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.](image-url)
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.

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 \( I = 2 \).


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.)

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

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.
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 separate 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 3.820 82.543505 -74.423528 86.821179 -51.066517 20170315 "HIP 27321"
471012052 0.760 301.774728  29.302823  297.694509   8.867385  20170315 "HIP 97649"
56453471 5.247  65.657165   5.318808   62.707802  26.480982  20170315 "HIP 19513"
141275283 5.529  171.450578   28.066414  184.377406  28.937216  20170315 "HIP 59923"
61811148 10.507  285.074753  -20.272113  289.389010 -42.702023  20170315 "TYC 7926-00099-1"
323292655 6.111  244.424456  -73.321828  130.806424  184.377406  20170315 "HIP 61295"
417604820 2.320   12.778101   68.913728  319.644818  62.585590  20170315 "HIP 105199"
67265166  5.835  175.297159   26.739177  187.158997  26.226954  20170315 "HIP 60880"
```

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  130.806424  184.377406  20170315 "HIP 61295"
7 417604820 2.320   12.778101   68.913728  319.644818  62.585590  20170315 "HIP 105199"
8 67265166  5.835  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

<table>
<thead>
<tr>
<th>Targets for SC (120 sec)</th>
<th>Targets for UC (20 sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets</td>
<td>Working Group (Target List)</td>
</tr>
<tr>
<td>4</td>
<td>WG0</td>
</tr>
<tr>
<td>450</td>
<td>WG1, WG2, WG7</td>
</tr>
<tr>
<td>5</td>
<td>WG3 Target List North (3.1)</td>
</tr>
<tr>
<td>4</td>
<td>WG3 Target List South (3.2)</td>
</tr>
<tr>
<td>120</td>
<td>WG4 Target List delta Scuti (4.1)</td>
</tr>
<tr>
<td>50</td>
<td>WG4 Target List roAp (4.2)</td>
</tr>
<tr>
<td>35</td>
<td>WG5</td>
</tr>
<tr>
<td>3</td>
<td>WG6</td>
</tr>
<tr>
<td>79</td>
<td>WG8</td>
</tr>
<tr>
<td>750</td>
<td>TASC SC</td>
</tr>
</tbody>
</table>

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, 127, 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 452706988 3.829 338.934070 36.638600 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
4 127.0 3 154360594 2.486 131.388885 43.270091 121.886033 24.304300
5 127.0 4 270577175 3.820 82.543505 338.934070 36.638600 326.161331 25.645067
6 127.0 5 401396260 3.871 338.934070 36.638600 326.161331 25.645067
```
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 the 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 target 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.