Kepler: A Search for Terrestrial Planets

Stellar Classification Program Plan

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Reference Documents

KGSS-14004	Ground Segment Requirements Document
KP-111	Science Requirements Document
KSOC-21112	SCP – SOC Interface Control Document

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DOCUMENT CHANGE LOG

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p2	9/8/2004	ALL	Revised draft, DWL
001	April 2005		Ready for Release
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List of Acronyms

CCD	Charge Coupled Device
FLWO	Fred Lawrence Whipple Observatory
FOV	Field of View
FS	Flight Segment
GSRD	Ground Segment Requirements Document
HAO	High Altitude Observatory
KIC	Kepler Input Catalog
LCO	Las Cumbres Observatory
NASA	National Aeronautics and Space Administration
PI	Principal Investigator
PSI	Planetary Science Institute
SAO	Smithsonian Astrophysical Observatory
SCP	Stellar Classification Program
SO	Science Office
SRD	Science Requirements Document
USNOFS	United States Naval Observatory Flagstaff Station

1. Introduction

1.1 Purpose

The Stellar Classification Program (SCP) for the Kepler Mission is responsible for preparing the Kepler Input Catalog (KIC) for delivery to the Science Office (SO) before 1 January 2008. The results of new multi-band ground-based photometry and spectroscopy being carried out by the SCP team will be combined with existing information for all known objects in the Kepler Field of View (FOV) to create the KIC. The Kepler SO will use the information in the KIC when selecting targets to be observed by Kepler.

1.2 Scope

This plan applies from Phase B through launch of the Kepler spacecraft.

2. Driving Requirements

The SCP tasks are determined by specific requirements flowing down from the Kepler Ground System Requirements Document (GSRD). The requirements are listed below.

2.1 GSRD Requirements

- GSRD174: The Stellar Classification Program (SCP) **shall** prepare and deliver the Kepler Input Catalog prior to the launch for the purpose of selecting *planetary target stars*.
  The SCP activity addressing this requirement is discussed in Section 4.5.

- GSRD175: Prior to launch the SCP **shall** identify and catalog the coordinates, brightnesses, and stellar radii of ≥ 150,000 of the brightest targets in the active FOV with a radius ≤ 2 solar radii.
  The SCP activity addressing this requirement is discussed in Sections 3.1 and 5.

- GSRD176: The SCP **shall** determine stellar radii to an uncertainty of less than 50%.
  The SCP activity addressing this requirement is discussed in Section 5.

- GSRD357: The Ground Segment **shall** plan to operate the FS (Flight Segment) with the photometer axis pointed near Right Ascension of 19h23m and Declination of +44°30'.
  The SCP activity addressing this requirement is discussed in Section 3.1.

3. Photometry

In November 2002 the Kepler Science Team recommended that a new ground-based multi-band photometric survey be carried out to assist in the selection of targets for the mission. In response to that recommendation, a team led by David W. Latham at the Smithsonian Astrophysical Observatory (SAO) was organized to explore the possibility of obtaining the needed photometry using the 48-inch telescope at SAO's Fred Lawrence Whipple Observatory (FLWO) located on Mount Hopkins in Arizona. In April 2004 this team was selected by the Kepler Mission to carry out the photometric survey.

3.1 Photometric Survey of the Kepler Target Region

The Charge Coupled Devices (CCDs) of the Kepler photometer cover an area larger than 100 square degrees in a field of view that spreads across more than 150 square degrees in the constellations of Cygnus, Draco, and Lyra, centered on Galactic longitude $\ell = 76.32°$ and latitude $b = +13.5°$, or right ascension $\alpha = 19^h\,22^m\,40^s$ and declination $\delta = +44°\ 30'\ 00''$. The KIC will cover the entire FOV including the gaps between the CCDs, with enough margin to allow for small changes in the final FOV.

The initial photometric observations were obtained with the venerable 4Shooter mosaic CCD camera on the 48-inch telescope. In parallel, a major effort was undertaken to replace the 4Shooter with a state-of-the-art CCD camera, KeplerCam, to improve both the efficiency and the quality of the photometric observations. KeplerCam went into routine operation with the 48-inch telescope on 1 September 2005. During the period 1 September 2004 to 31 July 2005 MiniCam, a state-of-the-art CCD camera built for the MMT, was used for the SCP photometry, on loan from the MMT.

A team of scientists from four institutions was assembled to carry out the photometric survey, the astrophysical interpretation of the results for inclusion in the KIC, and the actual preparation and delivery of the KIC.

The Planetary Science Institute (PSI, Mark Everett PI) is responsible for the development and maintenance of the pipeline for reducing raw images to instrumental magnitudes and positions of stars, for running the observations through the pipeline, and for delivery of those results for inclusion in the SCP database.

The Las Cumbres Observatory (LCO, Timothy M. Brown PI, formerly at the High Altitude Observatory) is responsible for the development and maintenance of the SCP database, for the transformation of the instrumental magnitudes to a standard photometric system, for the astrophysical interpretation of the calibrated photometry, for the inclusion of this information in the SCP database, and for delivery of this information in summary form for inclusion in the KIC.

The United States Naval Observatory, Flagstaff Station (USNOFS, David G. Monet PI) is responsible for the astrometric performance of the Photometric Survey and for the actual creation of interim and final versions of the KIC.

The Smithsonian Astrophysical Observatory (SAO, David W. Latham PI) is responsible for coordinating all the efforts related to the Photometric Survey and the preparation and delivery of the KIC. The Kepler FOV is observed using the 48-inch telescope and CCD cameras at FLWO. The telescope time and operational support are provided by SAO at no cost to NASA. Allocation of telescope time to the SCP is controlled by the CfA Time Allocation Committee (TAC). Latham prepares and submits requests for telescope time to the TAC.

4. Photometry Milestones

4.1 2003 Observations

Photometric observations with the 4Shooter CCD camera on the 48-inch telescope were scheduled on 39 nights. All of the observations have been processed.

4.2 2004 Observations

Photometric observations with the 4Shooter CCD camera on the 48-inch telescope were scheduled on 49 nights through July 2004. Photometric Observations with the MiniCam CCD camera on the 48-inch telescope were scheduled for 38 nights starting in September 2004. All of the observations have been processed. The results were included in an interim version of the KIC that was delivered in December 2004.

4.3 2005 Observations

Photometric Observations with the MiniCam CCD camera on the 48-inch telescope were scheduled for 66 nights through July 2005. Photometric Observations with the KeplerCam CCD camera on the 48-inch telescope were scheduled for 47 nights starting in September 2005. All of the observations have been processed. The results were included in an interim version of the KIC that was delivered in December 2005. As of 31 July 2005 the entire Kepler FOV had been observed at least once.

4.4 2006 and 2007 Observations

Photometric Observations with the KeplerCam CCD camera on the 48-inch telescope were scheduled for 89 nights through July 2006. A proposal for an additional 40 nights starting in September 2006 was submitted to the TAC. Proposals for similar numbers of nights will be submitted in 2007. The goal is to observe the entire Kepler FOV at least twice. An interim version of the KIC including all the new observations obtained in 2006 will be delivered in December 2006.

4.5 Kepler Input Catalog Delivery

The final version of the KIC will be delivered in December 2007.

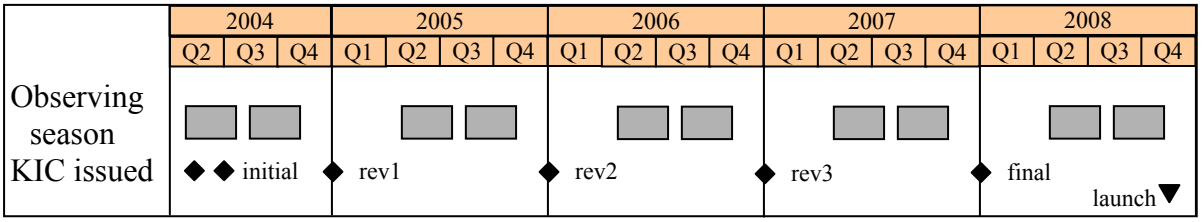

Figure 1: KIC Delivery Schedule

5. Spectroscopy

Hectochelle, the multi-fiber CCD echelle spectrograph on the MMT, is being used to obtain high-resolution spectra for samples of promising candidates for planetary target stars. These samples are selected using the most recent version of the KIC. The motivation is to improve the astrophysical characterization of promising candidates using high-resolution spectroscopy to derive values for effective temperature, surface gravity, metallicity, and rotational and radial velocities, thus allowing better estimates of the stellar radius and mass.

Hectochelle spectra are extracted and rectified to intensity versus wavelength using a pipeline in the Telescope Data Center at SAO. A library of synthetic spectra is then used for the derivation of effective temperature, surface gravity, metallicity, and rotational and radial velocities. Stellar models then allow estimates of stellar radius and mass.

The goal is to provide spectroscopically refined characteristics for more than 10,000 promising candidates for inclusion in the KIC. In particular, the goal is to provide radius estimates good to 50%.

The Smithsonian Astrophysical Observatory (SAO, David W. Latham PI) is responsible for coordinating all the efforts related to the spectroscopy of promising candidates. Telescope time and operational support for observing with Hectochelle on the MMT are provided by SAO at no cost to NASA. Allocation of telescope time is controlled by the CfA Time Allocation Committee (TAC). Latham prepares and submits requests for telescope time to the TAC.

6. Documents

The detailed specifications for the KIC and the delivery schedule are documented in the SCP-SOC ICD (KSOC-21112). The SCP tasks are determined by specific requirements flowing down from the Kepler Ground System Requirements Document (GSRD) (KGSS-14004), which in turn flow from the Science Requirements Document (SRD) (KP-111).