TASC Target selection procedure

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This document contains a description of the TASC target selection procedures. The organisation and structure of TASC (TESS Asteroseismic Science Consortium) is discussed in document SAC/TESS/0003, where the structure and role of TASC, the TASC Board, the TASC Steering Committee, the TASC Working Groups and the TASC membership are described. The aim of the present document is to describe the target selection procedures for TASC targets as well as the procedures for prioritizing targets. The agreement with and interface to the TESS project is described in SAC/TESS/0001 (including the formal 'Letter of Intent' that forms the agreement between TASC and the TESS PI).

1, The TESS mission

The Transiting Exoplanet Survey Satellite (TESS) is a NASA Explorer mission that will observe several hundred thousand stars at a cadence of 2 minutes, as well as generating Full Frame Images (FFI's) at cadence of 30 minutes (see Ricker, G. R., Winn, J. N., Vanderspek, R., Latham, D. W., et al. 2015, SPIE Journal of Astronomical Telescopes, Instruments, and Systems, 1, id.014003 for details). TESS aims to do wide-field surveys with the fine photometric precision and long intervals of uninterrupted observation, as can only be done in a space mission. Compared to Kepler, TESS will examine stars that are generally brighter by 4-5 magnitudes over a FOV at each pointing that is larger by a factor of 25. TESS will observe at each pointing for 27 d, and the overlap between fields means that a given target will be observed continuously for between 27d and 355 d, depending on the ecliptic latitude.

The specific locations of the TESS pointings are not known at present. However, the length of each time series can be estimated as a function of ecliptic latitude. The figure below is from Sullivan et al. (2015, ApJ, 809, 1) and shows the potential length of a time series for an object at a specific ecliptic latitude.

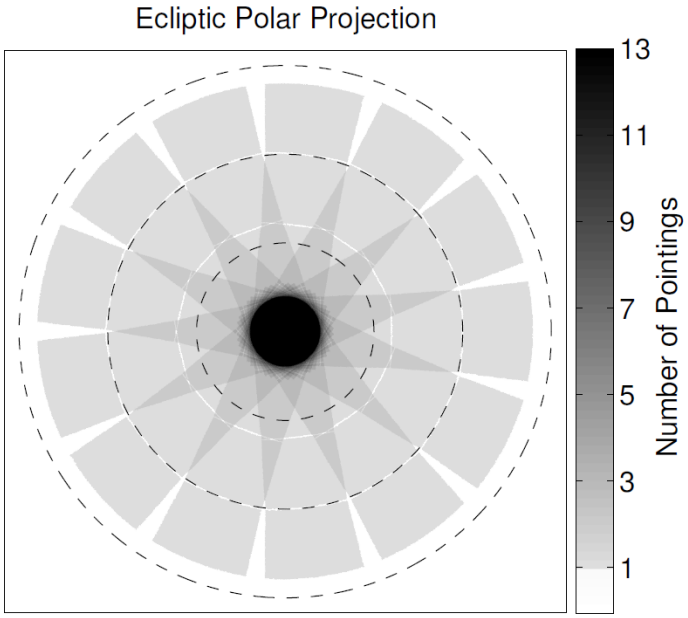

Figure from Sullivan et al. (2015, ApJ, 809, 1). Polar projection illustrating how each ecliptic hemisphere is divided into 13 pointings. At each pointing, TESS observes for a duration of 27.4 days, or two spacecraft orbits. The four TESS cameras have a combined field-of-view of 24° x 96°. The number of pointings that encompass a given star is primarily a function of the star's ecliptic latitude. The dashed circles show 0°, 30°, and 60° of ecliptic latitude. Coverage near the ecliptic (0°) is sacrificed in favour of coverage near the ecliptic poles, which receive nearly continuous coverage for 355 days.

The TESS spectral bandpass is 600-1000 nm. The red end is defined by the red limit of the silicon CCD sensitivity, and the width of 400 nm is a result of the optical design. The TESS bandpass is centered on the traditional Cousins *I* band but is significantly wider. The bandpass is shown in the figure below. Note that the bandpass is shifted towards longer wavelength compared to *Kepler*.

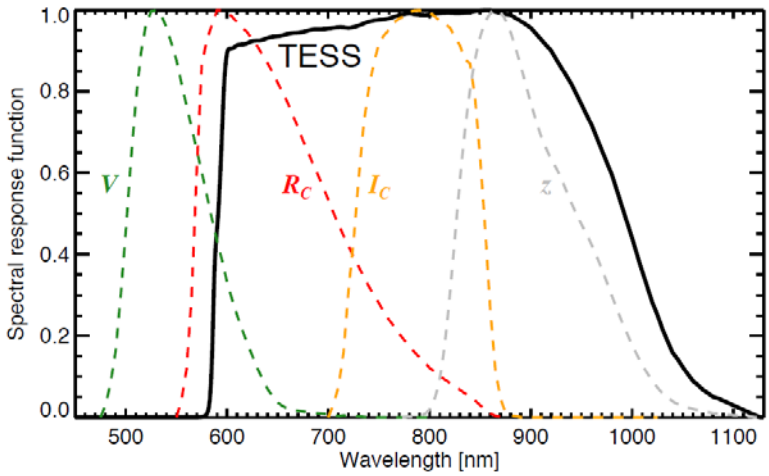

Figure from Ricker, G. R., Winn, J. N., Vanderspek, R., Latham, D. W., et al. (2015, SPIE Journal of Astronomical Telescopes, Instruments, and Systems, 1, id.014003). The TESS spectral response function (black line) is defined as the product of the long-pass filter transmission curve and the detector quantum efficiency curve.

The saturation limit for stars observed with TESS is around *I* = 6.7. Like we could do for Kepler we expect to be able to observe stars much brighter than the saturation limit. The limit could be at *I* = 2.

The noise level for a given star depends on the photon flux. Using the *I*-magnitude as the guideline Sullivan et al. (2015, ApJ, 809) gave correction factors for photon fluxes for stars at different spectral type.

For star brighter than *I* = 13 the main contribution to the instrumental noise is photon noise. To first order, one can estimate the expected quality of TESS time series data by taking a time series from the Kepler data base which is 5 magnitudes fainter. Using the throughput of TESS and the spectral bandpass, one may also use Table 1 below to estimate the noise. Note that those numbers do not include systematic errors, which may dominate for bright stars. The experience from Kepler, however, is that the systematic errors are small for timescales of solar-like oscillations.

Table 1: Instrumental noise levels for TESS (photon and background noise, RON, sky background etc.)

I	Noise / hr	Noise / 2 min	1σ-noise i amplitude (27 d)
2.0	4.4 ppm	24 ppm	0.31 ppm
3.0	7.0 ppm	38 ppm	0.49 ppm
4.0	11 ppm	61 ppm	0.78 ppm
5.0	18 ppm	96 ppm	1.2 ppm
6.0	28 ppm	150 ppm	2.0 ppm
7.0	44 ppm	240 ppm	3.1 ppm
8.0	70 ppm	380 ppm	4.9 ppm
9.0	110 ppm	610 ppm	7.8 ppm
10.0	180 ppm	970 ppm	12 ppm
11.0	290 ppm	1560 ppm	21 ppm
12.0	480 ppm	2600 ppm	34 ppm
13.0	860 ppm	4700 ppm	60 ppm
14.0	1700 ppm	9300 ppm	120 ppm
15.0	3600 ppm	19000 ppm	240 ppm

2. Selection of targets for science done within TASC

As discussed in document SAC/TESS/0003, TASC has set up a data centre: the TESS Asteroseismic Science Operations Center (TASOC) that will host a web-based data and information portal designed to serve the TASC. Information on scientific planning and management, TASC members, conferences and workshops, target selection, data analysis and publications will be distributed via the TASOC webpage. TASOC is hosted by the Stellar Astrophysics Centre at Aarhus University in Denmark. The webpage for TASOC is: https://tasoc.dk.

In the context of the TASC target selection, it is important to note that the following:

- TASC is a large scientific collaboration formed around the asteroseismic activities of the TESS mission. TASC aims at gathering a large fraction of the relevant research groups worldwide.

- TASC will contain a collaborative working-group structure that is aimed at supporting collaboration between many individual researchers and research groups around the world. Each working group (WG) has clear and scientifically well-defined tasks and aims. The main tasks will be: target selection, organizing ground-based observations (target classification, target selection and follow-up), coordination of data analysis, and publications. Each WG will also coordinate their activities with the TESS Team and other relevant missions (e.g. Kepler, K2, PLATO and Gaia). The nine WGs are:

  WG0. TASOC – Basic photometric algorithms / TASC data products
  Chairs: Rasmus Handberg and Mikkel Nørup Lund

  WG1. Asteroseismology of TESS exoplanet hosts
  Chairs: William Chaplin and Daniel Huber

  WG2. Oscillations in solar-type stars
  Chairs: William Chaplin and Thierry Appourchaux

  WG3. Oscillating stars in clusters
  Chairs: Sarbani Basu and Saskia Hekker

  WG4. Main Sequence AF classical pulsators
  Chairs: Victoria Antoci and Margarida Cunha

  WG5. Main Sequence OB classical pulsators
  Chairs: Peter De Cat and Gerald Handler

  WG6. RR Lyrae stars and Cepheids
  Chairs: Katrien Kolenberg and Róbert Szabó

  WG7. Red Giant oscillators
  Chairs: Victor Silva Aguirre and Dennis Stello

  WG8. Compact pulsators
  Chairs: Mike Montgomery and Stéphane Charpinet

- The goals of the TASC science program are:
  - Asteroseismic characterization of planet-hosting stars, including mass, age and particularly radius.
  - Understanding general stellar properties, including stellar structure modelling, and contributing to stellar characterization.

- TASC will identify stars suitable for asteroseismic analysis and provide the selection of targets for the asteroseismic program to be observed by the mission. The numbers of targets available for asteroseismology for each 27-day pointing are:

  - **60** targets with 20-sec sampling
  - **750** targets with standard 2-min sampling

- For the 20 sec cadence, TASC will identify targets where the sampling may need to be shorter than 2 minutes. TASC (and TASOC) will, in relation to those special targets, develop a pipeline for basic analysis of this type of data.

- TASC (through TASOC) will analyse the full frames (30 min sampling) in order to detect oscillations in red giants, SPBs, RR Lyraes, beta Cep stars, Cepheids, etc., and also to produce light curves for eclipsing binaries.

2.1 Target selection procedures

The selection of targets by TASC takes place in the working groups. The TASC target list is dynamic and can be updated throughout the TESS mission, as needed, in order to optimize the TASC science. The TASC target list will be created and merged with the TESS target list via the following phases:

Phase 1: WG target selection – WG Target lists

Each TASC working group (WG) will create a **prioritized target list** for the whole sky. Without regard to the specific pointing requirements, the list will describe the stars that the working group would like to have on the TESS target list. The priority assigned to targets on each WG list should reflect the following:

- **Scientific quality** (each proposed target is linked to a science project/proposal and will be reviewed by the WG chairs). A detailed description of the format and content of the projects/proposals can be found via: https://tasoc.dk/proposals/proposal_upload.php.

- **Length of time series** (taking into account ecliptic latitude and possibility for ground-based follow-up)
- **SNR** (based on expected signal, brightness and crowding)

Note that the WG target list will contain targets for the whole sky (or each hemisphere) and WGs will not create separate prioritized target lists for each TESS pointing.

We require the following information in relation to each WG target list:

- **Title**

- **Short abstract**

- **Cadence:** Indicate if this is the target lists for 20 sec or 2 min TESS sampling. Please do not merge the discussion for 20 sec and 2 min target lists into one file (upload two seperate proposals for this).

- **People:** Names of the WG members that contributed to the proposal (chairs of WG's should be listed first)

- **Science Case:** (Up to one page, figures do not count in this page limit). The discussion should focus on the expected outcome and impact of the TESS observations for those targets. References to literature can be included, but it is not the intention to provide a review of the status within the specific research field.

- **Length of the time series:** Discuss the impact of the length of the time series in general and for specific targets where relevant. The length of the time series will be between 27 days and one year (depending on ecliptic latitude).

- **Quality of TESS data** compared to other relevant data for those specific targets. Discuss the SNR, crowding, detection threshold, expected signal, number of targets and if there are any specific requirements for this specific proposal.

- **Priorities of the targets:** Discuss how the targets have been prioritized (highest priority at the top of the list) and if there is a minimum number of targets that needs to be observed in order to be able to do the specific science for a given WG. Target prioritization may include science return, length of time series, data quality, etc.

- **Ground-based observations in relation to this proposal:** Discuss if any ground-based observations/data are required and/or planned in relation to the proposal.

- **Additional remarks:** Any other issues that are relevant to know in order to assess the target list.

The prioritized target list submitted by each working group will contain the TIC-numbers (one per line) ordered such that the highest priority is at the top and the lowest priority at the bottom.

The list could be like the one below (example of a list submitted by WG4):

```
270577175
471012052
 56453471
141275283
 61811148
323292655
417604820
 67265166
406755195
328860893
331391396
280680714
393808058
  . . . .
```

The individual WG target lists are verified by TASOC and magnitudes and coordinates are added. For each WG (and each sample (20 sec and 2 min)) we create a new target list. The target list based on the above example (WG4) will contain the following information:

```
# TASC Target Selection
# Title: Asteroseismology of δ Sct Stars
# Working Group: 4
# Cadence: 120s
#
# Column 1: Priority
# Column 2: TIC identifier
# Column 3: TESS magnitude
# Column 4: Ecliptic longitude (degrees)
# Column 5: Ecliptic latitude (degrees)
# Column 6: Right ascension (degrees)
# Column 7: Declination (degrees)
# Column 8: Version of TIC parameters (yyyymmdd)
# Column 9: Alternative target name
#-----------------------------------------
    1  270577175   3.820   82.543505  -74.423528   86.821179 -51.066517  20170315 "HIP 27321"
    2  471012052   0.760  301.774728   29.302823  297.694509   8.867385  20170315 "HIP 97649"
    3   56453471   5.247   65.657165    5.318808   62.707802  26.480982  20170315 "HIP 19513"
    4  141275283   5.529  171.450578   28.066414  184.377406  28.937216  20170315 "HIP 59923"
    5   61811148  10.507  285.074753  -20.272113  289.389010 -42.702023  20170315 "TYC 7926-00099-1"
    6  323292655   6.111  244.424456  -73.321828  130.800944 -79.070084  20170315 "HIP 42794"
    7  417604820   2.320   12.778101   68.913728  319.644818  62.585590  20170315 "HIP 105199"
    8   67265166   5.835   89.711801  -32.821312   89.754524  -9.382266  20170315 "HIP 28321"
    9  406755195   6.158  177.363771   25.482180  188.392590  24.283033  20170315 "HIP 61295"
   10  328860893   6.282  173.248807   25.592845  184.758421  26.008312  20170315 "HIP 60066"
   11  331391396   4.552   41.798029   43.120750   17.775677  55.149902  20170315 "HIP 5542"
   12  280680714   6.277  117.554329  -18.578332  116.031816   2.405431  20170315 "HIP 37705"
   13  393808058   6.355  175.297159   26.739177  187.158997  26.226954  20170315 "HIP 60880"
  . . . . . .
```

Phase 2: Making a merged and prioritized target list – TASC Main Target List

The individual WG lists (from Phase 1) will be merged into one list based on scientific priorities that will be set by the TASC Board and the TASC Steering Committee. The target priorities are set by weighting the individual Working Group target lists using the average number of targets for each 27-day pointing as the guide line. The following numbers are used to create the first target prioritization (**Short Cadence (SC)**: 120 sec and **Ultra-short Cadence (UC**): 20 sec):

Target numbers used for merging the WG target lists

Targets for SC (120 sec)		Targets for UC (20 sec)	
Targets	Working Group (Target List)	Targets	Working Group (Target List)
4	WG0	**1**	WG0
450	WG1, WG2, WG7	**45**	WG1, WG2, WG7
5	WG3 Target List North (3.1)	**1**	WG3
4	WG3 Target List South (3.2)		
120	WG4 Target List delta Scuti (4.1)		
50	WG4 Target List roAp (4.2)	**3**	WG4
35	WG5		
3	WG6		
79	WG8	**10**	WG8
750	TASC SC	60	TASC UC

The number of targets for each working group list is used to normalize the individual prioritization for each working group target list. The higher the number the more targets in this specific group will be assigned a high priority.

Based on the above table one can then create a combined list. At present we only create a SC target list (and all UC targets are also included as SC targets). The combined prioritized list contain at present 28627 targets that are prioritized. The top targets in the combined list are shown below. The 1st column is the priority from 1 to 28627. The 2nd column indicate the specific working group: 0, 3, 4, 5, 6, 8 are individual working group numbers and 127 indicate the combined WG1, WG2 and WG7. For WG3 and WG4 we have two lists identified as 3.1, 3.2, 4.1 and 4.2 (see above). The UC targets are identified as 0.5, 3.5, 4.5, 8.5 and 127.5. The 3rd column indicate the individual WG priority. The 4th, 5th, 6th, 7th, 8th and 9th column are TIC-4 parameters, TIC-4#, TESS magnitude, ecliptic coordinates (in degrees) and RA (degrees) and DEC (degrees).

```
# TASC Target List
# Title: Priority of Combined TASC Targets: Version 2
# TASOC 2017-07-05
# TESS Cadence: 120 s
#
# Column 1: Priority
# Column 2: Working Group (0,127,3,4,5,6,8, .5: UC, .1/.2: two parts)
# Column 3: Internal Working Group Priority
# Column 4: TIC identifier (TIC-4)
# Column 5: TESS magnitude (TIC-4)
# Column 6: Ecliptic longitude (degrees) (TIC-4)
# Column 7: Ecliptic latitude (degrees) (TIC-4)
# Column 8: RA (degrees)
# Column 9: DEC (degrees)
#-------------------------------------------------------------------------------------------
     1    127.0      1   452706688    3.829  338.934070   36.638660  326.161331   25.645067
     2    127.0      2   396915247    4.398  167.566044    6.105264  170.981099   10.529424
     3    127.0      3   154360594    2.486  131.388885  -43.270091  121.886033  -24.304300
     4      4.1      1   270577175    3.820   82.543505  -74.423528   86.821179  -51.066517
     5    127.0      4   382600457    2.814  260.742897  -20.183570  258.038357  -43.239231
     6    127.0      5   401396260    3.871    2.583488    6.362966  359.827827    6.863292
```

7	8.0	1	457168745	11.101	54.764602	-16.625378	56.394015	2.797968
8	127.0	6	471011543	0.400	115.786861	-16.016836	114.827242	5.227508
9	127.0	7	4194999	4.481	110.742949	12.913202	114.791374	34.584358
10	4.1	2	471012052	0.760	301.774728	29.302823	297.694509	8.867385
11	127.0	8	65628544	5.078	29.762761	49.532850	359.285157	55.705723
12	127.0	9	167092249	3.343	338.608221	50.550963	318.697759	38.045261
13	4.2	1	158991675	8.937	303.757898	64.268735	289.284599	43.072807
14	127.0	10	262841041	3.693	320.440048	-47.850028	349.357481	-58.235767
15	127.5	1	245895478	6.200	69.878313	-6.126747	69.169598	15.869302
16	127.0	11	161025531	5.365	192.659615	60.056772	222.422306	48.720795
17	4.1	3	56453471	5.247	65.657165	5.318808	62.707802	26.480982
18	8.0	2	75586114	12.328	167.444364	41.619248	188.963132	42.377705
19	127.0	12	449201578	5.006	79.113049	-20.458655	79.796759	2.595856
20	5.0	1	165991532	3.461	157.456187	66.362116	211.097323	64.375862
21	127.0	13	88562096	3.834	262.880737	-6.629144	261.838652	-29.866964
22	127.0	14	453310524	4.877	93.742333	30.083578	95.442196	53.452194
23	127.0	15	150226696	2.744	127.264346	34.896125	143.214658	51.677353
24	4.1	4	141275283	5.529	171.450578	28.066414	184.377406	28.937216
.	.	.	.	.	.	.	.	.

Phase 3: Selecting unique TASC targets – The Final TASC Target List

When the TESS Science Office wants to create a target list for TESS, they will use latest TASC prioritized list of targets. The main TASC list for the whole sky will need additional filtering, since only a few percent of the stars on the list can be observed at a specific time. TASC is not the only external group that will be selecting targets for TESS. In particular, many targets will be selected for the TESS main science goal of searching for exoplanets. If a target is already on the TESS core target list (selected by the TESS team), it will be deleted from the TASC target list (no stars need to be selected twice). Those targets that remain will form the final TASC target list for that pointing (ecliptic longitude / hemisphere). The **top 750 stars (for 2 min cadence)** and **the top 60 stars (for 20 sec cadence)** will be put on the mission target list as TASC targets. Note that the target list will be converted to XML before it is shipped to TESS (defined in the Interface Control Document (ICD) between TASOC and POC).

2.2 Schedule for the TASC target selection

In order to understand the procedures for target selection and locate the main issues and problems that may exist in the detailed selection process, TASC will make draft versions of target documents and preliminary targets lists. Those target lists will be used by TASC, the WG chairs and the Steering Committees, as well as TASOC, to set up the procedures that will allow a well-defined, transparent and smooth selection throughout the four phases discussed above.

The present schedule for TASC target selection is as follows:

1. The TASC target selection process was introduced and discussed at the KASC9/TASC2-workshop in July 2016. Each WG discuss the specific issues related to target selection. Target lists for each WG was submitted in December 2016 in order to provide the first input for Phase 1.

2. A first draft version of the WG target lists will be ready will be discussed at the KASC10/TASC3-workshop in July 2017. We used those to test phases 1 and 2 of the target selection procedure.

3. An updated version of the TASC WG target lists will be constructed in September 2017 and used to test all four phases of the target selection.

4. TESS launch is expected in March 2018.