National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Kepler

Kepler Project

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Mission Director
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Ames Research Center

Ball

JPL

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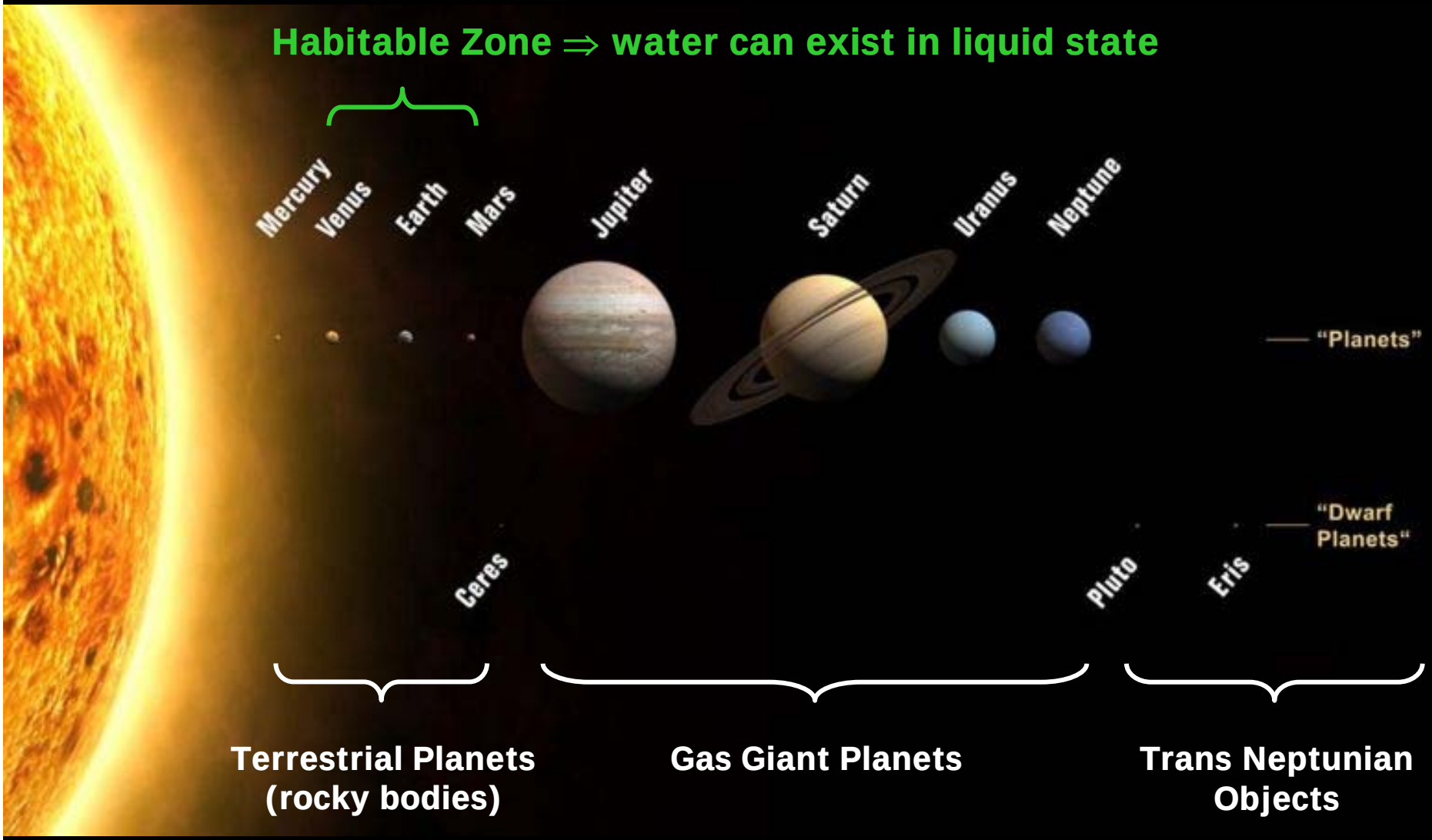
SETI INSTITUTE

STScI

Are Earth-like planets common or rare in the galaxy?



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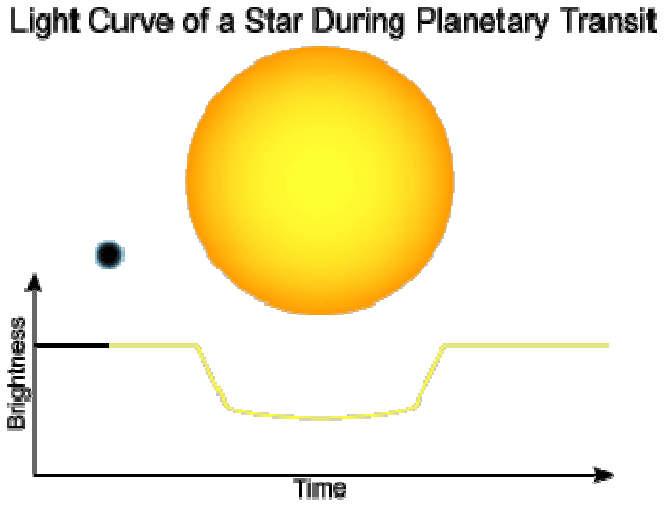
Kepler will find Earth size planets via the Transit method

Kepler

Salient Features

- Habitable Zone Planet Finder
- Heliocentric Earth-Trailing Orbit;
- Science Instrument: Photometer
  - 0.95 m aperture, 1.4 m primary
  - 42 CCDs, 96 million pixels; largest arrary of CCDs flown
- Launch date: March 5, 2009
- Launch Vehicle: Delta 2925-10L
- Operational life: 3.5 years
- Possible Extended Mission : Up to 2.5 Additional Years



Science

Explore the structure and diversity of planetary systems. Survey a large sample of stars to:

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

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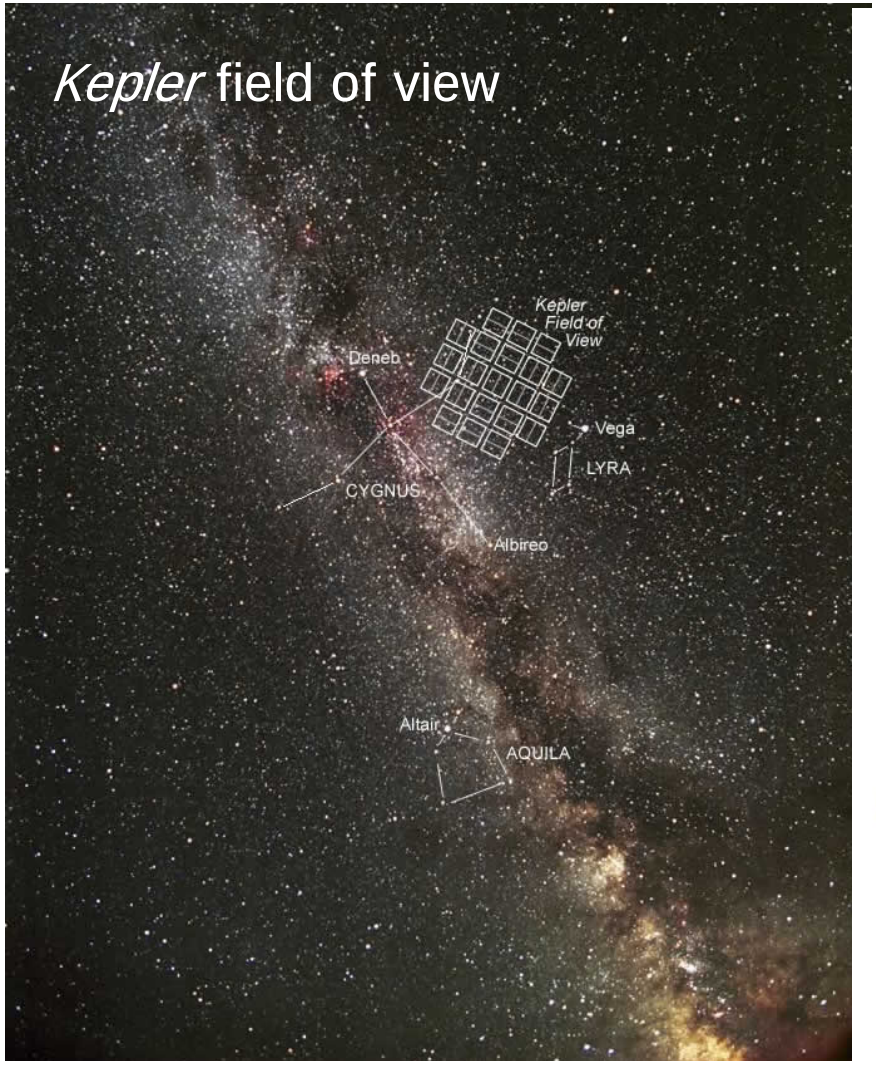
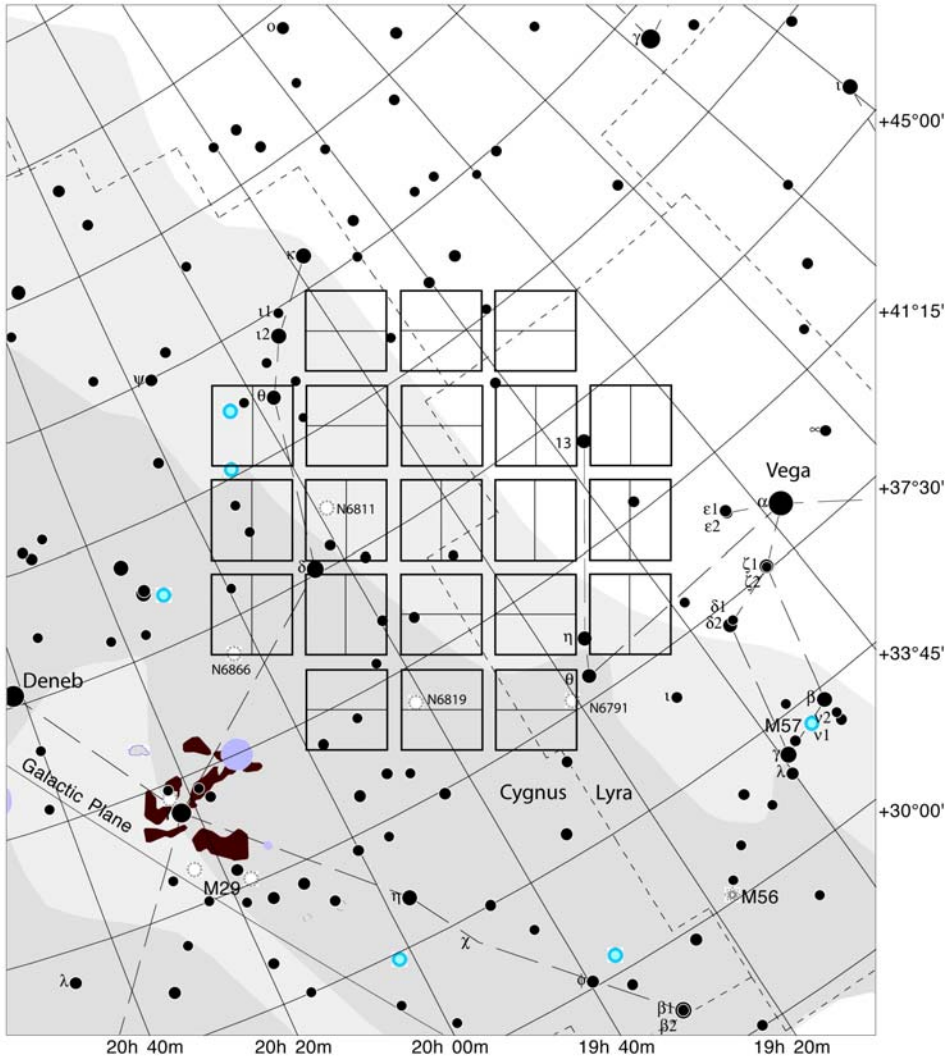
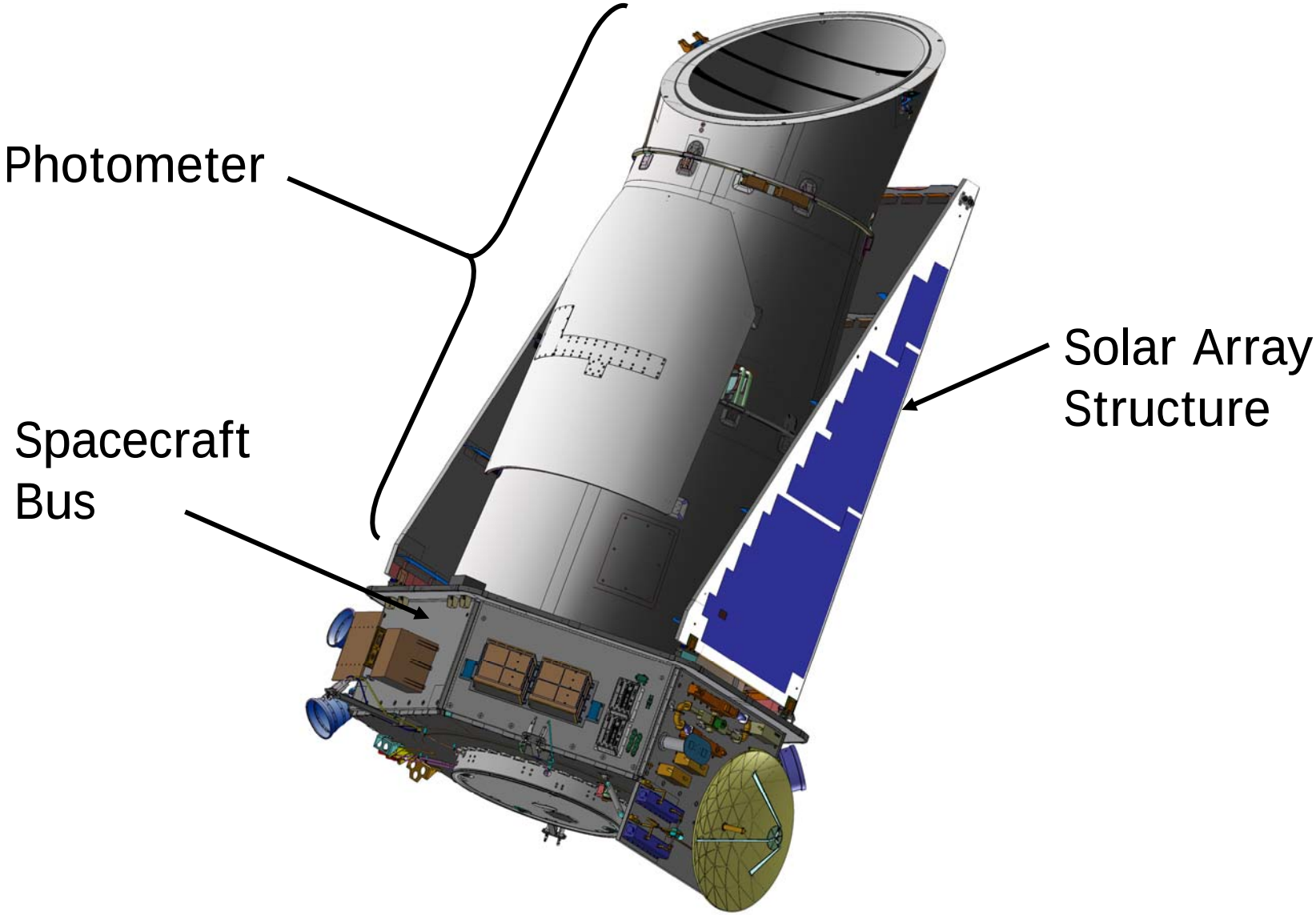
Kepler will continuously monitor 100,000 stars across 100 deg² of sky





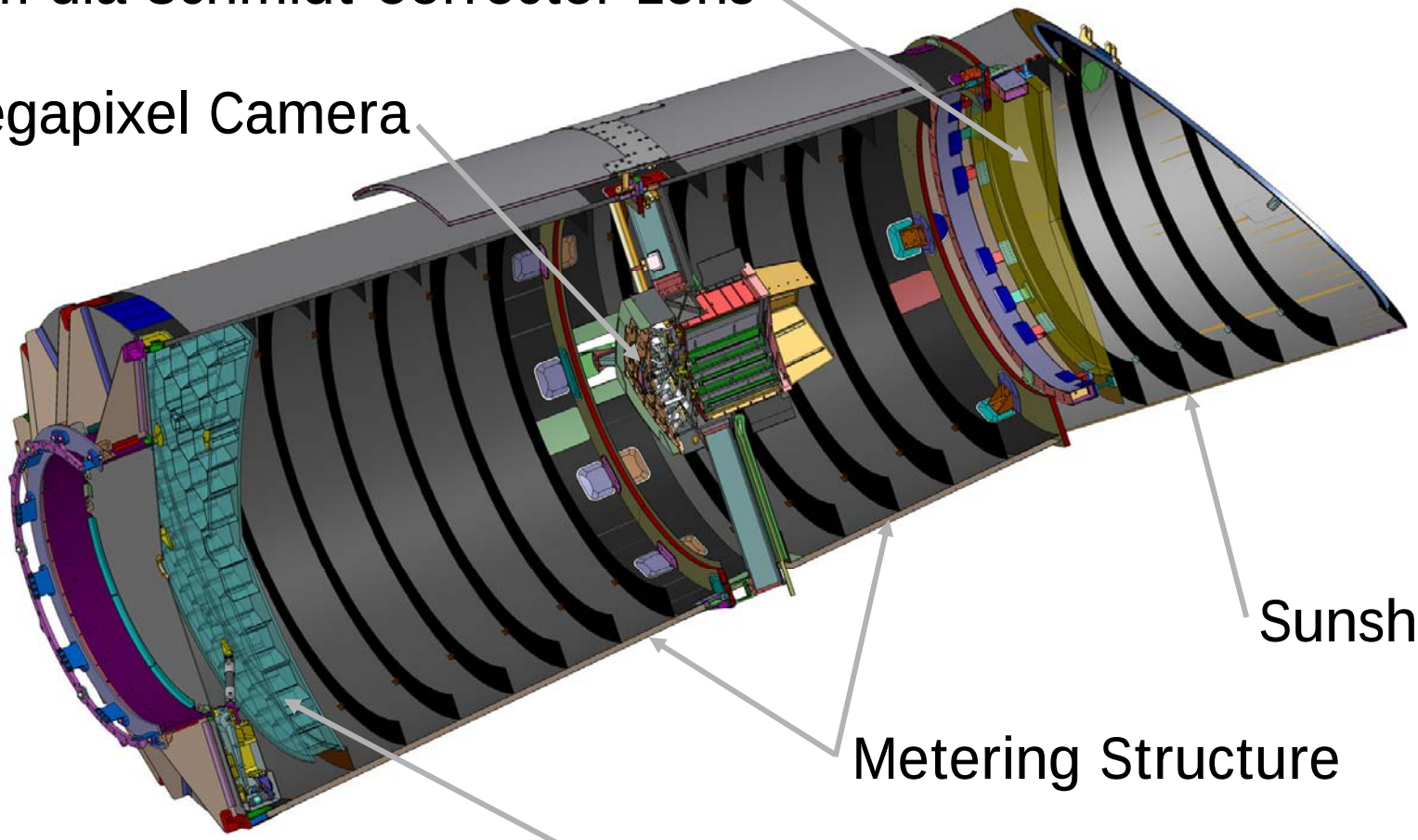
The *Kepler* Spacecraft



The Photometer is a wide-angle Schmidt camera

0.95 m dia Schmidt Corrector Lens

95 megapixel Camera



Sunshade

Metering Structure

1.4 m dia Primary Mirror

Kepler 96 Mpixel Camera

Mission Operations

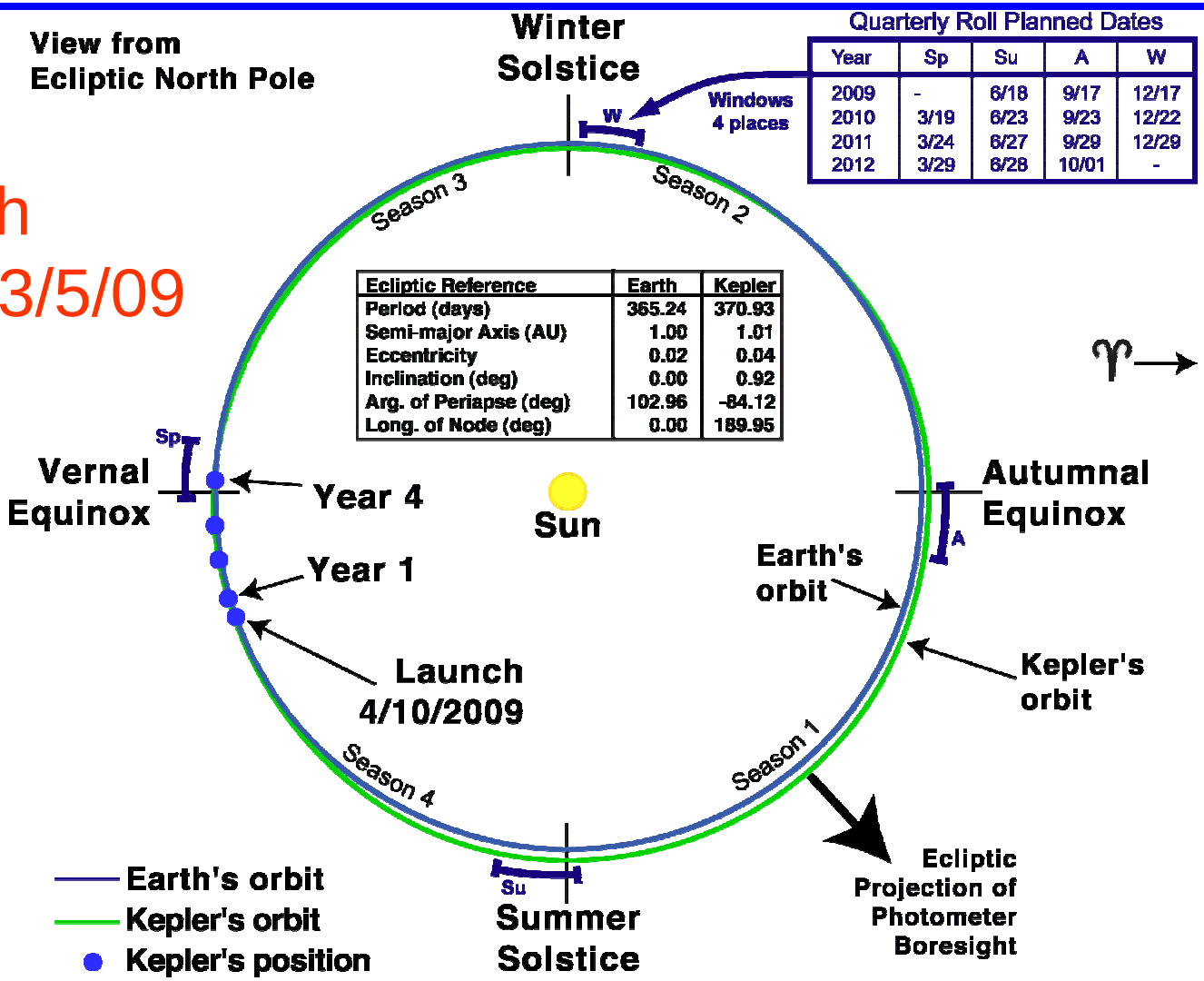
A Search for Habitable Planets

- Experiment design results in simple operations
  - Stare at same field for entire mission
  - Targets in that field:
    - Planned downselect after year 1 (stellar variability, reduced telecom bandwidth)
    - Redefine target location on CCDs after each quarterly roll
    - Small set of target changes for Guest Observers and higher resolution observations
  - Other than Launch and Initialization, Kepler has no "time-critical events" by typical DSN standards
  - Our time-sensitive events include:
    - Cover jettison is a commanded activity, deemed mission critical because it is irreversible and premature release could be mission ending
    - Can delay planned quarterly rolls 7+ days before fault protection enters safe-mode to meet sun-angle constraints

Kepler Trajectory

A Search for Habitable Planets

Launch date: 3/5/09



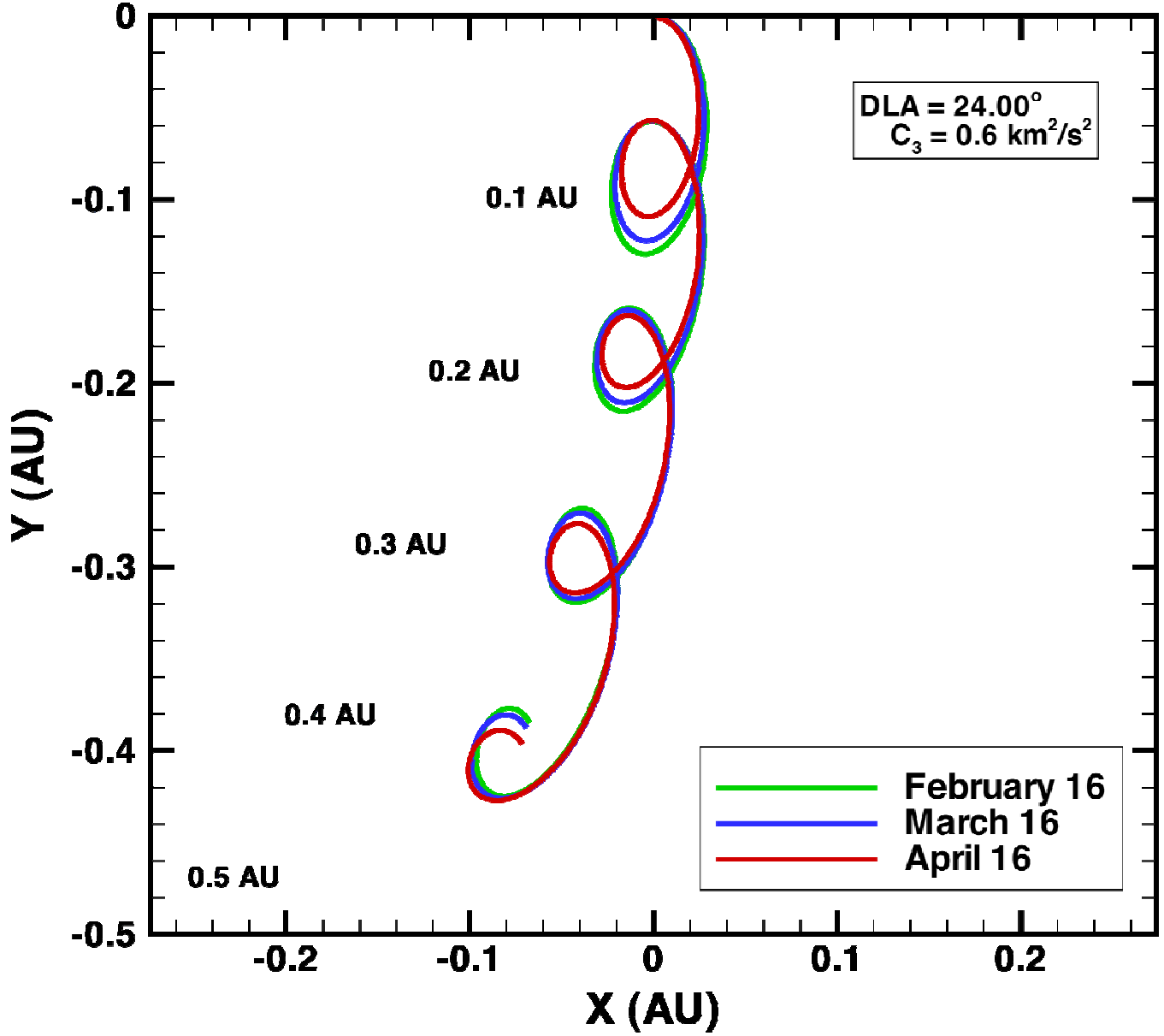
Quarterly Roll Planned Dates

Year	Sp	Su	A	W
2009	-	6/18	9/17	12/17
2010	3/19	6/23	9/23	12/22
2011	3/24	6/27	9/29	12/29
2012	3/29	6/28	10/01	-

Ecliptic Reference	Earth	Kepler
Period (days)	365.24	370.93
Semi-major Axis (AU)	1.00	1.01
Eccentricity	0.02	0.04
Inclination (deg)	0.00	0.92
Arg. of Periapse (deg)	102.96	-84.12
Long. of Node (deg)	0.00	189.95

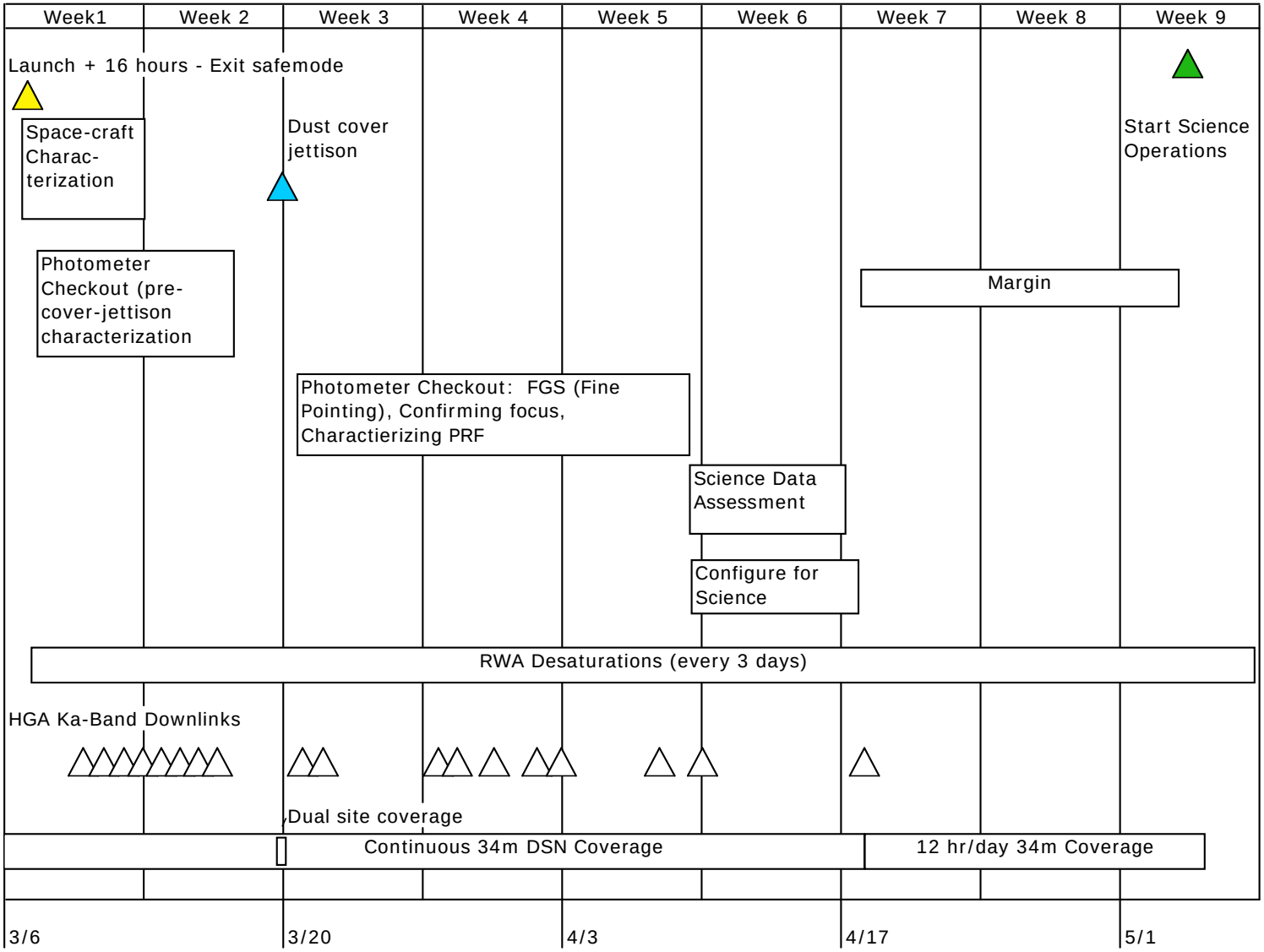
Earth Trailing Trajectory

A Search for Habitable Planets



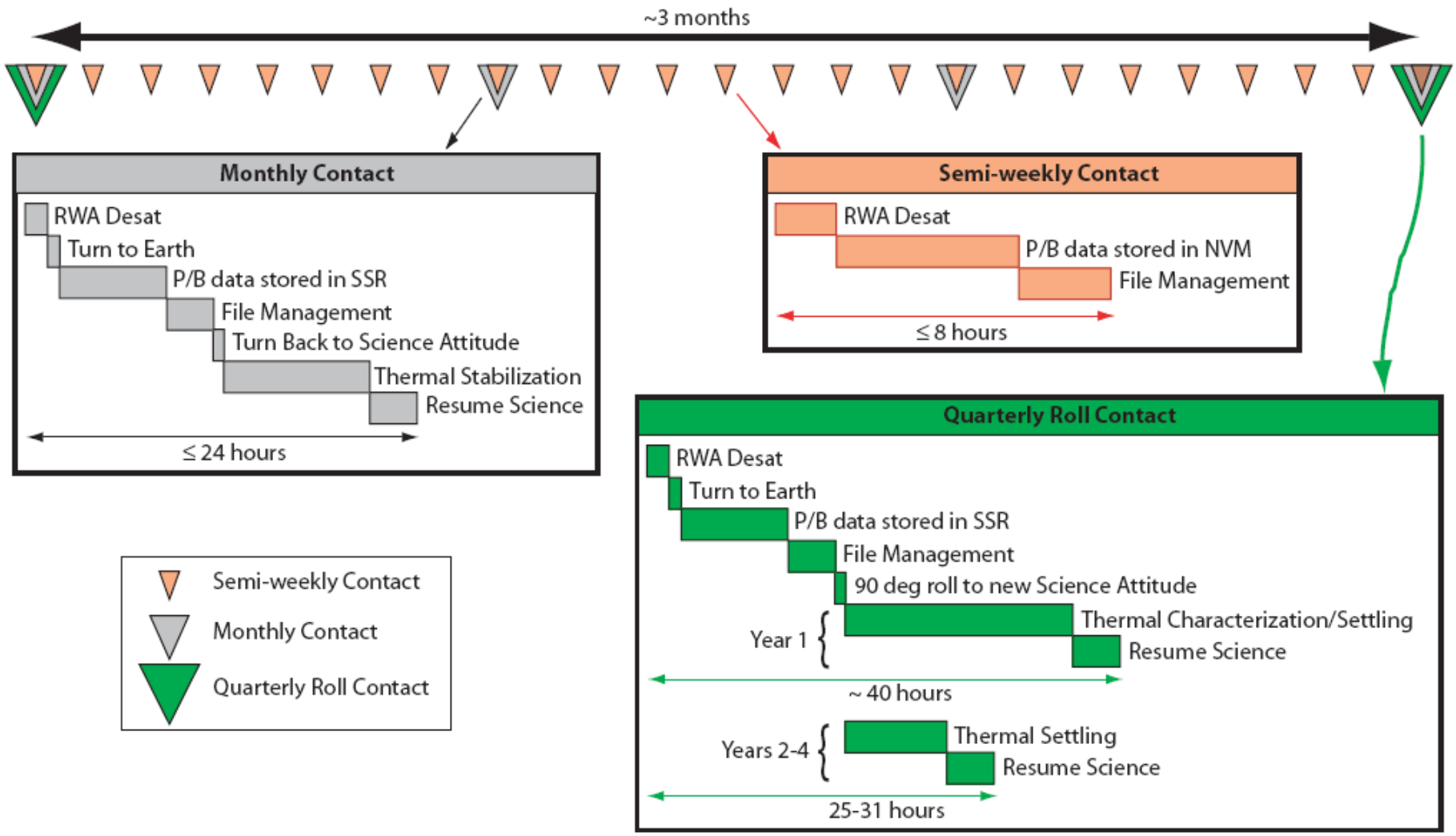
Commissioning Overview

A Search for Habitable Planets



Typical Science Operations Cycles

A Search for Habitable Planets



DSN Coverage Schedule

Mission Phase		Time Interval	Tracking Requested
Launch & Commissioning		L	Goldstone & Canberra: 2 DSSs, Acquisition Aid Goldston & Canberra: Radio Science Receiver (X-band only) Level 1 support
Commissioning		L to L+45 days L+45 to L+60 days	24 hour coverage (there will be gaps due to DSS view periods) 34m BWG (X-band and Ka-band) Level 2 support and dual site coverage for cover release 12 hr/day coverage
Early Science Operations		L+60 days to L+90 days	Daily 6 hour contacts using 34m BWG (X-band and Ka-band)
Standard Science Operations	4-day contact	L+90 days to L+3 yrs 8 months	8 hours once every 3 to 4.5 days 34m BWG (X-band only)
	Monthly contact		32 hour DSS coverage (there will be gaps due to DSS view periods) 34M BWG (X-band and Ka-band) Level 3 Support
	Roll Maneuvers		48 hour DSS coverage (there will be gaps due to DSS view periods) 34M BWG (X-band and Ka-band) Level 3 Support
Emergency Situations		Whole mission	As needed

Data Rates and Volumes

- Ka-band Downlink – stored science and engineering data:
  - Maximum (nominal) rate: 4.33 Mbps
  - Minimum rate: 2.8875 Mbps beginning in Year 4
  - Nominal downlink volume: 120 Gb
  - Maximum downlink volume: 275 Gb (contingency only)

- X-band Downlink – realtime engineering:
  - Maximum operational rate: 16 kbps (commissioning)
  - Minimum operational rate : 100 bps (year 4)
  - Safe mode rate: 100 bps

- X-band Uplink:
  - Operational Maximum rate: 2 kbps
  - Operational minimum rate: 125 bps
  - Safe mode rate: 7.8125 bps

Key Challenges

- Science data obtained via Ka-band downlinks once per month
  - Must slew off target to downlink to Earth, interrupting science data acquisition
  - Have limited storage margin on solid state recorder
- Science results obtained at end of mission based on entire data set
  - Detection of faint periodic signals places stringent demands on data completeness (time on target) and data contiguity (can't afford too many gaps in the data)

  ⇒ Every monthly pass is crucial

  ⇒ Must respond quickly to anomalies affecting science data quality

  ⇒ DSN Ka-band assets must work reliably