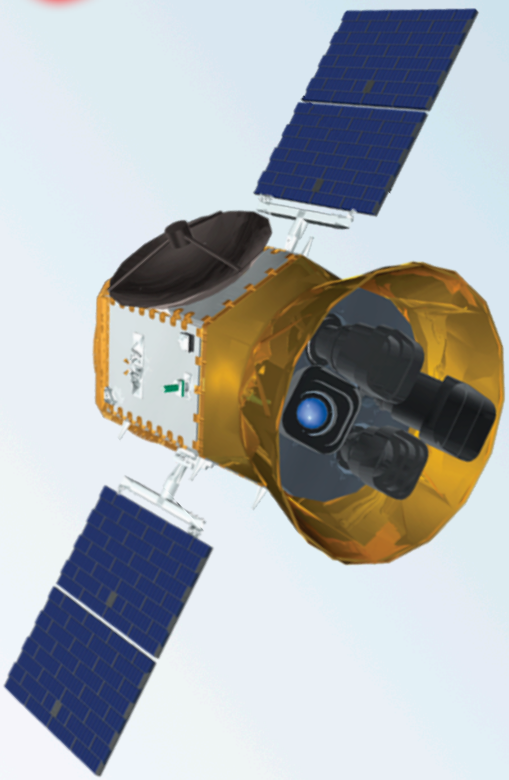
Transiting Exoplanet Survey Satellite



TESS Follow-up Observing Program

David W. Latham for the TFOP WG

Astronomy & Astrophysics Advisory Committee

Thursday 25 January 2018

Transiting Exoplanet Survey Satellite

- All-sky survey to identify the nearest systems of transiting planet candidates
- Best targets for follow-up work to confirm and characterize the planets
  - *Planet masses from Precise Radial Velocities*
  - *Spectroscopy of planetary atmospheres*
- Other Astrophysics
  - *Asteroseismology*
  - *Guest Investigator Program*

TESS Science Office

- Located at CfA and MIT in Cambridge
  - *Dave Latham, Director of Science, TSO lead at CfA*
  - *Sara Seager, Deputy Director of Science, TSO lead at MIT*

- TESS Science Office roles
  - *Prepare TESS Input Catalog and Candidate Target List*
  - *Identify TESS Objects of Interest*
  - *Orchestrate TESS Follow-up Observing Program*
  - *Organize the TESS Science Team and Meetings*
    - *TESS Science Team Meeting #14 Thursday/Friday 1/2 February*
  - *Coordinate TESS Science Team publications*

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TESS Working Groups

- Following the example of very successful Kepler WGs
- Organized by WG leads
- Charters developed by the WG members
- Participation of experts from the community is solicited
  - *Target Star Selection WG*
  - *TESS Objects of Interest WG*
  - *Follow-up Observing Program WG*
  - *Atmospheric Characterization WG*
  - *Full Frame Images (FFI) WG*
  - *Non-Exoplanet Science WG*
  - *Asteroseismology WG*
  - *Open Cluster Survey WG*
  - *Simulations WG*
  - *Extended Missions WG*
  - *Circumbinary Planets WG*
  - *Habitability WG*
  - *Community Science and Guest Investigator Program WG*
- WG members are invited to participate in Science Team meetings and have access to the TESS Wiki

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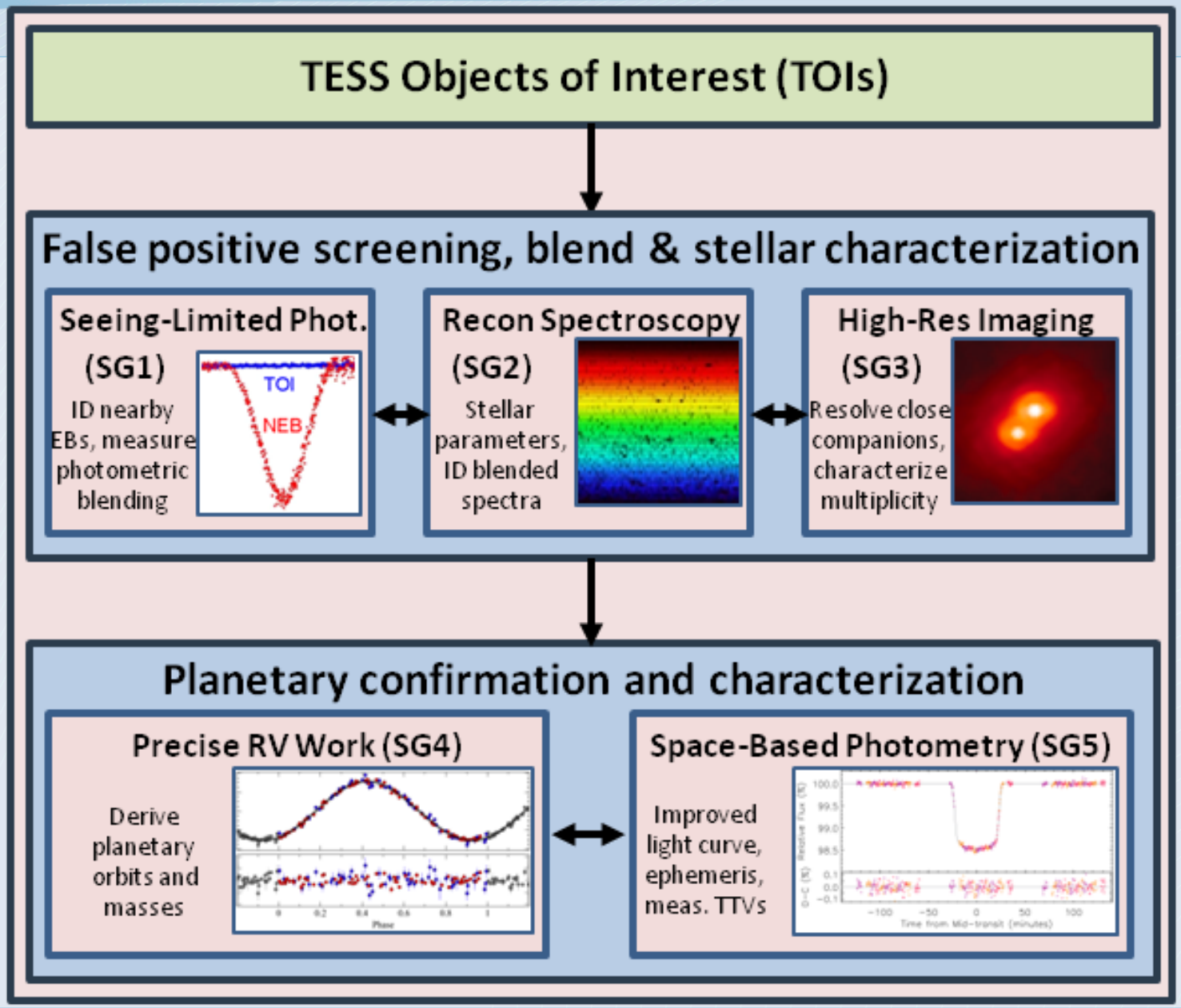
TESS Follow-up Observing Program WG

- TFOP Working Group Goals
  - *Achieve Level One Science Requirements*
    - *Measure masses for 50 planets smaller than 4 Earth radii*
  - *Foster communication and coordination*
    - *Among the TESS Science Team and the Community*
    - *Minimize unnecessary duplication of effort, maximize scientific output*
    - *Look beyond the Level One Requirements*
- Significant directed effort funded by the mission
  - *LCO for both photometry and spectroscopy (N&S)*
  - *CfA for photometry (MEarth N&S) and spectroscopy (TRES)*
- Very large effort contributed by the community
  - *50 WG members already, each representing a team & facility*
  - *Coordinated and archived in collaboration with NExScI: ExoFOP-TESS*

TFOP WG Documented on TESS Wiki



Overview of Five TFOP WG Sub Groups

- SG1 – Seeing-limited Photometry, Dr. Karen Collins Lead
  - *Identify nearby eclipsing binaries contaminating the TESS aperture*
  - *Provide refined photometry of contaminating sources for better planet radii*
- SG2 – Recon Spectroscopy, Dr. Sam Quinn Lead
  - *Identify astrophysical false positives*
  - *Provide improved stellar parameters*
- SG3 – High-resolution Imaging, Dr. David Ciardi Lead
  - *Identify very close companions contaminating the TESS aperture*
- SG4 – Precise Radial Velocity Work, Dr. David Latham Lead
  - *Orbital solutions and planetary masses for small planets*
- SG5 – Space-based Photometry, Dr. Diana Dragomir Lead
  - *Confirm/improve light curves for small planets, better radii*
  - *Extend the TESS photometric ephemerides for future work*
- Steering Committee
  - *SG Leads + Sara Seager, Ian Crossfield, Jessie Christiansen*

Follow-up Work Partially Funded by TESS

- LCO will provide seeing-limited images and NRES spectra
  - *Major commitment of telescope time funded by TESS*
  - *More than doubled by LCO Key Projects plus partners*
  - *Imaging network in routine operation, working well*
  - *NRES-1 installed and operating at CTIO*
  - *NRES-2 installed and operating at McDonald Observatory*
  - *NRES-3 installed at SAAO in South Africa, in commissioning*
  - *NRES-4 In shipping crates at Wise Observatory in Israel*
- CFA will provide seeing-limited images and TRES spectra
  - *Half time on MEarth, both South and North, funded by TESS*
  - *TAC assigned time on KeplerCam (48")*
  - *TAC assigned time on Tillinghast Reflector Echelle Spectrograph (60")*

TRES Exoplanet Spectra Since 2011

Project	Observations	Targets
HATNet	3,400	1,455
KELT	2,168	568
QES	1,868	739
Kepler	1,932	1,342
K2	1,034	598
Total	10,402	4,702
TESS	3,000?	1,500

Kepler/K2 targets for PRV and planet masses with HARPS-N
Orbits, Rossiter-McLaughlin, Doppler Tomography

TRES Team

Perry Berlind, Mike Calkins, Gil Esquerdo,
Allyson Bieryla, Jessica Mink, Lars Buchhave,
John Geary, Gabor Fűrész, Andrew Szentgyorgyi

Roles of MAST and ExoFOP-TESS

- All TESS funded products are archived at MAST at STScI
  - *Photometric data products from the mission*
  - *TESS Objects of Interest identified by the mission*
  - *Follow-up observations funded by the mission*
- NExScI funded by HQ to support community science
  - *ExoFOP-TESS is the main website to support the community*
  - *Tools to encourage coordination and collaboration for follow up work*
  - *Repository for useful information about all TESS objects*
  - *TESS funded follow-up data and results uploaded or pulled from MAST*
  - *Everyone encouraged to upload their follow-up data and results*
- ExoFOP-TESS development coordinated with TSO
  - *Led at NExSci by Jessie Christiansen and David Ciardi*

Backup Slides

PRV Facilities in TFOP WG SG4

Visible	Infrared
HIRES	ISHELL
HARPS	APOGEE
HARPS-N	ISHELL
CARMENESvis	CARMENESir
APF	APOGEE-S
PFS	IRD
HDS	SPIRou
SOPHIE	PARVI
CORALIE	
PEPSI	
MINERVA	
NRES	
NEID	

Sky from Year One Accessible to the North

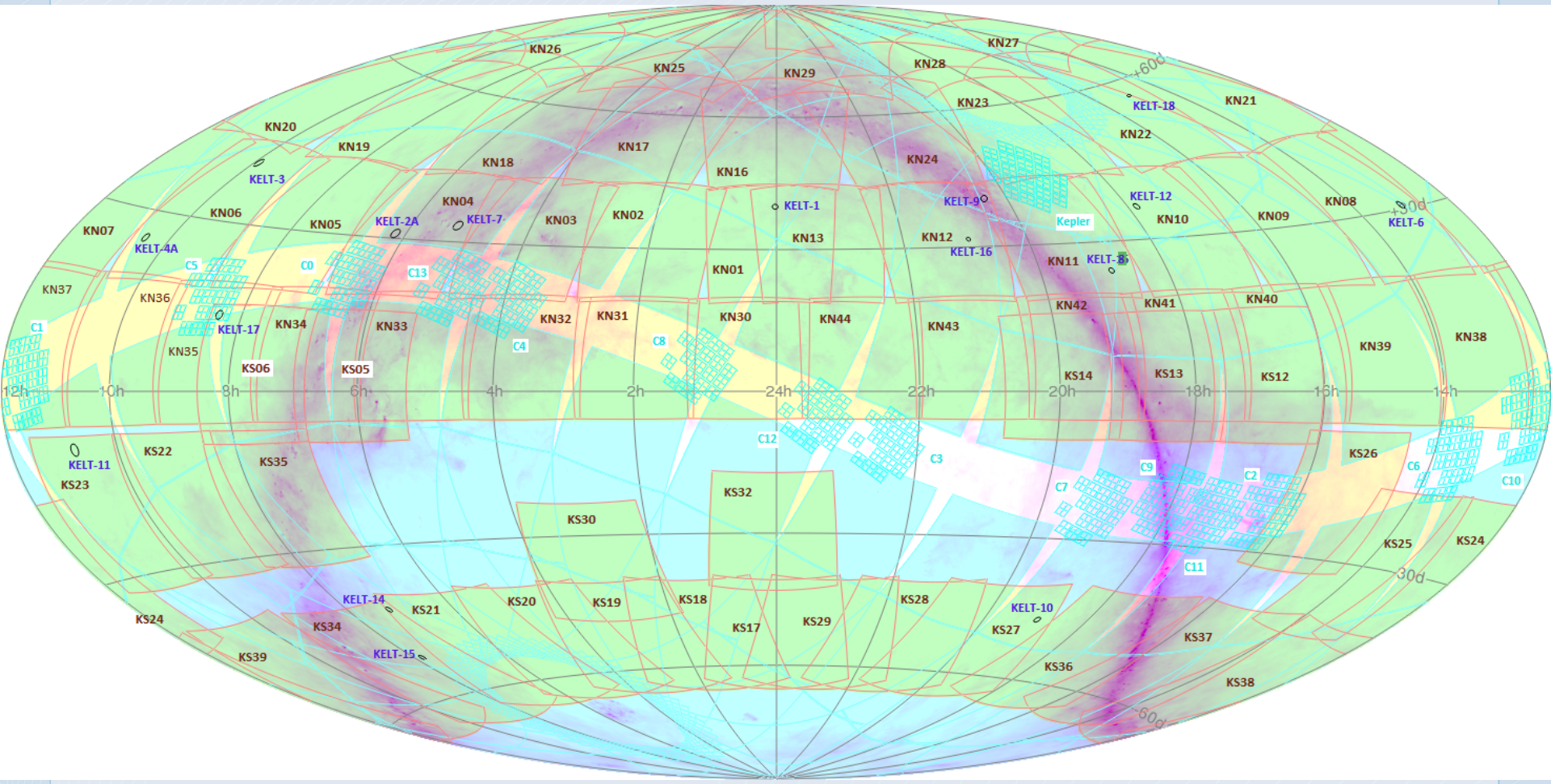
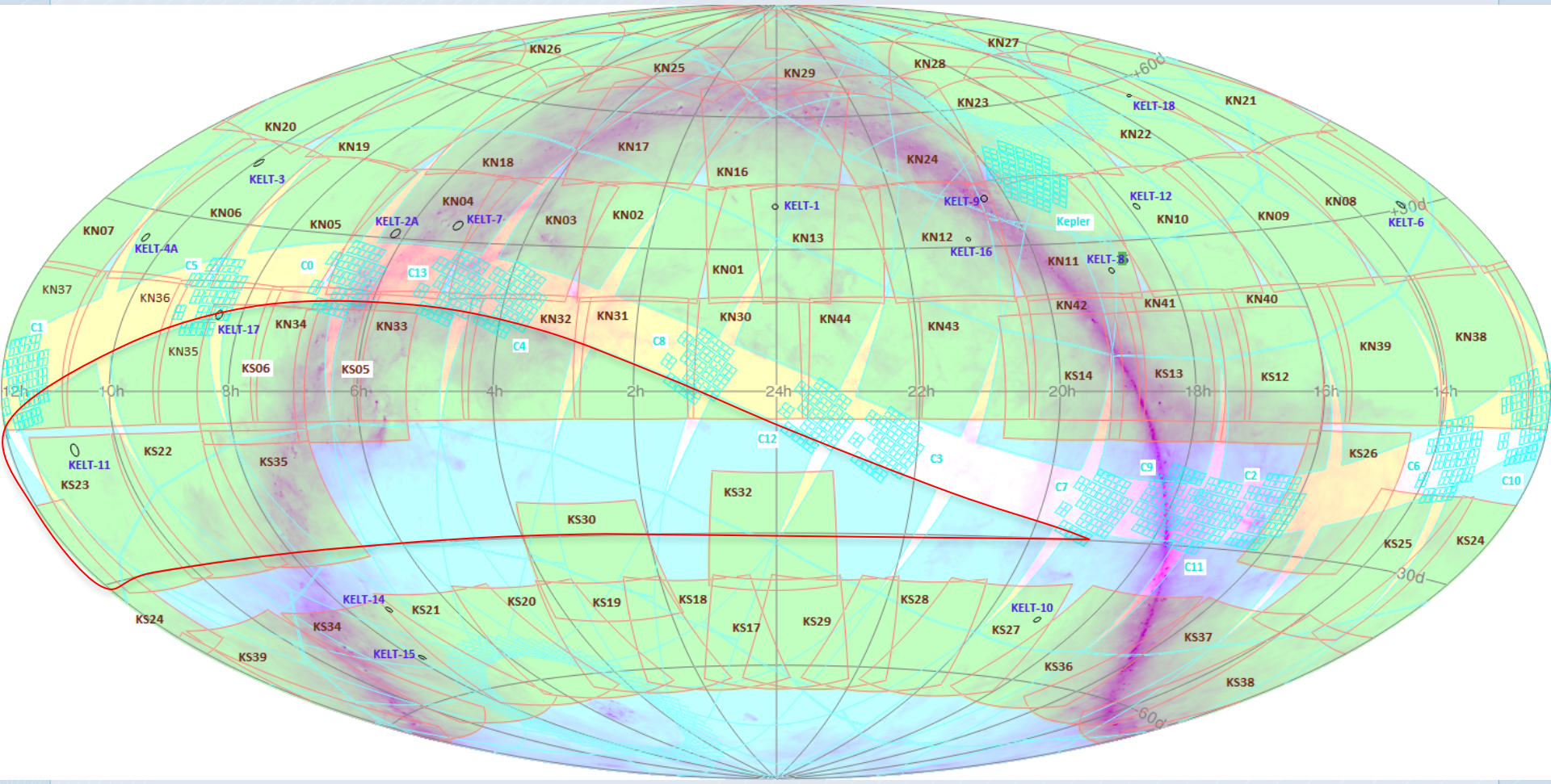


Figure credit: Bruce Berriman and John Good at IPAC

Sky from Year One Accessible to the North



Most northern telescopes can easily reach -30 dec

Figure credit: Bruce Berriman and John Good at IPAC

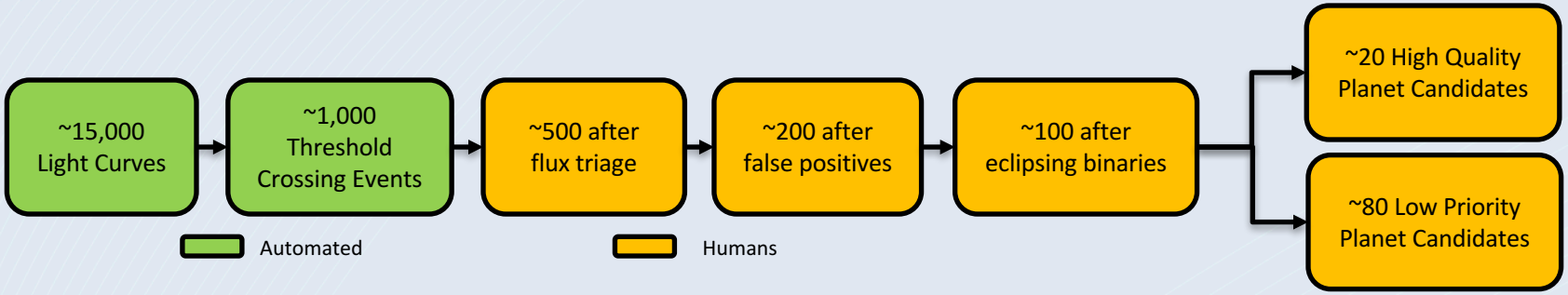
TFOP WG Charter

- Primary Goal: Provide follow-up observations and analysis to facilitate achievement of the Level One Science Requirement: Measure masses for 50 transiting planets smaller than four Earth Radii

- Secondary Goal: Foster communication, coordination, and collaboration within the Science Team and with the community to minimize wasteful duplication of effort and resources and optimize the science return from the mission. Although the primary focus is on achieving the Level One Science Requirement, any science coming out of TESS can benefit.

TOI Identification and Follow-Up Program

- These yield numbers are the highest expected per sector; the average will be about half
  - *Yields now based on simulations paper (Sullivan et al. 2015, ApJ, 809, 77).*
- A vetting team reviews all the available data and identifies ~100 planet candidates per sector



- Lists of TOIs are delivered to MAST on quarterly schedule
- The TSO coordinates follow-up observations by funded facilities and the Community

TFOP Assets for Recon Observations
10,750 Hours Committed

RECON: Measuring Instrument	Telescope	Technique	Observing Time (hrs)	Targets	Leads	Commitment	Funding
LCOGT	1-m network N/S	Seeing-limited Imaging	300	5000	Brown	Committed	Partial
MEarth	16 X 0.4 m N/S	Photometric light curves	4000	500	Charbonneau	Committed	Partial
KeplerCam	FLWO 1.2m N	Photometric light curves	400	50	Latham	TAC	Partial
LCOGT	1-m network S	Recon spectra	2100	1750	Brown	Committed	Partial
CORALIE	Swiss 1.2m S	Recon spectra	1200	1200	Udry	Collab	Collab
TRES	FLWO 1.2m N	Recon spectra	2000	2000	Latham	TAC	Partial
Tull coude	McDonald 2.7m	Recon spectra	200	400	Cochran	TAC	Collab
FIES	NOT 2.5m	Recon spectra	200	400	Andersen	TAC	Collab
Robo AO	Palomar 1.5m N	Recon AO	200	3000	Ciardi	TAC	Collab
200-Inch AO	Palomar 5m N	Deep AO	150	250	Ciardi	TAC	Collab
		Total RECON Hours ≃	**10750**				

TFOP Assets for Orbits & Masses
~4,500 Hours Committed

MASS: Measuring Instrument	Telescope	Band	PRV [m s^{-1}]	Available	Leads	Observing Time [hr]	Commitment	Funding
HARPS-N	TNG 3.6m N	Opt	0.7	Now	Latham, Sasselov	960	Collaboration	Partial
HARPS	ESO 3.6m S	Opt	0.7	Now	Udry, Pepe	720	TACs	Collab
SOPHIE	OHP 2m N	Opt	3	Now	Bouchy	1500	TACs	Collab
LCOGT	1-m network S	Opt	3	2015	Brown	720	Committed	Partial
HDS	Subaru 8.2m N	Opt	3	Now	Narita	100	TACs	Collab
IRD	Subaru 8.2m N	IR	1-3	2015	Narita	100	TACs	Collab
HRS	HET 9.2m N	Opt	3	2014	Cochran	200	TACs	Collab
CARMINES	Calar Alto 3.5m N	OPT/IR	1-3	2015	Quirrenbach	200	TAC	Collab
ESPRESSO	VLT 8.2m S	OPT	0.1	2016	Pepe, Udry	?	TACs	Collab
SPIRou	CFHT 3.6m N	OPT/IR	1-3	2017	Doyon	?	TACs	Collab
SPIRou	NTT 3.6m S	Opt/IR	1-3	2017	Hebrard	?	TACs	Collab
					Total Hours ≃	**4500**		

TFOP Assets for Follow-Up Observations

TFOP Assets for Recon Observations: 10,750 Hours Committed

RECON: Measuring Instrument	Telescope	Technique	Observing Time (hrs)	Targets	Leads	Commitment	Funding
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MEarth	16 X 0.4 m N/S	Photometric light curves	4000	500	Charbonneau	Committed	Partial
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TFOP Assets for Orbits and Masses: ~4,500 Hours Committed

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TESS Science Team Meeting #14, Plenary Session, Thursday 1 February 2018
MIT, Marlar Lounge, Room 37-252, 70 Vassar Street, Cambridge and WebEx
DRAFT, 24 January 2018, Version 7

09:30 Sign-in, coffee
10:00 George Ricker: TESS Mission Update
10:15 Roland Vanderspek: Commissioning Plans
10:30 Tom Barclay: Guest Investigator Program Update
10:50 Dan Foreman-Mackey: "Preparing for TESS" Meeting
11:00 Jørgen Christensen-Dalsgaard: TASC & TASOC Update
11:20 Jacob Bean: Atmospheric Characterization Working Group Overview
11:30 Eliza Kempton: Atmospheric Characterization Follow-up Priorities
11:45 Daniel Tamayo: Fast Stability Predictions for Multi-planet Systems

12:00 Lunch Break

01:30 Sara Seager: TESS Objects of Interest
01:45 Natalia Guerrero: TOI Vetting Process
02:05 Chelsea Huang: TOIs from the TESS MIT Quick Look Pipeline
02:25 Tim Brown: Status of LCO's NRES Network
02:45 Cullen Blake: Status of NEID

03:00 Break

03:30 Arfon Smith: Exploring Commercial Cloud for TESS Archives
03:40 Susan Mullally: Role of MAST for TESS*
04:05 Scott Fleming: MAST Tools Update
04:15 Jessie Christiansen: ExoFOP-TESS Update
04:35 Sam Quinn: TFOP WG Priority Schemes
04:50 George Ricker: Invitations to Witness the Launch
05:00 General Discussion
05:45 Adjourn