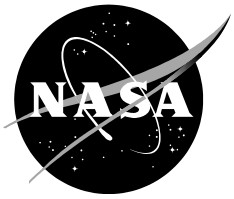
NASA/TM—2019–220180



TESS Data Release Notes:
Sectors 1 – 3, Multi-sector Search, DR6

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Acknowledgements

These Data Release Notes provide information on the processing and export of data from the Transiting Exoplanet Survey Satellite (TESS). This data release is a combined, multi-sector search only. The underlying data products from individual observing sectors have been previously released. The data products included in this data release are the Data Validation (DV) reports, time series, and associated xml files for the threshold crossing events (TCEs) found by searching a combined data set including data from multiple observing sectors.

These data products were generated by the TESS Science Processing Operations Center (SPOC, Jenkins et al., 2016) at NASA Ames Research Center from data collected by the TESS instrument, which is managed by the TESS Payload Operations Center (POC) at Massachusetts Institute of Technology (MIT). The format and content of these data products are documented in the Science Data Product Description Document (SDPDD)[1]. The SPOC science algorithms are based heavily on those of the Kepler Mission science pipeline, and are described in the Kepler Data Processing Handbook (Jenkins, 2017).[2] The Data Validation algorithms are documented in Twicken et al. (2018) and Li et al. (2019). The TESS Instrument Handbook[3] (Vanderspek et al., 2018) contains more information about the TESS instrument design, detector layout, data properties, and mission operations.

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This report is available in electronic form at
https://archive.stsci.edu/tess/

[1] https://archive.stsci.edu/missions/tess/doc/EXP-TESS-ARC-ICD-TM-0014.pdf
[2] https://archive.stsci.edu/kepler/manuals/KSCI-19081-002-KDPH.pdf
[3] https://archive.stsci.edu/missions/tess/doc/TESS_Instrument_Handbook_v0.1.pdf

1 Data

TESS Data Release 6 consists of results from a transiting planet search conducted in the combined data from Sectors 1 through 3. Figure 1 shows the Right Ascension (RA) and Declination (Dec) of all two-minute targets, color-coded by the number of sectors for which each target was observed. Targets with new data in Sector 3 and at least one other earlier sector were subject to a multi-sector planet search, using the same 2-minute cotrended data presented in previous single sector data releases. Table 1 provides basic information and data release note URL entries for the observations of each sector. The observations span a 84.1 day interval.

Table 2 summarizes the total number of targets with multi-sector data. A supplemental table is available[4] that lists the targets searched in this data release, including a string indicating which sectors the target was observed in, whether the target produced a TCE or not, and whether the target completed DV analysis or not.

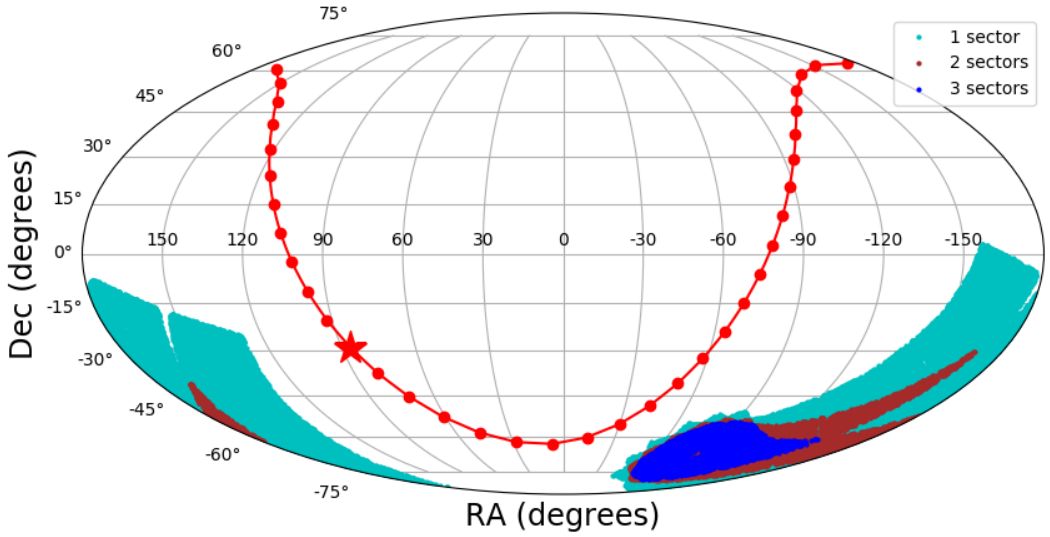

Figure 1: Right Ascension and Declination for all TESS two-minute targets, color-coded by the number of sectors in which that target was observed.

2 Transit Search and Data Validation

The light curves of 7853 targets observed in sectors 1 through 3 were subjected to the transit search in TPS. Figure 2 shows the 1-hour CDPP for the combined light curves of these targets. Threshold Crossing Events (TCEs) at the 7.1σ level were generated for 827 of these targets. A search for additional TCEs in potential multiple planet systems was

[4] https://archive.stsci.edu/missions/tess/catalogs/targetinfo/tess_multisector_01_03_drn06_targetinfo_v01.txt

Table 1: Sectors Searched

Sector #	Physical Orbits	Start TJD[a]	End TJD	Data Release #
1	9,10	1325.293	1353.178	1
2	11,12	1354.101	1381.515	2
3	13,14	1382.040	1409.388	3

[a] TJD = TESS JD = JD - 2,457,000.0

Table 2: Targets With Number of Sectors Observed

Number of Sectors	Target Count
2	2502
3	5351

conducted in DV through calls to TPS. A total of 1448 TCEs were identified in the SPOC pipeline on 827 unique target stars. There were 0 targets that caused a run-time error in DV. Table 3 provides a breakdown of the number of TCEs by target. Note that targets with large numbers of TCEs are likely to include false positives.

Table 3: Sector 1 – 3 TCE Numbers

Number of TCEs	Number of Targets	Total TCEs
1	471	471
2	199	398
3	80	240
4	54	216
5	15	75
6	8	48
–	827	1448

Figure 3 gives the distribution in period–transit depth space of the TCEs found in the multi-sector search. The top panel shows the distribution of orbital periods for the TCEs. After rapidly declining for periods between 1 and 5 days, the distribution shows a concentration of TCEs at 14–15 days. There are also weak excesses of TCEs at about 30, 45 and 55 days. These feature can primarily be associated with scattered light features that appear in the cameras towards the ends of the TESS orbits in Sectors 2 and 3 (see below).

The vertical histogram in the right panel of Figure 3 shows the distribution of transit depths derived from limb-darkened transiting planet model fits for TCEs. The model transit depths range down to the order of 100 ppm, but the bulk of the transit depths are considerably larger.

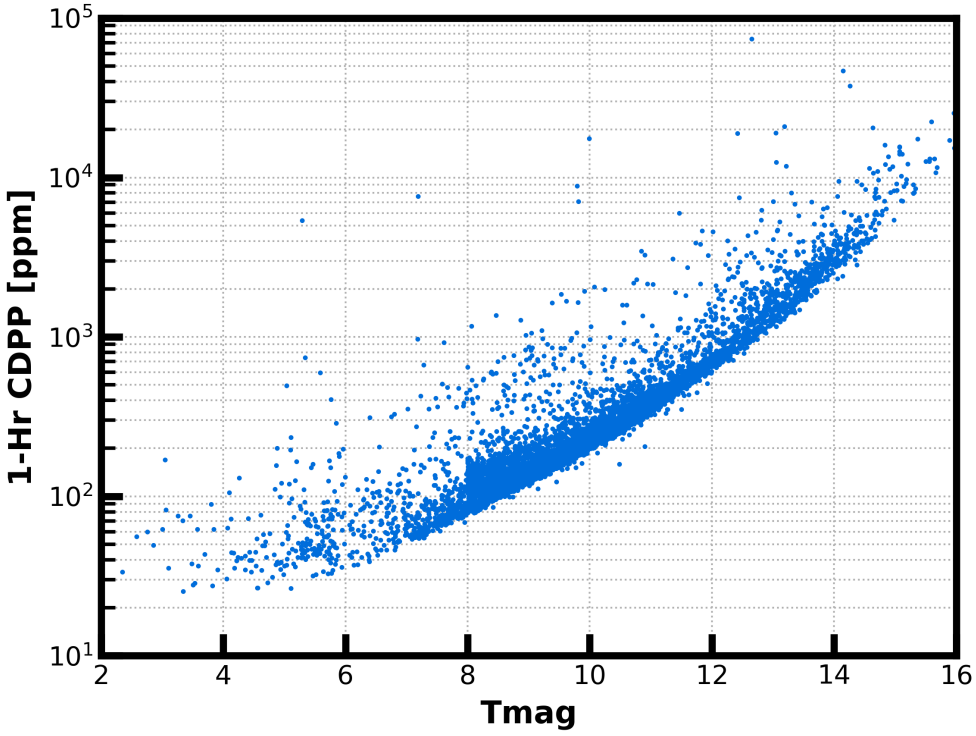

Figure 2: 1-hour CDPP. The points are RMS CDPP measurements for the 7853 light curves from the Sectors 1 – 3 multi-sector search plotted as a function of TESS magnitude.

Figure 4 shows the number of TCEs at a given cadence that exhibit a transit signal and highlights observing epochs with pointing and scattered light variations. Problematic epochs can be identified with the large ($>3\sigma$) peaks. The main features to be aware of are

1. There is a peak in the second half of Sector 1 that is associated with anomalously high pointing jitter.

2. There are $\sim 2\sigma$ peaks towards the end of the individual orbits of Sector 2, and the largest 3σ peak is at the same phase of TESS's orbital period in the first orbit of Sector 3. Strong scattered light patterns have been observed at these times, caused by the rise of the Earth above the sunshade and moving closer to the boresight of Camera 1. These features explain the peak at 15 days in the orbital period histogram and the weak excesses at integer multiples therefore (Figure 3).

3. The remaining peaks are associated with momentum dumps.

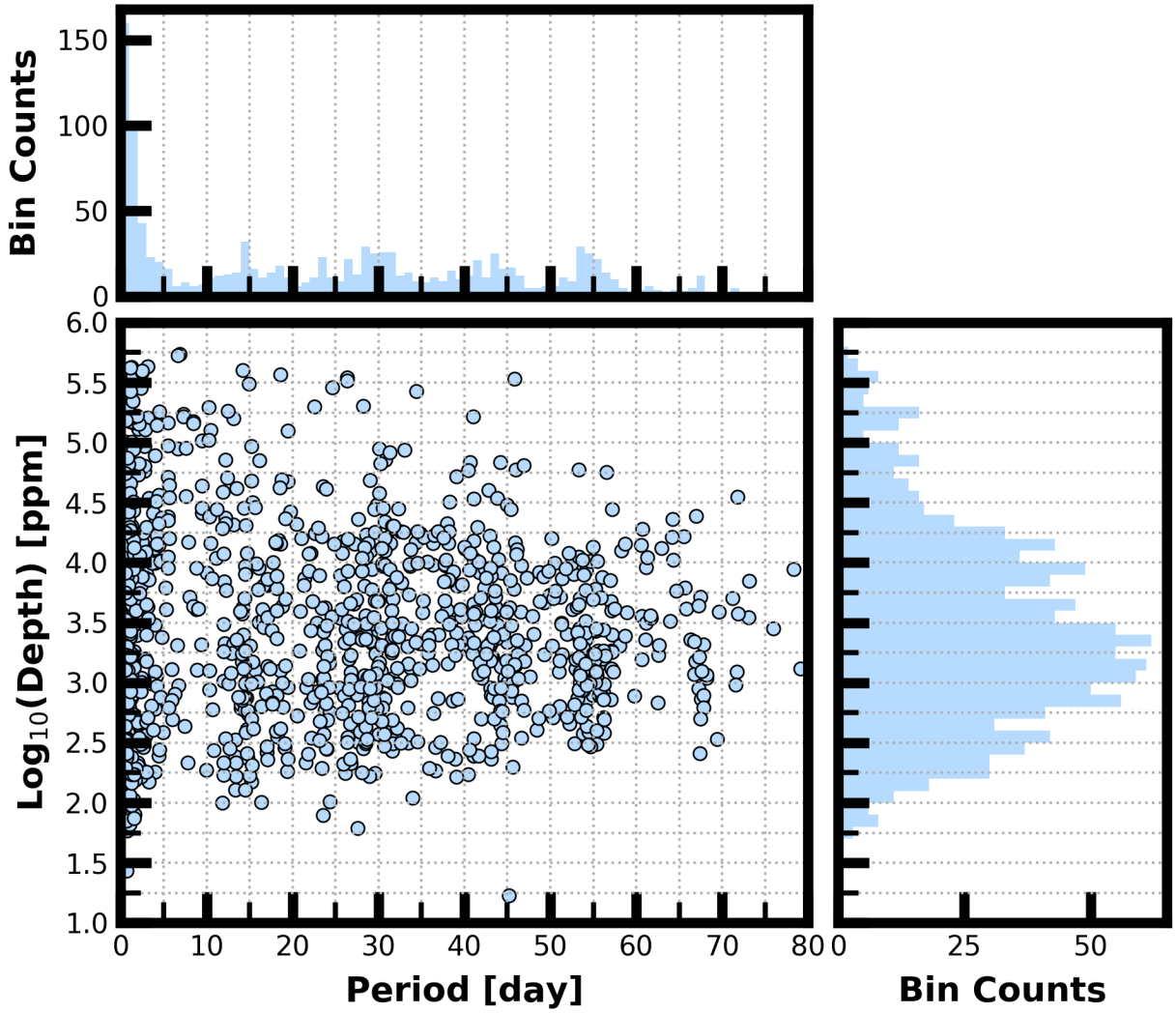

Figure 3: Lower Left Panel: Transit depth as a function of orbital period for the 1448 TCEs identified for the Sectors 1 – 3 multi-sector search. For enhanced visibility of long period detections, TCEs with orbital period <0.5 days are not shown. Reported depth comes from the DV limb darkened transit fit depth when available, and when not available, the DV trapezoid model fit depth. Top Panel: Orbital period distribution of the TCEs shown in the lower left panel. Right Panel: Transit depth distribution for the TCEs shown in the lower left panel.

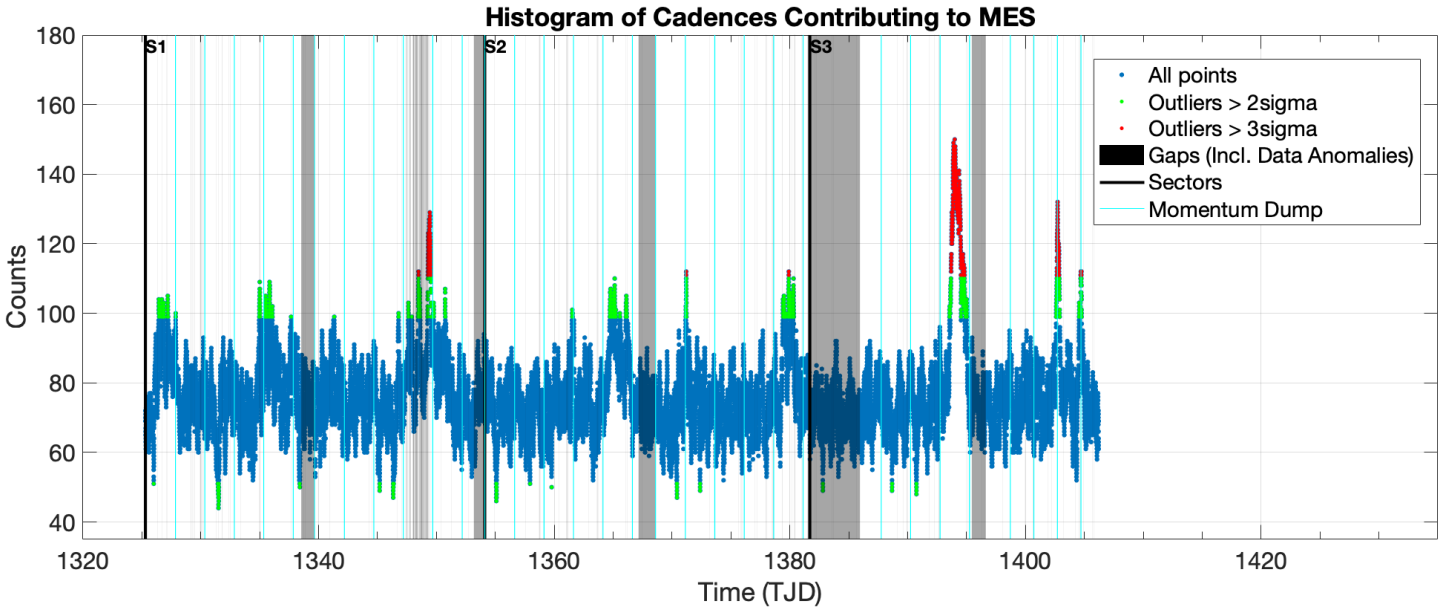

Figure 4: Number of TCEs at a given cadence exhibiting a transit signal. Isolated peaks are caused by a single event and result in spurious TCEs. The peaks typically align with pointing instabilities and strong background variations.

References

Jenkins, J. M. 2017, Kepler Data Processing Handbook: Overview of the Science Operations Center, Tech. rep., NASA Ames Research Center

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Li, J., Tenenbaum, P., Twicken, J. D., et al. 2019, *PASP*, 131, 024506

Twicken, J. D., Catanzarite, J. H., Clarke, B. D., et al. 2018, *PASP*, 130, 064502

Vanderspek, R., Doty, J., Fausnaugh, M., & Villaseñor, J. 2018, TESS Instrument Handbook, Tech. rep., Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology

Acronyms and Abbreviation List

BTJD Barycentric-corrected TESS Julian Date

CAL Calibration Pipeline Module

CBV Cotrending Basis Vector

CCD Charge Coupled Device

CDPP Combined Differential Photometric Precision

COA Compute Optimal Aperture Pipeline Module

CSCI Computer Software Configuration Item

CTE Charge Transfer Efficiency

Dec Declination

DR Data Release

DV Data Validation Pipeline Module

DVA Differential Velocity Aberration

FFI Full Frame Image

FIN FFI Index Number

FITS Flexible Image Transport System

FOV Field of View

FPG Focal Plane Geometry model

KDPH Kepler Data Processing Handbook

KIH Kepler Instrument Handbook

KOI Kepler Object of Interest

MAD Median Absolute Deviation

MAP Maximum A Posteriori

MAST Mikulski Archive for Space Telescopes

MES Multiple Event Statistic

NAS NASA Advanced Supercomputing Division

PA Photometric Analysis Pipeline Module

PDC Pre-Search Data Conditioning Pipeline Module

PDC-MAP Pre-Search Data Conditioning Maximum A Posteriori algorithm

PDC-msMAP Pre-Search Data Conditioning Multiscale Maximum A Posteriori algorithm

PDF Portable Document Format

POC Payload Operations Center

POU Propagation of Uncertainties

ppm Parts-per-million

PRF Pixel Response Function

RA Right Ascension

RMS Root Mean Square

SAP Simple Aperture Photometry

SDPDD Science Data Product Description Document

SNR Signal-to-Noise Ratio

SPOC Science Processing Operations Center

SVD Singular Value Decomposition

TCE Threshold Crossing Event

TESS Transiting Exoplanet Survey Satellite

TIC TESS Input Catalog

TIH TESS Instrument Handbook

TJD TESS Julian Date

TOI TESS Object of Interest

TPS Transiting Planet Search Pipeline Module

UTC Coordinated Universal Time

XML Extensible Markup Language