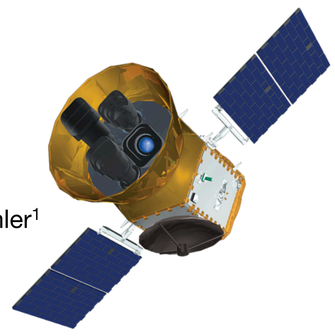
Abstract 30336 P1.29

Reduce, Reuse, Recycle:

The Success of the *Kepler* Transit Finding Pipeline and its Adaptation to the Transiting Exoplanet Survey Satellite (*TESS*)



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For details see "The TESS Science Processing Operations Center" by Jon M. Jenkins et al.,
Proc. SPIE 9913, Software and Cyberinfrastructure for Astronomy III, 99133E (August 8, 2016); doi:10.1117/12.2233418

Abstract

Building upon the great success of the Kepler mission, the team at NASA Ames Research Center is adapting the Kepler Science Processing Pipeline for use with the Transiting Exoplanet Survey Satellite (TESS), which will conduct a search for Earth's closest cousins starting in late 2017. TESS will conduct an all-sky transit survey of F, G and K dwarf stars between 4 and 12 magnitudes and most known M dwarf stars within 200 light years. TESS will discover ~1,000 small planets and measure the masses of at least 50 planets of less than 4 Earth radii. For each 27.4-day period, TESS will observe a 24° by 96° swath of sky extending from near the ecliptic equator to the ecliptic pole.

The TESS Science Processing Operations Center (SPOC) is being developed based on the Kepler Science Operations Center. The pipeline will run on the NAS Pleiades supercomputer and provide calibrated pixels, simple and systematic error-corrected aperture photometry, and centroid locations for all 200,000+ target stars observed over the 2-year mission, along with associated uncertainties.

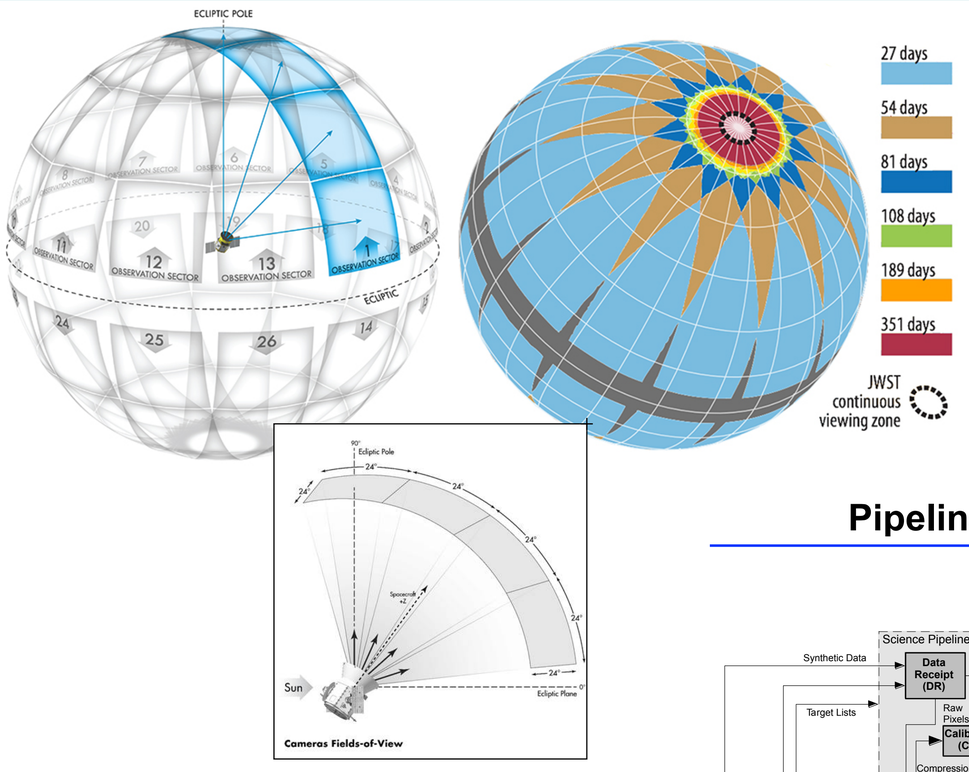
The TESS pipeline will search through all light curves for evidence of periodic transit signals that occur when a planet crosses the disk of its host star. It will generate a suite of diagnostic metrics for each transit-like signature discovered, and extract planetary parameters by fitting a limb-darkened transit model to each potential planetary signature. The results of the transit search will be similar in content to the highly successful *Kepler* transit search products (tabulated numerical results, time series products, and pdf reports) all of which are modeled on the *Kepler* products and will be archived to the Mikulski Archive for Space Telescopes (MAST).

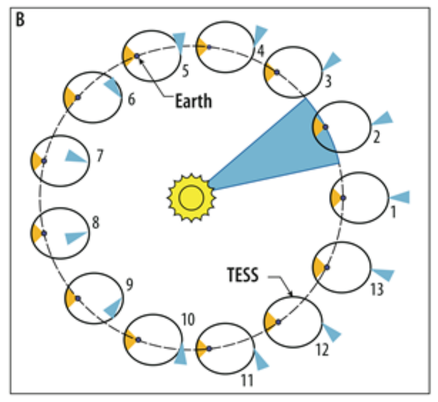
Why Kepler SOC ➡ TESS SPOC?

- Essentially, the same basic mission:
  - –~Same raw data
  - –~Same pixel calibrations necessary
  - –~Same types of systematics
  - –~Same science goals
  - –~Same science data products
- Can utilize Kepler personnel, wisdom and heritage
- ~67% reuse of Kepler Java pipeline infrastructure code
- ~74% reuse of Kepler Matlab science processing code
- Most changes are simply due to differences in data rates between Kepler and TESS
- *Estimate is that the total software development time will be only 14% versus developing the SPOC from scratch*

TESS and Kepler Data Rates.

	Kepler	TESS	TESS/Kepler
# stars	165,000	15,000	0.09
samples per day	48	720	15.00
pixels per star	32	100	3.13
days FOV^{-1}	93	27.3	0.29
Mission Duration (years)	4	2	0.5
target star pixels day^{-1}	253,440,000	1,080,000,000	4.26
Background Target Pixels	378,000	0	0.00
Background Pixels day^{-1}	18,144,000	0	0.00
Collateral Pixels	280,056	3,908,864	13.96
Collateral Pixels day^{-1}	13,442,688	2,814,382,080	209.36
All Science Pixels day^{-1}	285,026,688	3,894,382,080	13.66
All Science Data GiB day^{-1}	1.06	14.51	13.66
All Science Data GiB observing window^{-1})	0.10	0.39	4.01
All Science Data GiB mission^{-1}	1.51	10.34	6.83
FFI pixels	97,370,112	71,017,728	0.73
FFI samples day^{-1}	0.03	48.00	1,488
FFI pixels day^{-1}	3,140,971	3,408,850,944	1,085.29
FFI GiB day^{-1}	0.01	12.70	1,085.29
Science+FFI GiB day^{-1}	1.07	27.21	25.34
Science+FFI GiB FOV^{-1}	99.84	743.33	7.45
Science+FFI GiB mission^{-1}	1,567	19,861	12.67

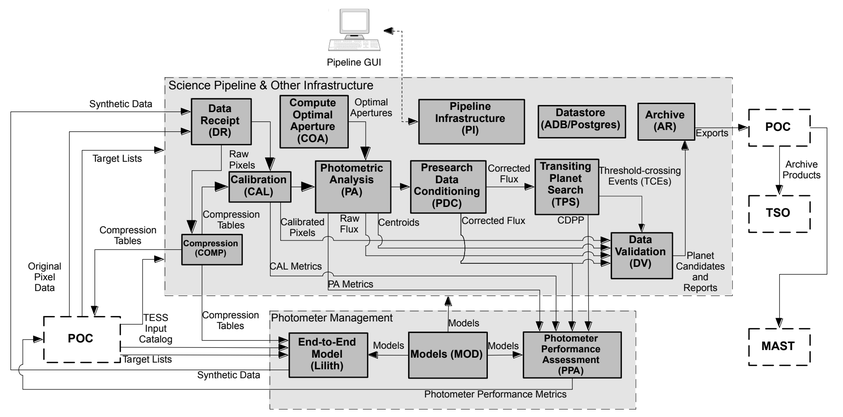


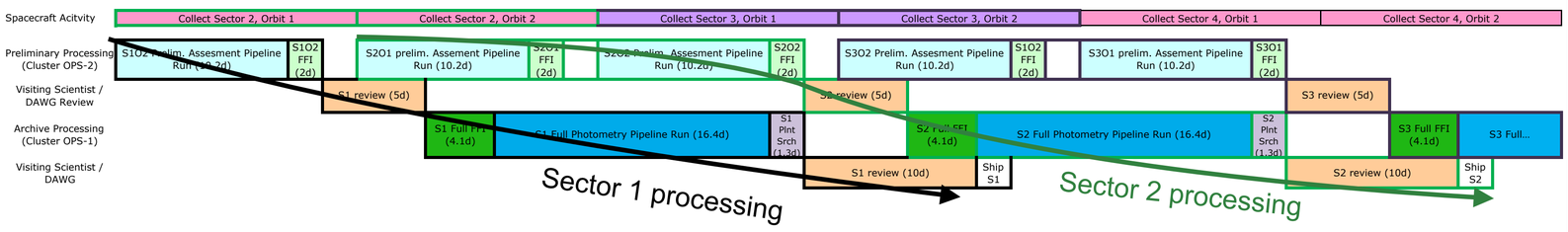


Monthly Processing Schedule

- New data downlink every two weeks (one orbit)!
- First two weeks of data processed to assess photometer performance and set configuration parameters for final processing of all ~27.4 days of data
- Each full sector processing task can take no longer than 27.4 days
- Polar targets with multi-sector data will be searched with multi-sector transit searche
- *With two clusters we can overlap the sector processing and fit within the 27.4 day budget with margin.*

Pipeline Architecture Flow Chart





Key Updates to Kepler Pipeline to Keep Up With Faster TESS Data and Processing Rates

- Calibration module re-written in C++
  - Bias, dark current, cosmic rays, pixel-pixel sensitivity, shutterless smear, read-out electronics corrections, & etc…
  - –Matlab is an excellent platform for data processing, analysis and debugging but not fast enough for a 27 day turnaround time for the raw pixel data calibrations.
- Other bottleneck functions re-written in C++ and called in Matlab
- Full processing to occur on the NASA Pleiades Supercomputer
- Data storage, memory and data transmission rates have also increased since the Kepler pipeline development.
- Lessons learned from 8 years of Kepler processing have resulted in many small tweaks in performance adjustments as we transport the code for use with TESS.
  - ***Starting with an extremely mature and well understood codebase***

TESS SPOC Data Products

- Single-Sector Data Products:
  - Target Pixel Files: Raw and calibrated pixel data
  - Target Light Curve Files: Photometric Analysis and cotrended time series data
  - Full Frame Image (FFI) Files: Raw, calibrated and uncertainty images of the CCDs
  - Collateral Pixel Files: Raw and calibrated collateral pixel data
  - Cotrending Basis Vectors (CBVs): The set of systematic trends present in the ensemble flux data
  - Focal Plane Characteristics (FC) models: updated FC models used in the SPOC pipeline
- Planet Search Data Products (Data Validation Reports):
  - DV Results Files: TCE (Threshold Crossing Event) ephemeris and diagnostic results from DV, one per target
  - DV Full Reports: Multi-page reports containing data and plots, one per target
  - DV Summary Reports: Single-page reports containing plots and data on each TCE, one per planet candidate
  - DV Time Series Data: Several types of flux time series data produced by DV, one per target

DV Summary Report Example