



The Importance of Planet Detection

The *Kepler Mission* is specifically designed to survey the extended solar neighborhood to detect and characterize hundreds of terrestrial and larger planets in or near the habitable zone and provide fundamental progress and large leaps in our understanding of planetary systems. The results will yield a broad understanding of planetary formation, the frequency of formation, the structure of individual planetary systems and the generic characteristics of stars with terrestrial planets.

Kepler Mission Science Objectives

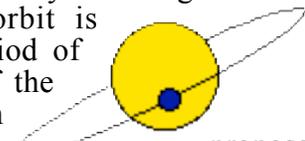
The scientific goal of the *Kepler Mission* is to explore the structure and diversity of planetary systems. This is achieved by surveying a large sample of dwarf (main-sequence) stars to:

1. Determine the frequency of terrestrial and larger planets in or near the habitable zone of a wide variety of spectral types of stars
2. Determine the distributions of planet sizes and their orbital semi-major axes
3. Estimate the frequency and orbital distribution of planets in multiple-stellar systems
4. Determine the distributions of semi-major axis, albedo, size, mass, and density of short-period giant planets
5. Identify additional members of each photometrically discovered planetary system using complementary techniques
6. Determine the properties of those stars that harbor planetary systems.

The *Kepler Mission* supports the objectives of the Origin's theme and directly contributes to the design of the Terrestrial Planet Finder as recommended in the NRC 2001 decadal survey.

Mission Overview

Kepler measures repetitive stellar brightness changes on the order of 100 parts per million lasting for 2 to 16 hours caused by transiting terrestrial planets. The planet's orbit is calculated from the period of the transits. The size of the planet is calculated from the transit depth. The



proposed differential photometer continuously and simultaneously monitors the brightness of 100,000 dwarf stars for four years; long enough to see four transits of a terrestrial planet in the habitable zone of a solar-like star. To obtain the required precision, the

photometer must be spaceborne; this also eliminates the day-night and seasonal cycle interruptions of ground-based observing.

Expected Results

We expect to perform a census of planets with periods from days to a few years and to detect:

Transits of terrestrial planets near 1 AU

- About 50 planets if most have radii about equal to the Earth ($R \sim 1.0 R_{\oplus}$)
- About 185 planets if most have $R \sim 1.3 R_{\oplus}$
- About 640 planets if most have $R \sim 2.2 R_{\oplus}$

Transits of thousands of terrestrial planets

- If most have orbits much less than 1 AU

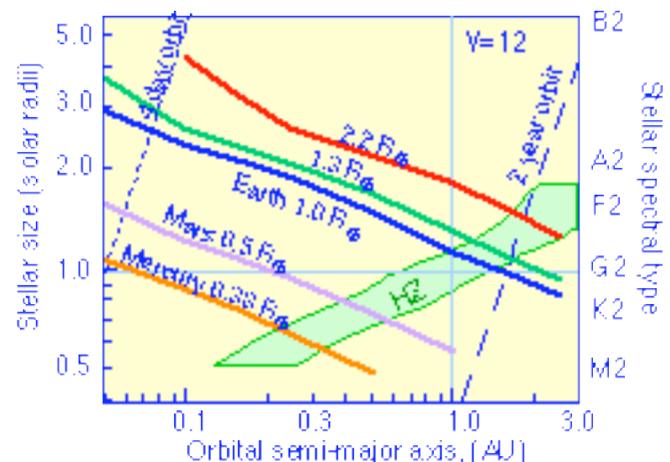
Modulation of the reflected light of giant inner planets

- About 870 planets with periods ≤ 1 week

Transits of giant planets

- About 135 inner-orbit planets with albedos for about 100 of these giants
- Densities for 35 inner-orbit planets
- About 30 outer-orbit planets.

The results likely consist of a mix of all of the above. From these results, we can explore the structure and diversity of planetary systems. The results are also still significant even if no planets are found, since the mission is designed to detect so many terrestrial planets.



Detectable Planet Size. Curves are shown for the detectable planet size for near-central transits of a $V=12$ dwarf star. Detections are based on a total SNR ≥ 8 and ≥ 3 transits in 4 years. The mission is optimized to detect terrestrial planets in the HZ where liquid water can exist on a planet's surface, but can also find Mercurys.

Flight Segment Characteristics

The photometer and spacecraft are robust; use flight-proven and conservative designs; have no single-point failures and are thoroughly tested. All software will undergo an independent verification and validation.

Photometer: 0.95-m aperture
 Primary mirror: 1.4 m dia., 85% lightweighted
 Detectors: 42 CCDs –2200 x 1024 pixels
 Photometer noise level: <10ppm
 Total noise, $m_v=12$ solar-like star (1 σ): <20ppm
 Data rate: 5.5 (8.1) Gbits/day in yrs 2-4 (yr 1)
 Mechanisms: Focus, HGA, ejected cover
 Photometer and spacecraft budgets:
 Mass: 903 kg (includes resv) plus 34% margin
 Power: 613 W (includes resv) plus 32% margin

Mission Characteristics

Launch vehicle: D2925-10L (Delta II)
 Orbit: Earth-trailing heliocentric
 Pointing: Continuously stare at one star field
 Search: 100,000 dwarf stars for transits of terrestrial or larger planets
 Mission lifetime: 4 years of flight
 Telemetry: Ka-and X-band, DSN

Mission Team

NASA Ames

Principal Investigator: William Borucki

Deputy Principal Investigator: David Koch

Science team Co-I (blue) SWG (green)

Ball Aerospace Harold Reitsema

Carnegie Institution of Washington Alan Boss

Harvard University Dimitar Sasselov

High Altitude Observatory Timothy Brown

Lowell Observatory Edward Dunham

NASA Ames Jack Lissauer, David Morrison

NASA/GSFC Yoji Kondo

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Space Telescope Science Inst. Ronald Gilliland

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University of Hawaii Tobias Owen

University of Texas at Austin William Cochran

University of Washington Donald Brownlee

York University John Caldwell

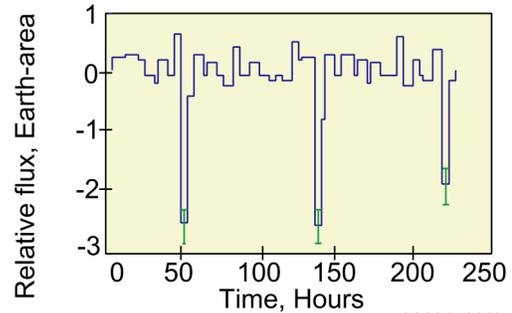
Development manager Chet Sasaki, JPL

Photometer & ops manager Larry Webster, ARC

Industrial partner Ball Aerospace

New Technology

The mission is low risk, incorporating proven technologies, which require no additional development. We plan to transfer CCD technology to historically black and minority colleges.



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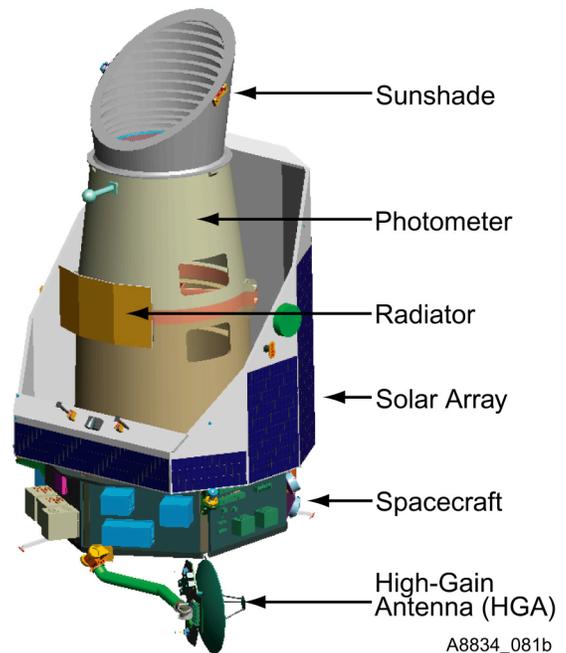
Sample transits measured with a flight-type CCD for a 12th magnitude star. The technology demonstration of the end-to-end system showed that differential ensemble photometry can be used to reliably detect Earth-size transits (1 Earth=84ppm) in the presence of all confounding noise sources.

Education and Public Outreach (E/PO)

The E/PO program has formal, informal and public outreach components leveraging the resources, capabilities and experiences of our E/PO partners. Products include curriculum materials, planetarium programs, exhibits, amateur astronomer support, and StarDate and PBS-style programs.

Mission Schedule

Phase B	10/02-10/04
Phase C/D	11/04-11/07
Launch	10/07
Phase E	11/07-11/12
Educational program	10/02-11/12



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Kepler Flight Segment

4/03

“Discoveries, both the pleasant and unexpected, come to those who are looking.” Rudolph F. Norden