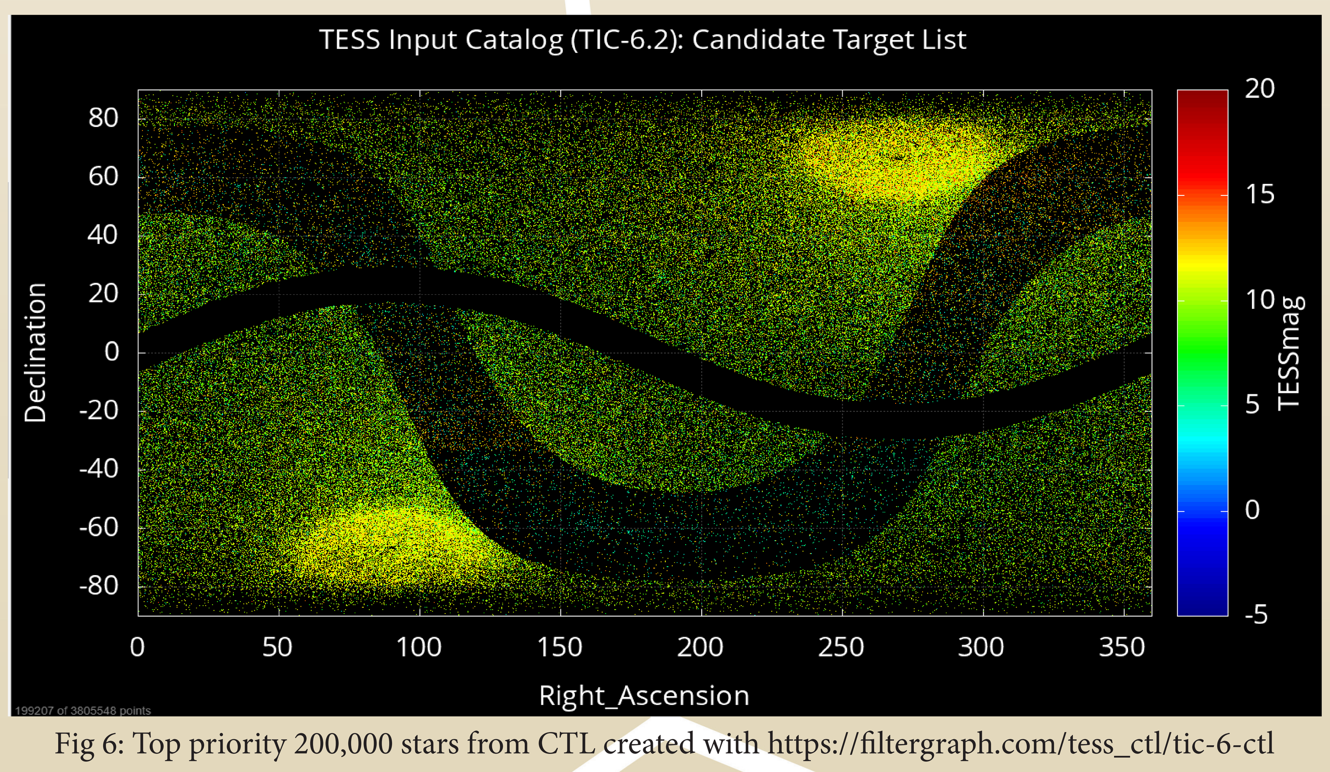


Fig 6: Top priority 200,000 stars from CTL created with https://filtergraph.com/tess_ctl/tic-6-ctl

References

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- [3] Ricker, George R., et al. „Transiting Exoplanet Survey Satellite" (2014)
- [4] TESS Science Support Center, NASA Goddard Space Flight Center „TESS Observatory Guide" (2017)
- [5] https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140007518.pdf, retrieved June 10, 2018
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