End-to-End 6 TESS Simulated Data Set

This data set is a simulation of observations conducted with the TESS observatory from approximately JD = 2458612.846 to JD = 2458641.4699 at a nominal pointing of RA = 250.5398°, DEC = 32.4779°, and roll angle = 346.9795°. The data products indicate that the sector number is 14 for the purposes of this simulation exercise. The simulated 2-min cadence data consist of 20,610 cadences. The simulated image data were processed through the TESS Science Processing Operations Center (SPOC) science pipeline to generate archival data products similar to those that will be produced for actual flight data.

The data products include:

- Uncalibrated Full Frame Images
- Calibrated Full Frame Images
- Target Pixel Files: calibrated and uncalibrated pixels for each 2-min target
- Light Curve Files: simple aperture photometry, brightness-weighted centroids, and systematic error-corrected photometry
- Co-trending Basis Vectors
- Collateral pixel files
- Full Data Validation Reports for each target star with at least one Threshold Crossing Event (TCE –transit-like feature detected by the transiting planet search pipeline)
- Summary Reports for each TCE
- Data Validation results
- Data Validation Time Series

The format and contents are described in the TESS Science Products Description Document (SDP – EXP-TESS-ARC-ICD-0014), and also by a forthcoming TESS Archive Manual.

The synthetic data and data products should allow the astronomical community to prepare their own analysis software and follow-up observation strategies for actual data products from the TESS Mission, which are expected to be delivered to the MAST within 6 months of the start of science operations later in 2018.

The data set was produced to support testing and qualification of the TESS ground system as part of an end-to-end test. The data simulator, Lilith (Tenenbaum et al., in prep.) was based significantly on the *Kepler* Mission End-to-End Model (Jenkins et al., 2004; Bryson et al., 2010), and incorporates models for the CCDs, readout electronics, camera optics, behavior of the attitude control system (ACS), spacecraft orbit, and the sky, including zodiacal light, and the TESS Input Catalog (Stassun et al. 2017). Though the simulation was aimed at producing the most realistic synthetic science data from the standpoint of generating the pixel data, it relies on several assumptions and simplifications that may not reflect actual mission operations and instrumental and spacecraft behavior conditions. In addition, the simulation was geared towards verifying that the ground system software met its formal requirements and therefore some aspects of the data are not realistic. The major features to be aware of while analyzing and interpreting the data are summarized below:

- The simulation includes transiting planets, eclipsing binaries, and stellar variability. These signals were only injected in the 15,000 target stars selected for 2-minute cadence observations.
- The input distribution of planets was chosen to test the sensitivity of the SPOC transiting planet search pipeline and is not based on a realistic distribution of exoplanets and background eclipsing binaries.
- Background eclipsing binaries (BEBs) were injected at random locations near a subset of the target stars to test the ability of the SPOC pipeline to provide diagnostics indicating the presence of such BEBs. The sources of these BEBs do not appear in the TESS Input Catalog (TIC).
- Stellar variability was modeled on *Kepler* Mission observations and was only injected into a subset of the target stars (not into background field stars). Since the *Kepler* observations include *Kepler* instrumental noise, the observation noise for the simulated TESS target stars may be slightly higher than for actual observations.
- The expected image motion was simulated at full resolution only for science target pixels in each 11x11 postage stamp. The positions of background field stars in the FFIs were only updated once per day. This was necessary to limit the requisite computational intensity needed to produce full sector-volume FFI data sets in a reasonable amount of time.
- Note that while the postage stamps for 2-min targets in this simulation are 11x11 pixel regions, this will not necessarily be the case for actual flight data.
- The spacecraft pointing jitter was based on a pre-flight model of the onboard ACS that may not be accurate. The highest frequency motions (f>0.5 Hz) were incorporated directly into the Pixel Response Function (PRF).
- The PRF may not reflect inflight characteristics and represents the waveform expected for a K0 star, i.e., chromatic effects are not simulated for stars as a function of effective temperature.
- The flat field used in the simulations was measured in a 780±25 nm passband. Simulations conducted to investigate the color effects of the flat field and the PRF indicated that these effects should be relatively small on transit time scales and were thus neglected. However, these effects may be important for non-transit-photometry-related investigations and may introduce biases in derived parameters for transiting exoplanets.
- The relative pointing of each camera was based on a model using nominal relative pointing angles – the actual relative camera pointing angles will not be known until commissioning.
- Other image characteristics were subject to models of the electronics and sky background, which are not guaranteed to reflect the inflight image characteristics. These effects included read noise, gain and nonlinearity, quantization noise,

sudden pixel sensitivity dropouts, and focus changes due to thermal transients during periapsis passage.

- There was a discrepancy between the mission pointing profile provided by the Payload Operations Center (POC) and the SPOC pointing model that resulted in the stars being rendered slightly off center in their respective postage stamps. This discrepancy has been addressed and should not occur for actual flight data.
- The simulation length was slightly longer than two orbits due to a discrepancy between the simulation start and end times and the spacecraft trajectory, resulting in a gap of 6.53 hours starting at JD = 2458640.67829, so there is a short segment of data after the second download gap that corresponds to a third orbit.
- The science pipeline's module parameters have not been optimized for processing TESS science data. That will be accomplished during commissioning and early science operations when we see how the actual instrument performs in flight. Thus, the quality and characteristics of the calibrated science data products may be significantly different than that of the simulated data products.

Please be aware that some minor changes were made to the archival file exporters as a consequence of findings made in the End-To-End exercise so that investigators should consult the SDP and the forthcoming TESS Archive Manual in case of any discrepancies between the test data set provided here and actual flight data products.

References:

1. Bryson, S. T., Jenkins, J. M., Peters, D. J., et al. 2010a. "The *Kepler* End-to-End Model: Creating High-Fidelity Simulations to Test Kepler Ground Processing," in Proc. SPIE, Vol. 7738, Modeling, Systems Engineering, and Project Management for Astronomy IV, 773808

2. Jenkins, J. M., Peters, D. J., & Murphy, D. W. 2004. "An Efficient End-to-End Model for the *Kepler* Photometer," in Proc. SPIE, Vol. 5497, Modeling and Systems Engineering for Astronomy, ed. S. C. Craig & M. J. Cullum, 202–212

3. Stassun, K.G., Oelkers, R. J., Pepper, J., et al. 2017. "The TESS Input Catalog and Candidate Target List," arXiv:1706.00495