TESS Payload Operations

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We present an overview of the operation of the TESS Payload Operations Center at MIT. The flow and timing of operations, from target selection through contact monitoring and data processing, are described. The process of selecting targets from the various candidate target lists (exoplanet, GI, asteroseismology, DDT) is described in detail. The effect of scattered light on observations is discussed.

What we do at POC Operations:

- Mission planning – target and guide star selection
- Pointing determination
- DSN contact monitoring and data handling/unpacking
- Orbit scheduling and downloads
- Spacecraft and Instrument health monitoring
- Time kernel generation
- Data processing and delivery to SPOC
- Data delivery to MAST

Year 1 Coverage and Highlights

- All 13 sectors in year 1 were observed as planned
- Improved pointing stability by optimizing spacecraft attitude control (thanks, Orbital/NGS!) and camera/guide star selection
- Improved momentum dump management, leading to longer continuous coverage (from 2.5 days between dumps to the current 3.375 days)
- Evaluated stray light and its effects
- Streamlined planning and data processing

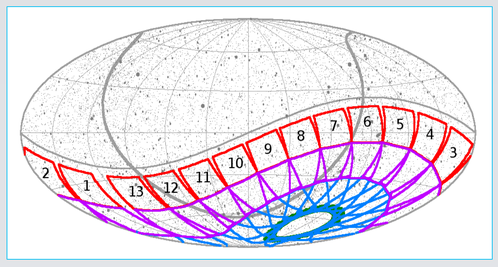


Fig. 1: Sectors in Year 1.

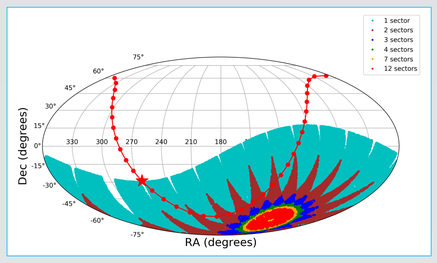


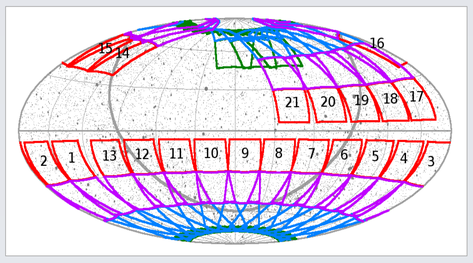
Fig. 2: Map of selected targets, color-coded by number of sectors observed.

Over 140,000 unique targets were observed during Year 1. Thousands were observed in multiple sectors (Fig 2). Over 5,500 exoplanet targets were observed for >240 days, allowing for detection of longer-period planets.

What's next for Year 2?

Increased scattered light levels for northern pointings will make observations in cameras 1 and 2 difficult in several sectors. The instrument pointing will be shifted north by 31° for at least Sectors 14 and 15, and potentially also for Sectors 16, 24, 25, and 26.

Fig. 3: The proposed map of Sectors 1-21, including northward shifts of Sectors 14-16. A determination of whether to shift Sectors 24-26 will be made based on evaluation of data from Sectors 14-16..

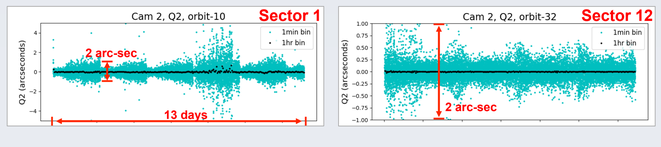


Spacecraft Stability

TESS uses data from the science cameras to provide feedback to the spacecraft attitude control system (ACS). The centroids of 200 "guide stars" per camera are measured by the instrument every 2 seconds and combined with measurements of momentum wheel speeds as part of the spacecraft stabilization algorithm.

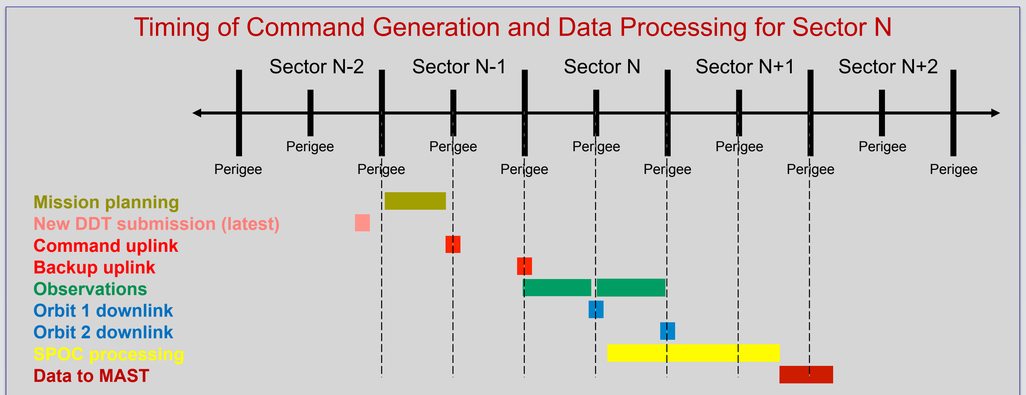
The overall stability of the spacecraft is key to the photometric performance of the instruments for bright stars (Nguyen 2019). When the spacecraft stability measured during instrument commissioning did not meet requirements, significant effort was made by Northrup Grumman to improve the ACS algorithm. The new algorithm, which relies only on camera measurements, has significantly improved spacecraft stability.

Fig. 4: Stability improvement. Sector1/orbit-10 was taken in the early part of the year, and Sector12/orbit-32 shows lower pointing error



Mission Operations Flow and Timing

Mission Operations flow is keyed to the contact schedule of the spacecraft. Science data are downlinked during perigee passes, every ~2 weeks. Observation sectors consist of two orbits and begin every other perigee.



- Mission planning consists of guide star and target star generation and test, stray light assessment, and the verification of the command load with the Mission Operations Center (MOC) at NGIS.
- Command uplinks are nominally done one orbit in advance. In case of issues, the command load can be uplinked at one of the two perigee contacts immediately before the sector begins.
- Data are downlinked every orbit during perigee passes. If the first contact fails, the data can be downlinked during the second contact. If both fail, there is sufficient memory on board to store the data until the next contact.
- SPOC processing includes pixel calibration, light curve generation and cotrending, detection of threshold crossing events, and data validation. Data are prepared for archive and validated by the Data Analysis Working Group (DAWG).
- Data and Data Release Notes are posted to MAST when ready. Currently, data for Sector N are posted at MAST within a few days of the end of Sector N+1.

Target Selection

TESS observes 20,000 stars at 2-minute cadence in each Sector. These targets include 1,200 stars used for photometric precision assessment (PPA). The remaining stars are selected from prioritized Candidate Target Lists (CTLs) from the categories in the table below. Targets are selected from each CTL in order until its allocation is filled. The targets selected for each sector are available at https://tess.mit.edu/observations.

The table summarizes the distribution of targets selected during Year 1 by category. Overlap in the CTLs of the various categories can result in more targets observed in a category than its allocation.

Target Category	Number Allocated per Sector	Total Observed	Typical Number Observed per Sector
Bright (T<6)	All of them	5,300	660
Exoplanet	13,000-15,000	107,000	16,000
Asteroseismology	750	9,400	1,600
Guest Investigator	1500	34,700	5,400
DDT*	1500	5,700	1,000

* Director's Discretionary Targets (DDT) are intended for small programs that may not fit into the other categories. Instructions for applying for DDT targets can be found at **https://tess.mit.edu/science/ddt**.

References

- Ricker, G. R., Winn, J. N., Vanderspek, R., et al. Journal of Astronomical Telescopes, Instruments, and Systems, 1, 014003 (2015)
- Nguyen et al. J. of Astronomical Telescopes, Instruments, and Systems, 4(4), 047001 (2018)

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