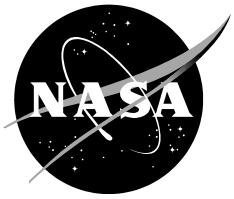
NASA/TM—2020—5003111



TESS Data Release Notes:
Sectors 14 – 23, Multi-sector Search, DR34

Christopher J. Burke, Michael M. Fausnaugh
Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

Douglas A. Caldwell
SETI Institute, Mountain View, California

Jon M. Jenkins
NASA Ames Research Center, Moffett Field, California

Jeffrey C. Smith, Joseph D. Twicken
SETI Institute, Mountain View, California

Roland Vanderspek
Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

John P. Doty
Noqsi Aerospace Ltd, Billerica, Massachusetts

Eric B. Ting
Ames Research Center, Moffett Field, California

Joel S. Villasenor
Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

May 27, 2020

NASA STI Program ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.
The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM.
  Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION.
  Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION.
  Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION.
  English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

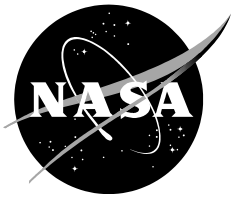
- Access the NASA STI program home page at http://www.sti.nasa.gov

- E-mail your question to help@sti.nasa.gov

- Phone the NASA STI Information Desk at 757-864-9658

- Write to:
  NASA STI Information Desk
  Mail Stop 148
  NASA Langley Research Center
  Hampton, VA 23681-2199

NASA/TM—2020—2020—5003111



TESS Data Release Notes:
Sectors 14 – 23, Multi-sector Search, DR34

Christopher J. Burke, Michael M. Fausnaugh
Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

Douglas A. Caldwell
SETI Institute, Mountain View, California

Jon M. Jenkins
NASA Ames Research Center, Moffett Field, California

Jeffrey C. Smith, Joseph D. Twicken
SETI Institute, Mountain View, California

Roland Vanderspek
Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

John P. Doty
Noqsi Aerospace Ltd, Billerica, Massachusetts

Eric B. Ting
Ames Research Center, Moffett Field, California

Joel S. Villasenor
Kavli Institute for Astrophysics and Space Science, Massachusetts Institute of Technology, Cambridge, Massachusetts

May 27, 2020

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 transit 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 Products 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, 2020)[2]. The Data Validation algorithms are documented in Twicken et al. (2018) and Li et al. (2019). The TESS Instrument Handbook (Vanderspek et al., 2018)[3] contains more information about the TESS instrument design, detector layout, data properties, and mission operations.

The TESS Mission is funded by NASA's Science Mission Directorate.

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-19081-003-KDPH.pdf
[3] https://archive.stsci.edu/missions/tess/doc/TESS_Instrument_Handbook_v0.1.pdf

1 Data

TESS Data Release DR34 consists of results from a transiting planet search conducted with the combined data from Sectors 14 through 23. 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 any of Sectors 20–23 that were observed in multiple sectors were subjected to a multi-sector planet search (see Data Release 23 for Sector 14–16 multi-sector planet search and Data Release 28 for Sector 14–19 multi-sector planet search). The data are the same 2-minute cotrended light curves presented in previous single sector data releases. Table 1 provides basic information and data release numbers for the observations of each sector. The observations span a 272 day period.

Table 2 summarizes the total number of targets with multi-sector data for this data release. A supplemental table[4] lists the targets searched, 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.

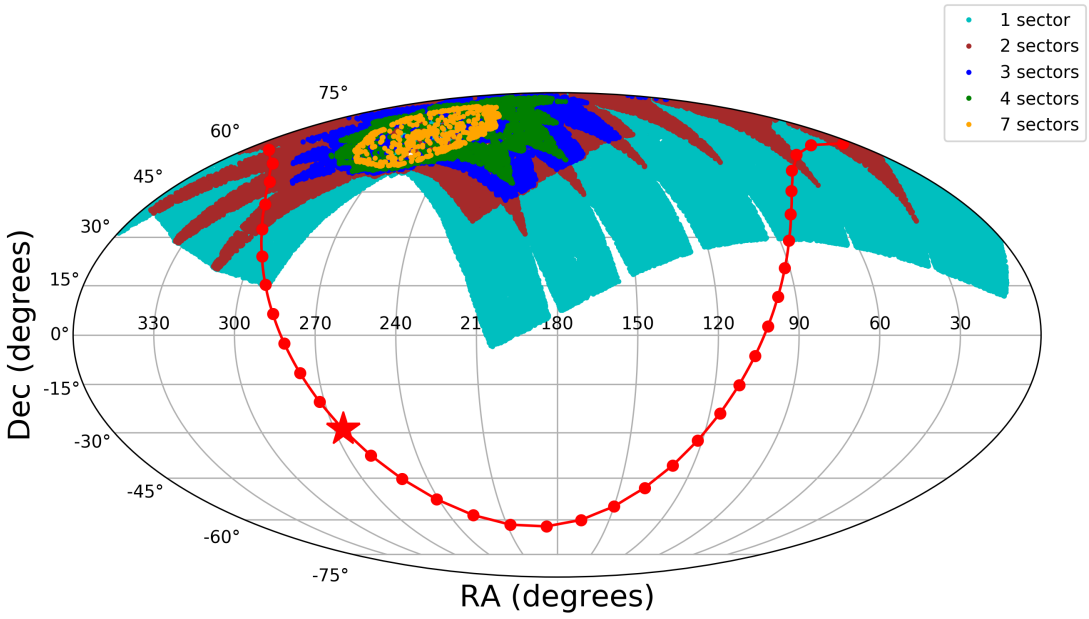


Figure 1: Right Ascension and Declination for TESS two-minute targets, color-coded by the number of sectors in which that target was observed.

[4] https://archive.stsci.edu/missions/tess/catalogs/targetinfo/tess_multisector_14_23_drn34_targetinfo_v01.txt

Table 1: Sectors Searched

Sector #	Physical Orbits	Start TJD[a]	End TJD	Data Release #
14	35,36	1683.348	1710.204	19
15	37,38	1711.359	1737.409	21
16	39,40	1738.647	1763.319	22
17	41,42	1764.679	1789.694	24
18	43,44	1790.651	1815.030	25
19	45,46	1816.077	1841.148	26
20	47,48	1842.498	1868.822	27
21	49,50	1870.429	1897.780	29
22	51,52	1899.301	1926.493	31
23	53,54	1928.100	1954.875	32

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

Table 2: Targets in this Data Release With Number of Sectors Observed

Number of Sectors	Target Count
2	6000
3	4293
4	2356
5	1257
6	979
7	772
8	1179
9	2989
10	2928

2 Transit Search and Data Validation

The light curves of 22753 targets observed in Sectors 14 through 23 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 7.1 σ level were generated for 1939 of these targets. A search for additional TCEs in potential multiple planet systems was conducted in DV through calls to TPS. A total of 3745 TCEs were identified in the SPOC pipeline on 1939 unique target stars. 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.

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 out to 5 days, the distribution shows a broad tail towards the longest period allowed ($\lesssim$70 day) while requiring at least two transit events. Small

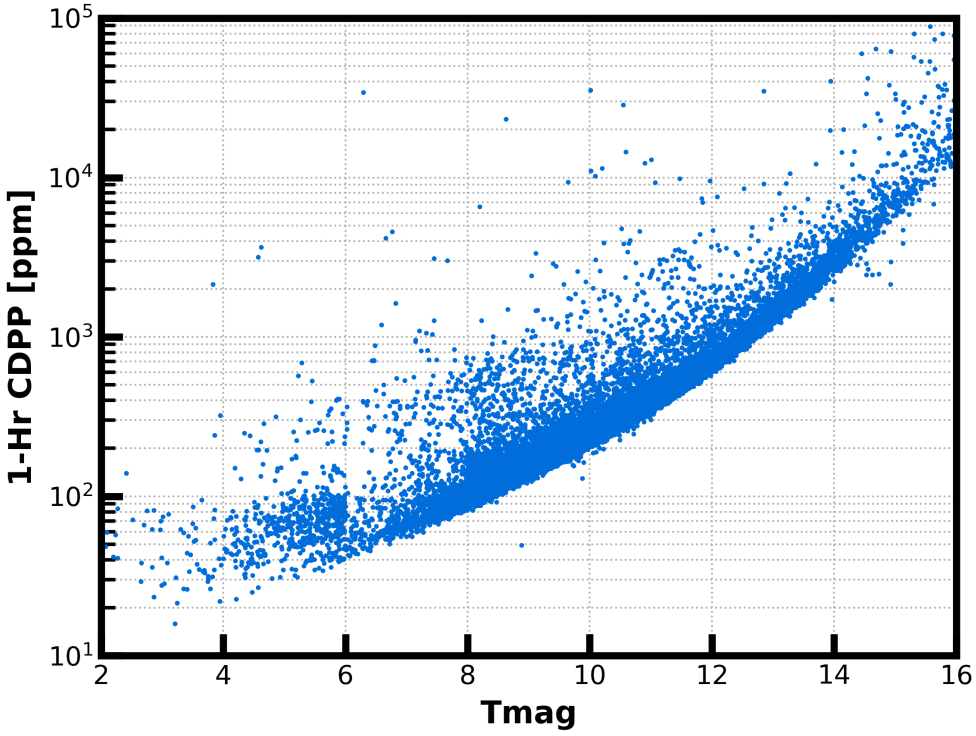


Figure 2: 1-hour CDPP. The points are RMS CDPP measurements for the 22753 light curves from the Sectors 14 – 23 multi-sector search plotted as a function of TESS magnitude.

excesses of TCEs at a given period can primarily be associated with scattered light, pointing jitter, or attitude tweaks (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 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 highlighted in red.

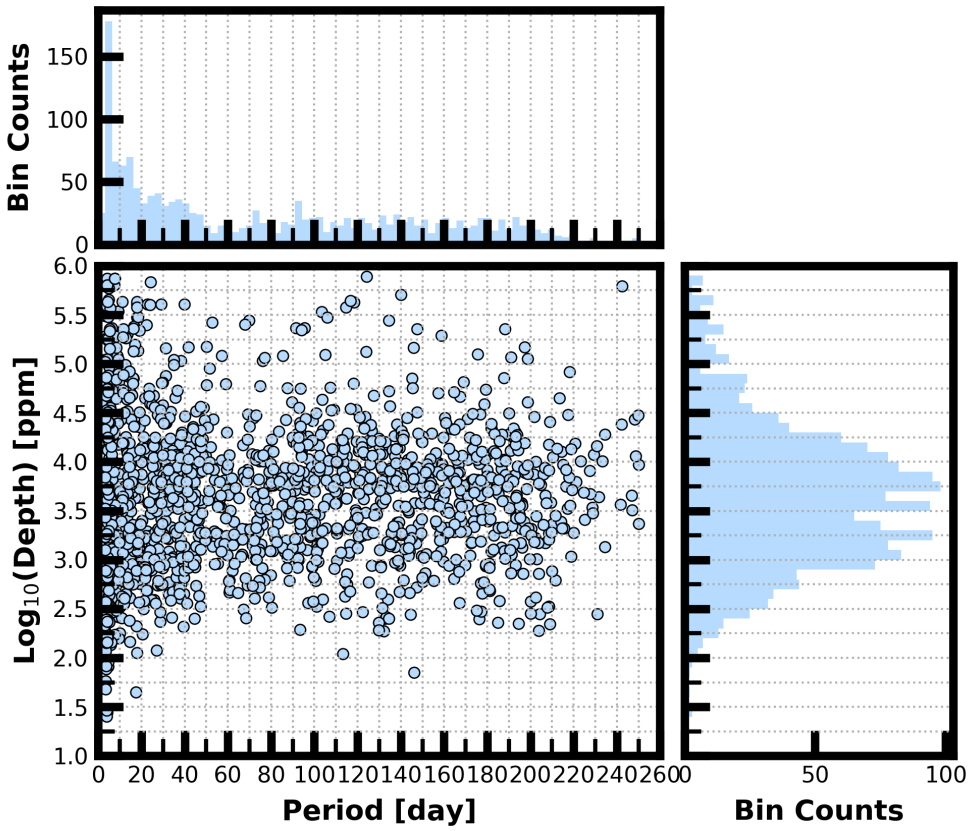


Figure 3: Lower Left Panel: Transit depth as a function of orbital period for the 3745 TCEs identified for the Sectors 14 – 23 multi-sector search. For enhanced visibility of long period detections, TCEs with orbital period <0.5 day are not shown. Reported depth comes from the DV limb darkened transit fit depth when available (or the DV trapezoid model fit depth if the limb darkened transit fit is not available). 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.

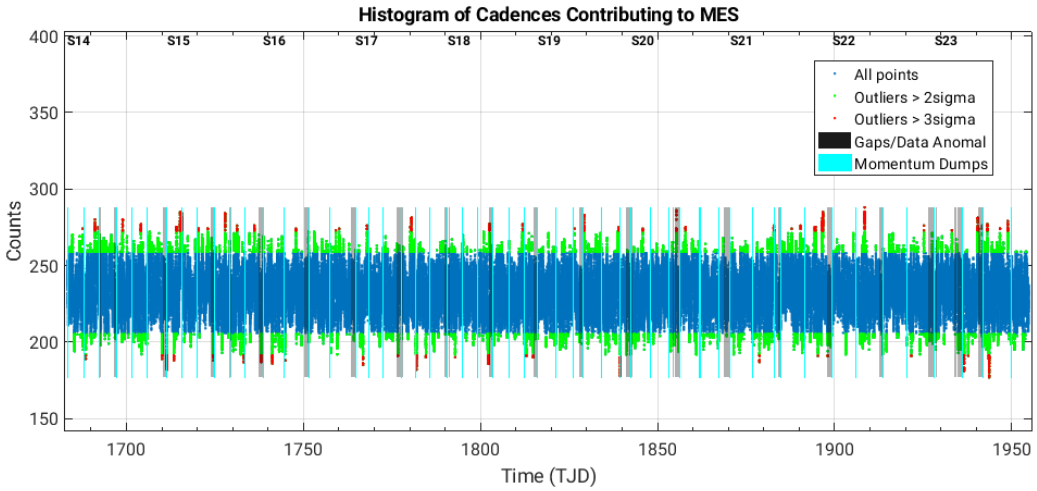


Figure 4: Number of TCEs at a given cadence exhibiting a transit signal. Isolated peaks are caused by a single event and result in spurious TCEs. The peaks typically align with pointing instabilities and strong background variations. TCE ephemerides are projected back to the start of Sector 14 even if the associated targets were not observed that early in the mission.

Table 3: Sector 14 – 23 TCE Numbers

Number of TCEs	Number of Targets	Total TCEs
1	943	943
2	582	1164
3	201	603
4	96	384
5	51	255
6	66	396
–	1939	3745

References

Jenkins, J. M. 2020, Kepler Data Processing Handbook: Overview of the Science Operations Center, Tech. rep., NASA Ames Research Center

Jenkins, J. M., Twicken, J. D., McCauliff, S., et al. 2016, in Proc. SPIE, Vol. 9913, Software and Cyberinfrastructure for Astronomy IV, 99133E, doi: 10.1117/12.2233418

Li, J., Tenenbaum, P., Twicken, J. D., et al. 2019, *PASP*, 131, 024506. http://stacks.iop.org/1538-3873/131/i=996/a=024506

Twicken, J. D., Catanzarite, J. H., Clarke, B. D., et al. 2018, *PASP*, 130, 064502, doi: 10.1088/1538-3873/aab694

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

CDPP Combined Differential Photometric Precision

Dec Declination

DV Data Validation Pipeline Module

KDPH Kepler Data Processing Handbook

MAST Mikulski Archive for Space Telescopes

MES Multiple Event Statistic

NAN Numerical Not-A-Number

POC Payload Operations Center

ppm Parts-per-million

RA Right Ascension

RMS Root Mean Square

SDPDD Science Data Products Description Document

SNR Signal-to-Noise Ratio

SPOC Science Processing Operations Center

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