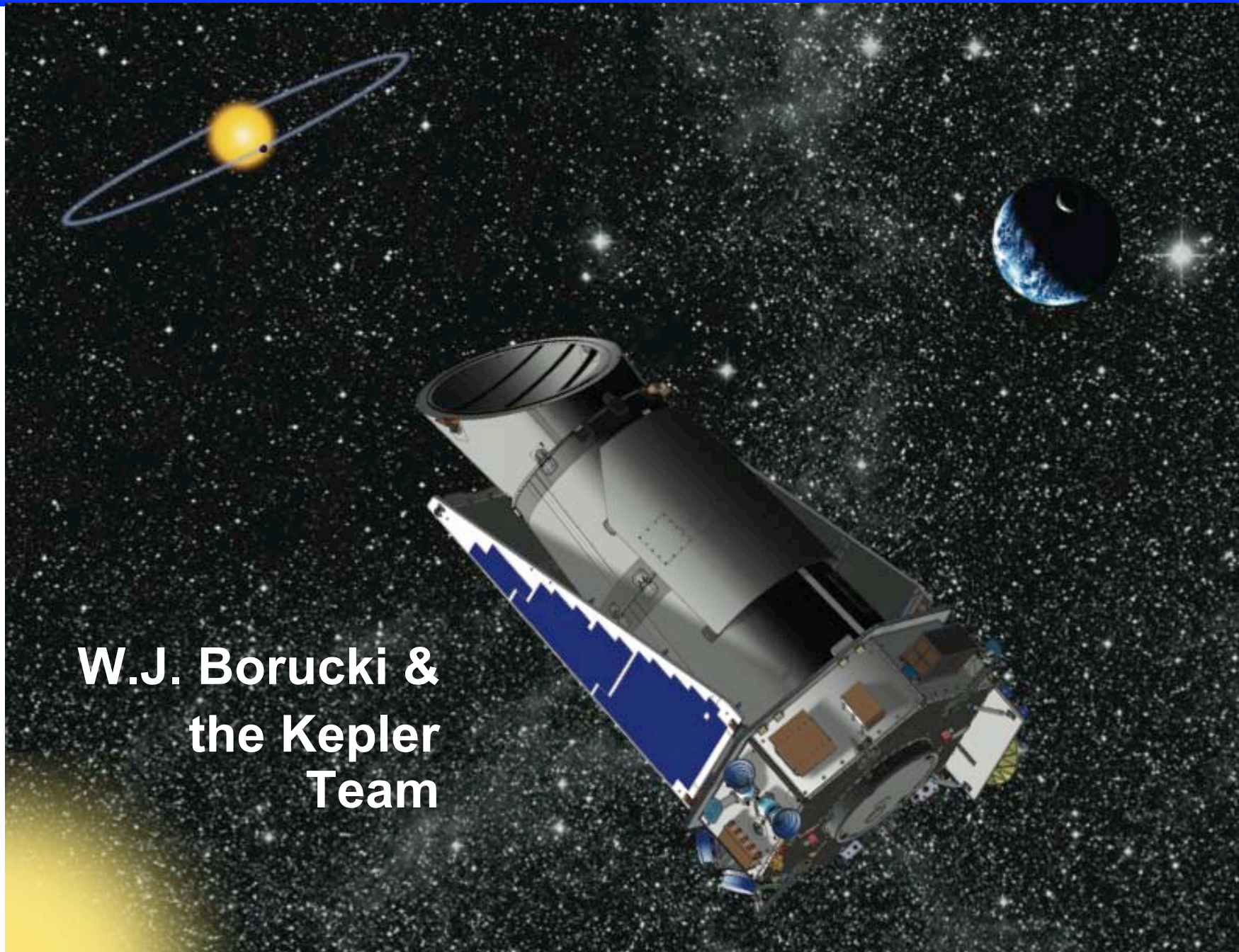


KEPLER; CONTRIBUTING TO ASTEROSEISMIC SCIENCE

Kepler
A Search for Habitable Planets



**W.J. Borucki &
the Kepler
Team**



CAPABILITIES OF THE SCIENCE TEAM *Kepler*

A Search for Habitable Planets

William J. Borucki, Science PI, and David Koch, Deputy Science PI

Stellar Occultations & High-Precision

CCD Photometry

- Timothy Brown, Los Cumbres Obs.
- Edward Dunham, Lowell Obs.
- John Geary, SAO
- Ronald Gilliland, STScI
- Steve Howell, U. Ariz
- Jon M. Jenkins, SETI Institute

Doppler Velocity Planet Searches

- William Cochran, UTexas
- David Latham, SAO
- Geoff Marcy, U. Cal., Berkeley

Stellar Variability

- Gibor Basri, U. Cal., Berkeley
- Joergen Christensen-Dalsgaard, Denmark
- Andrea Dupree, SAO
- Dmitri Sasselov, Harvard

Theoretical Studies

- Jack Lissauer, NASA Ames
- Alan Boss, Carnegie Institute Wash.

Mission Operations

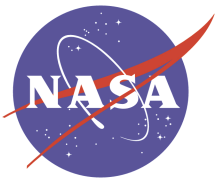
- Donald Brownlee, U. of Washington
- Nick Gautier, JPL
- Yoji Kondo, NASA GSGC

General Overview

- John Caldwell, York U.
- David Morrison, NASA Ames
- Tobias Owen, U of Hawaii
- Harold Reitsema, Ball Aerospace Co.
- Jill Tarter, SETI Institute

Education and Public Outreach

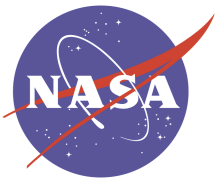
- Edna DeVore, SETI Institute
- Alan Gould, Lawrence Hall of Science



SCIENTIFIC OBJECTIVES

Explore the diversity of extrasolar planetary systems & determine the:

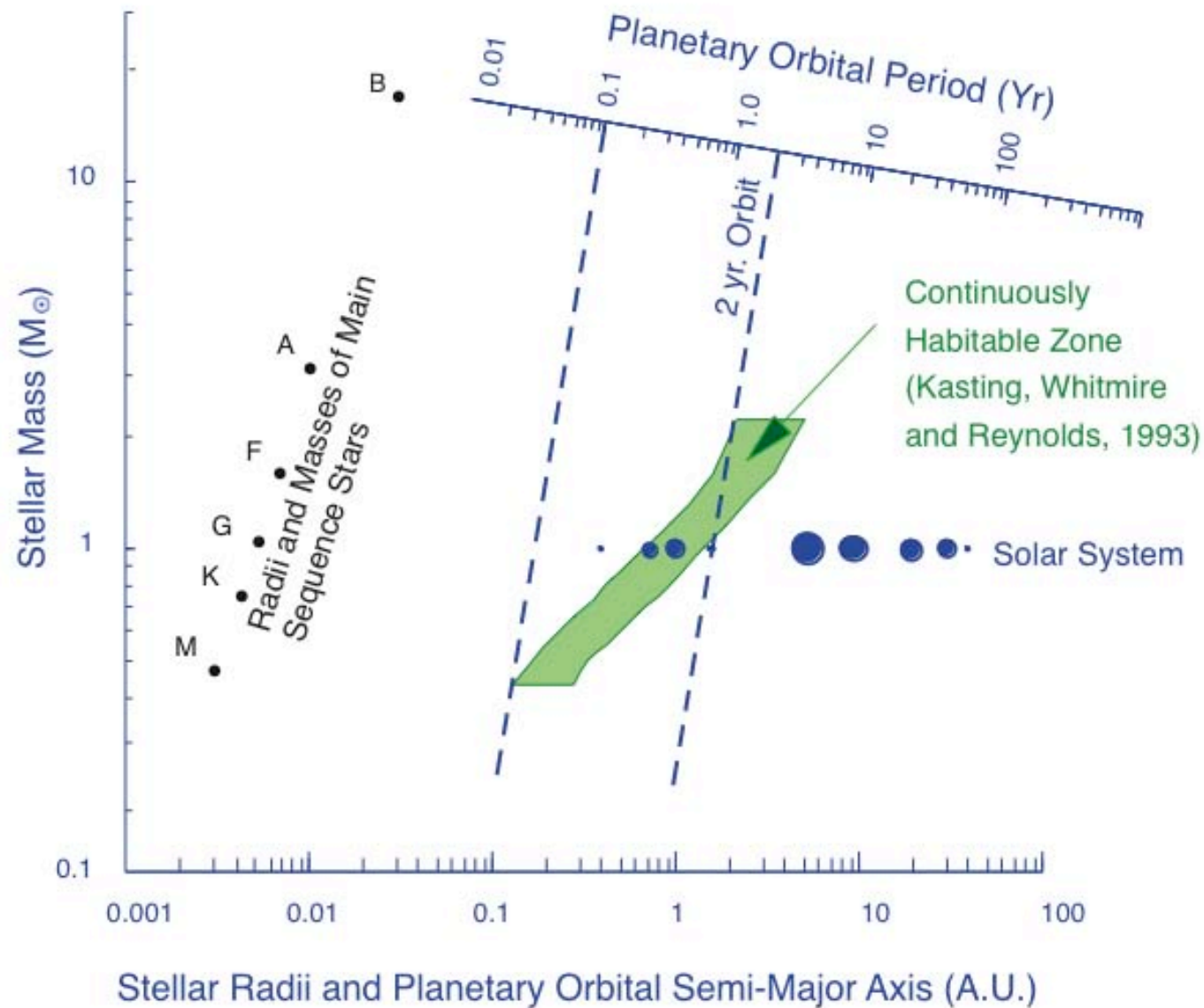
- **Frequency of terrestrial and larger planets in or near the habitable zone of a wide variety of stellar spectral types**
- **Distribution of sizes and semi-major axes of planets**
- **If there are additional members of each planetary system using other techniques**
- **Distributions of semi-major axis, albedo, size, and density of short-period giant planets**
- **Percentage and orbital distribution of planets orbiting multiple star systems**
- **Association of discovery results with stellar characteristics**



The Terrestrial Accretion Zone and The Habitable Zone for Various Stellar Types



A Search for Habitable Planets



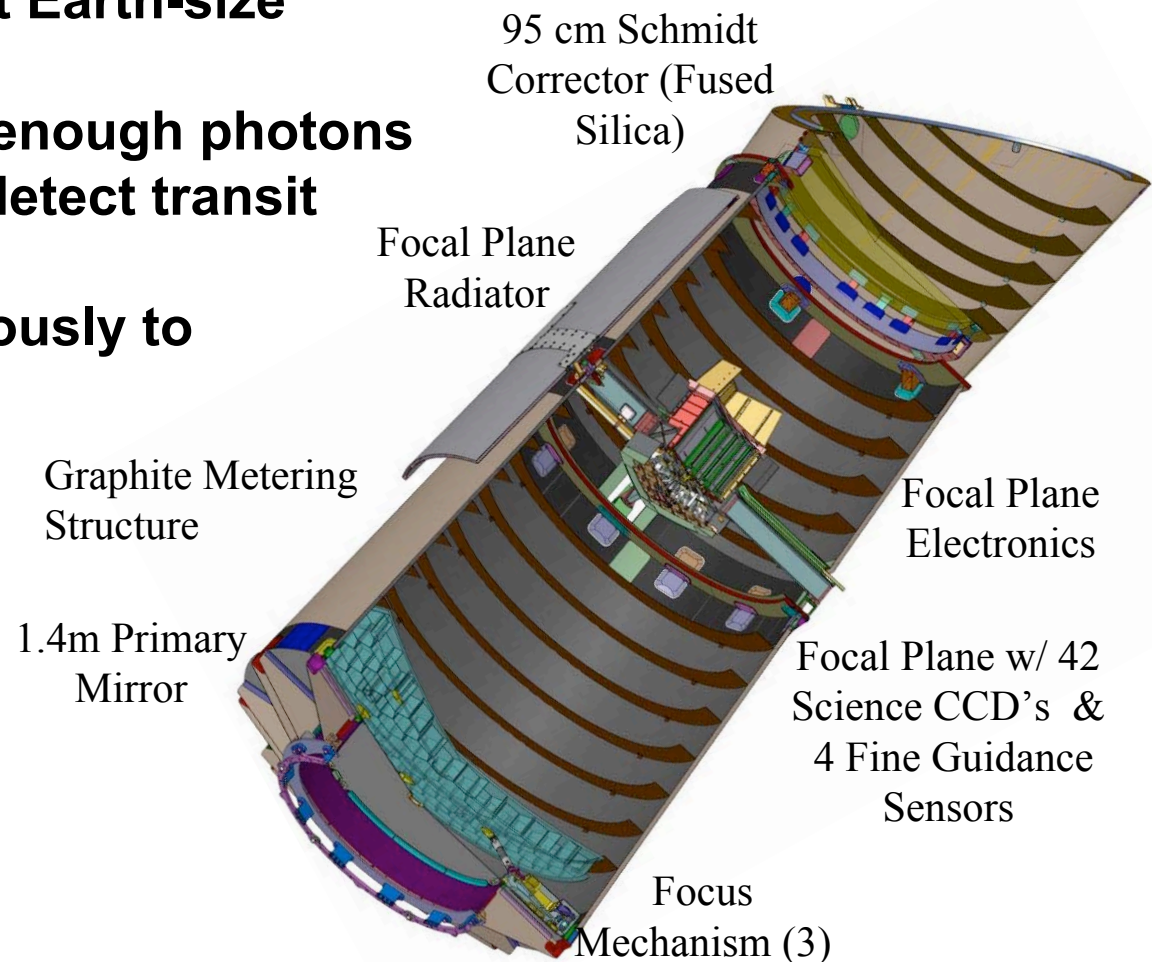
KEPLER: A Wide FOV Photometer that Monitors 100,000 Stars for 3.5 years with Enough Precision to Find Earth-size Planets in the HZ

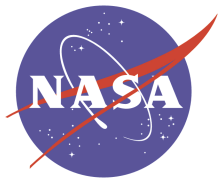
Use transit photometry to detect Earth-size planets

- **0.95 meter aperture provides enough photons**
- **Observe for several years to detect transit patterns**
- **Monitor a single FOV continuously to avoid missing transits**
- **Use heliocentric orbit**

Get statistically valid results by monitoring 100,000 stars

- **Wide FOV telescope**
- **Large array of CCD detectors**





SPACECRAFT ENCLOSSES INSTRUMENT

Kepler

A Search for Habitable Planets

Single science instrument:

**Photometer: 0.95m aperture, 42 CCDs,
420-890nm, passive cooling,
focusable primary**

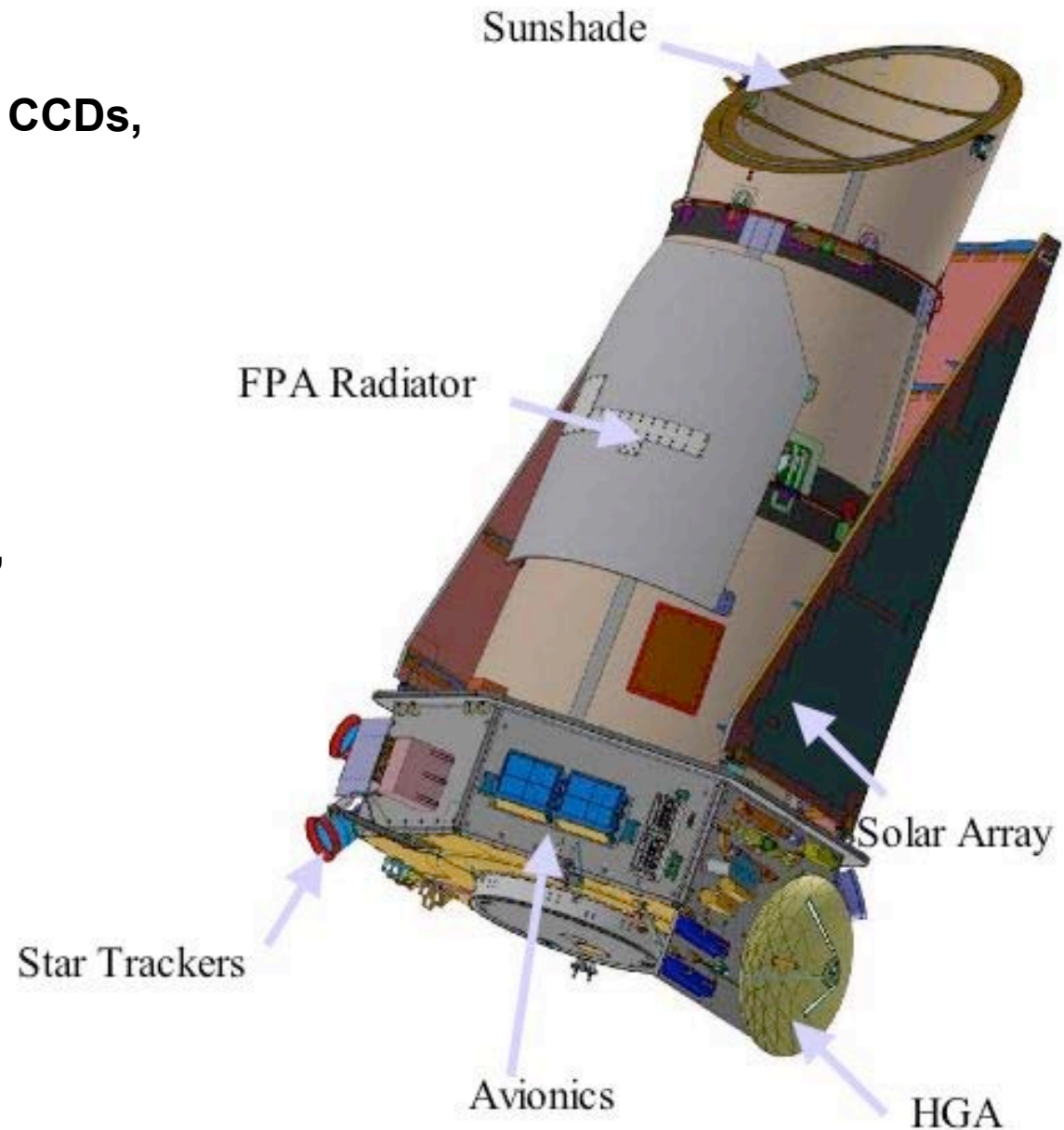
**FOV: 100 sq deg. centered &
fixed at 19h23m, 44° 30'**

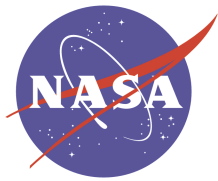
**Spacecraft provides power,
guidance, telecommunications,
and fault protection.**

Launch Vehicle: Delta 2925-10L

Launch date: Feb. 2009

**Operational life: 3.5 years with
expendables for 6 years**





Photometer Assembly Is Nearing Completion *Kepler*



Dust Cover

Sunshade



Thermal Radiator



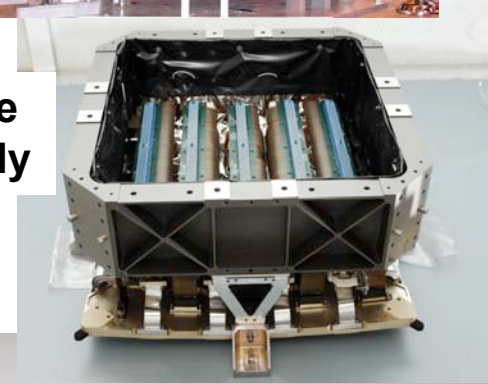
Upper Housing



Photometer Flight Harness

Lower Housing

Focal Plane Array Assbly

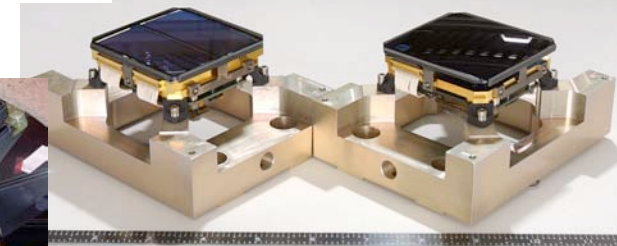
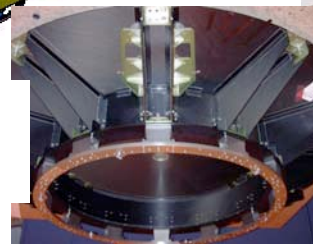
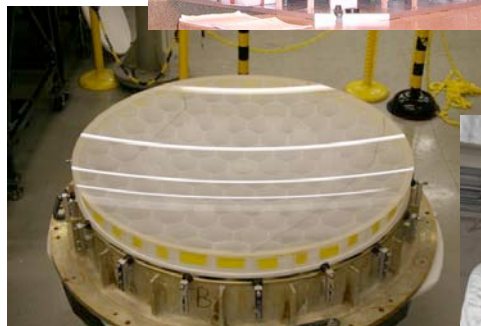


Primary Mirror Assembly

Detector Modules

Focus Mechanism Assy (3X)

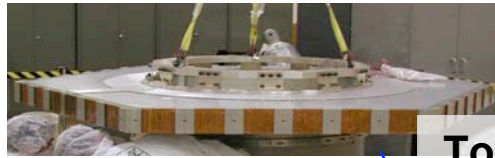
Aft Bulkhead





Nearly all Spacecraft components are in house at BATC

Kepler



Top deck



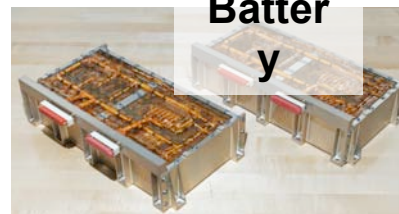
LGAs



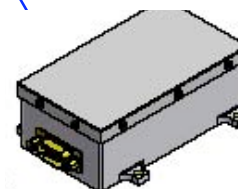
RCS deck



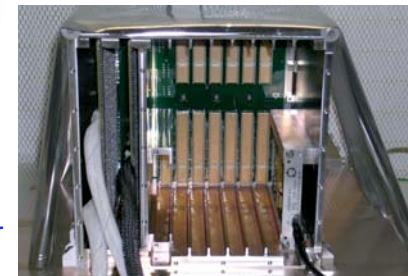
Star Trackers



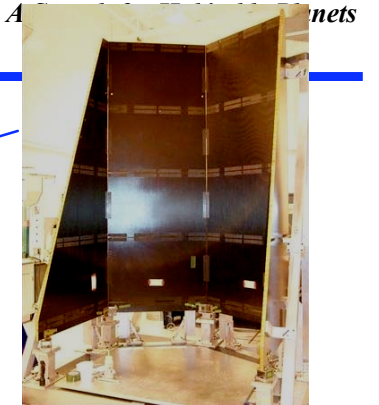
Batter
y



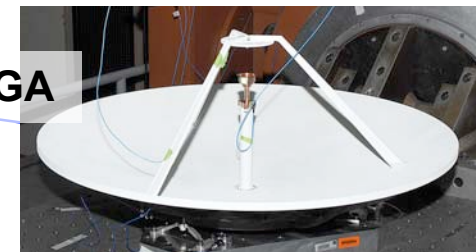
S/C Bus,
Bottom
Deck,
LV Adapter
Precision
External Clock



Avionics & Solid State Recorder

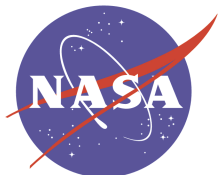


Solar Array
Structure



HGA

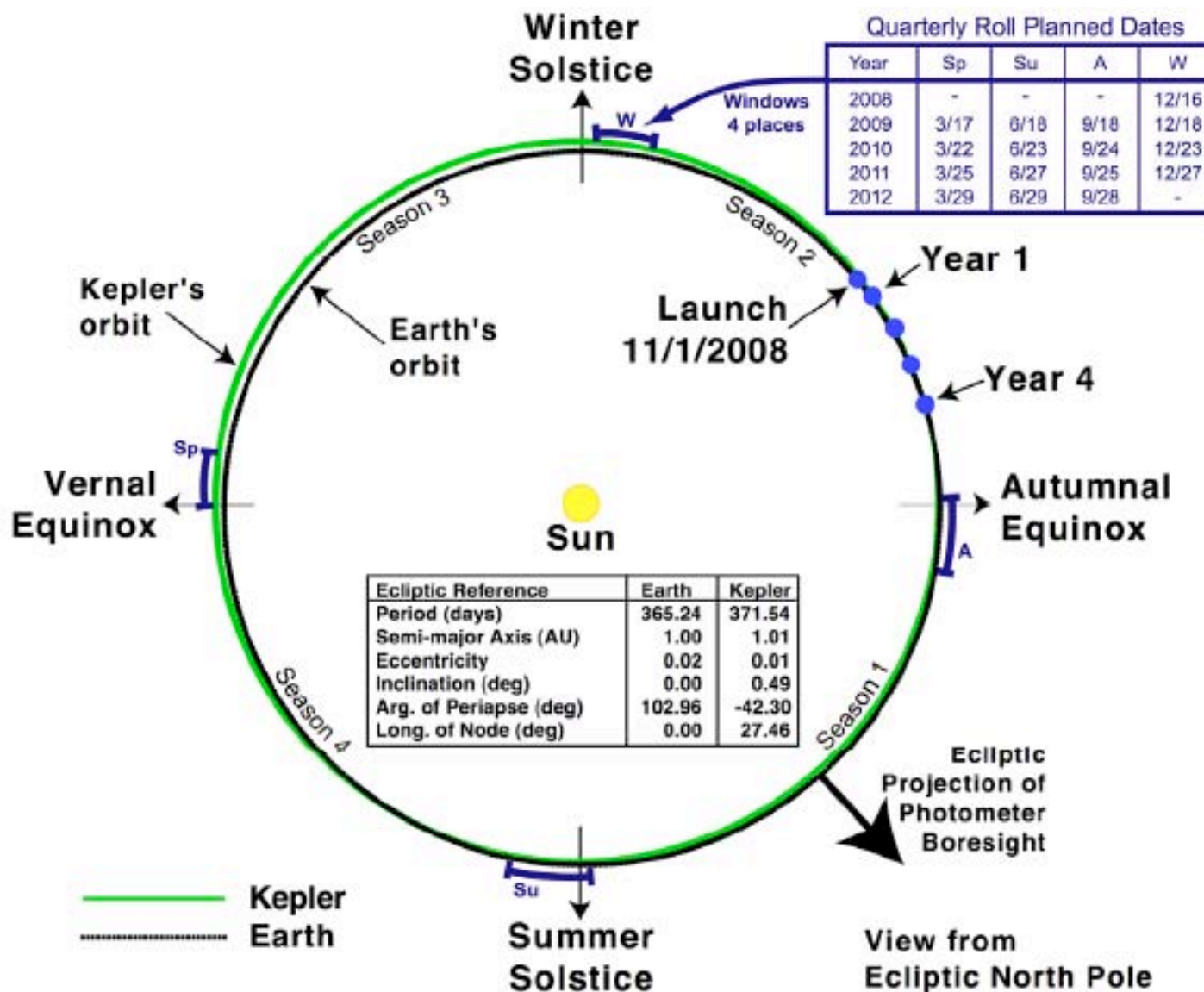


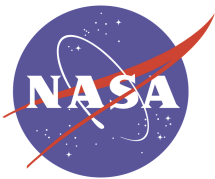


KEPLER IS IN AN EARTH-TRAILING ORBIT

Kepler

A Search for Habitable Planets



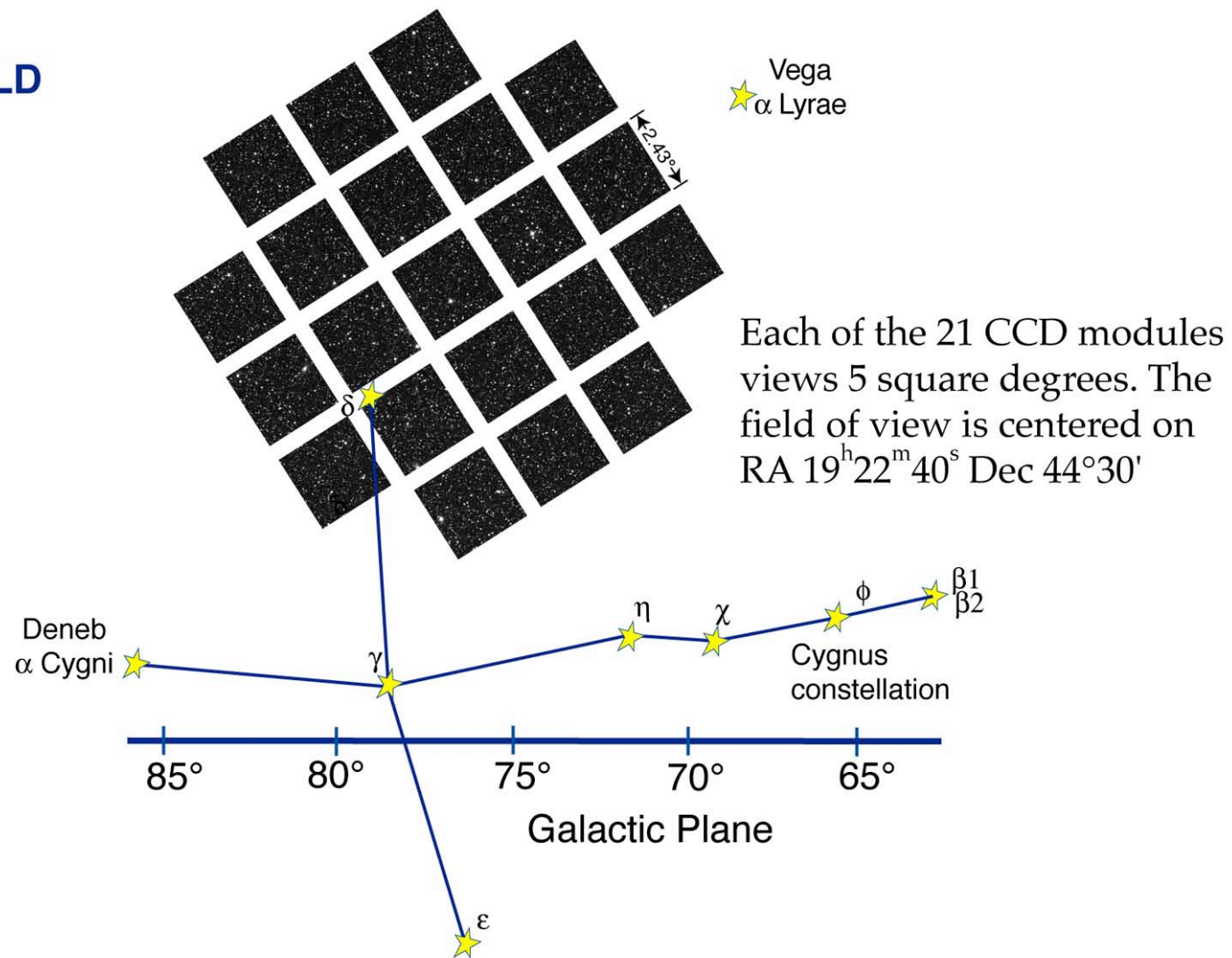


KEPLER FIELD OF VIEW



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STAR FIELD



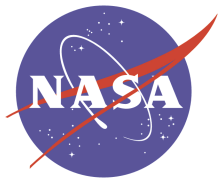


Kepler Input Catalog



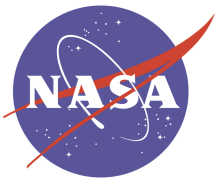
- Includes all known stars in Kepler FOV
 - ~ 20 million stars (USNO-B)
- Photometry
 - 2MASS JHK + SDSS griz + D51
 - ~ 2 million stars down to K~14.5 mag
- Astrophysical characteristics
 - T_{eff} , $\log(g)$, $[\text{Fe}/\text{H}]$, reddening; Mass, Radius
 - Radial and rotational velocities
- Used to select optimum targets:
 - Late F through M dwarfs for planet detection
 - Expect ~ 170,000 through 16th mag
 - ~ 1/3 will be younger than the Sun & too noisy

Dave Latham will provide a comprehensive discussion.



EXPECTED NOISE LEVEL VS STELLAR MAGNITUDE

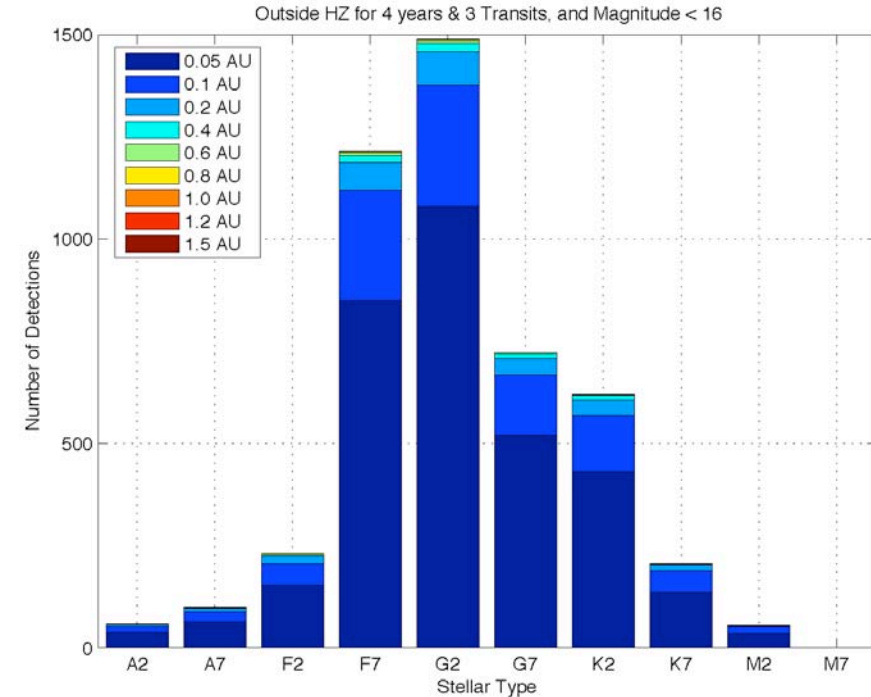
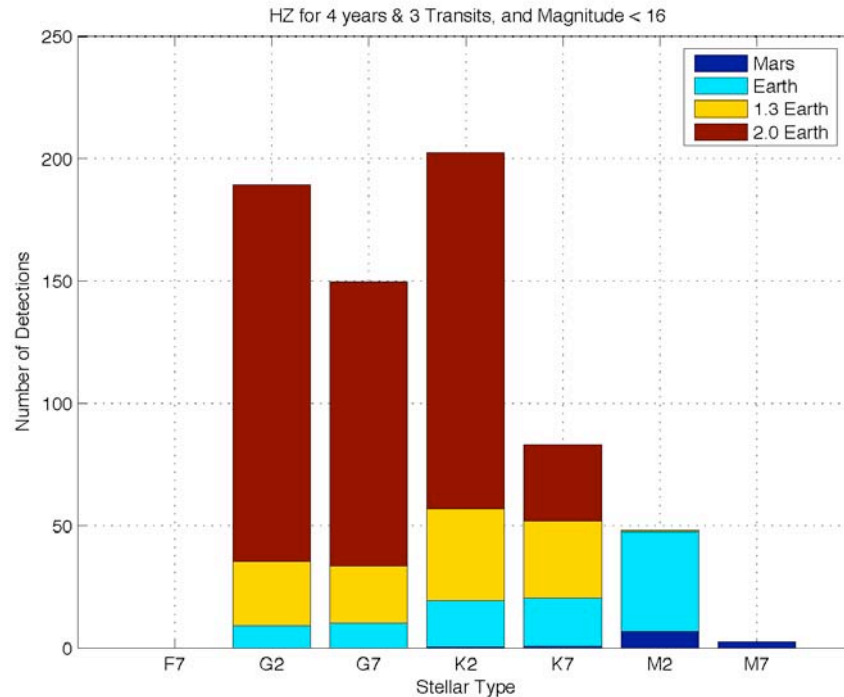
• m_v	Prediction (ppm) For 6.5 hr integrations
• 9	
• 10	6.5
• 11	10
• 12	17
• 13	28
• 14	50
• 15	95
• 16	200



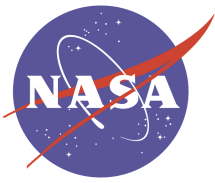
KEPLER SHOULD DETECT THOUSANDS OF TERRESTRIAL PLANETS



A Search for Habitable Planets



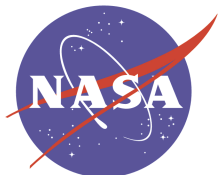
- Several hundred terrestrial planets are expected in the HZ if they are common. A null result would mean Earths in the HZ are rare in our galaxy.
- Several thousand Earth-size planets should be detected outside the HZ. The actual occurrence frequency will dramatically affect theories of planet formation.
- Jon Jenkins will discuss the data analysis.



VALIDATION OF DISCOVERIES



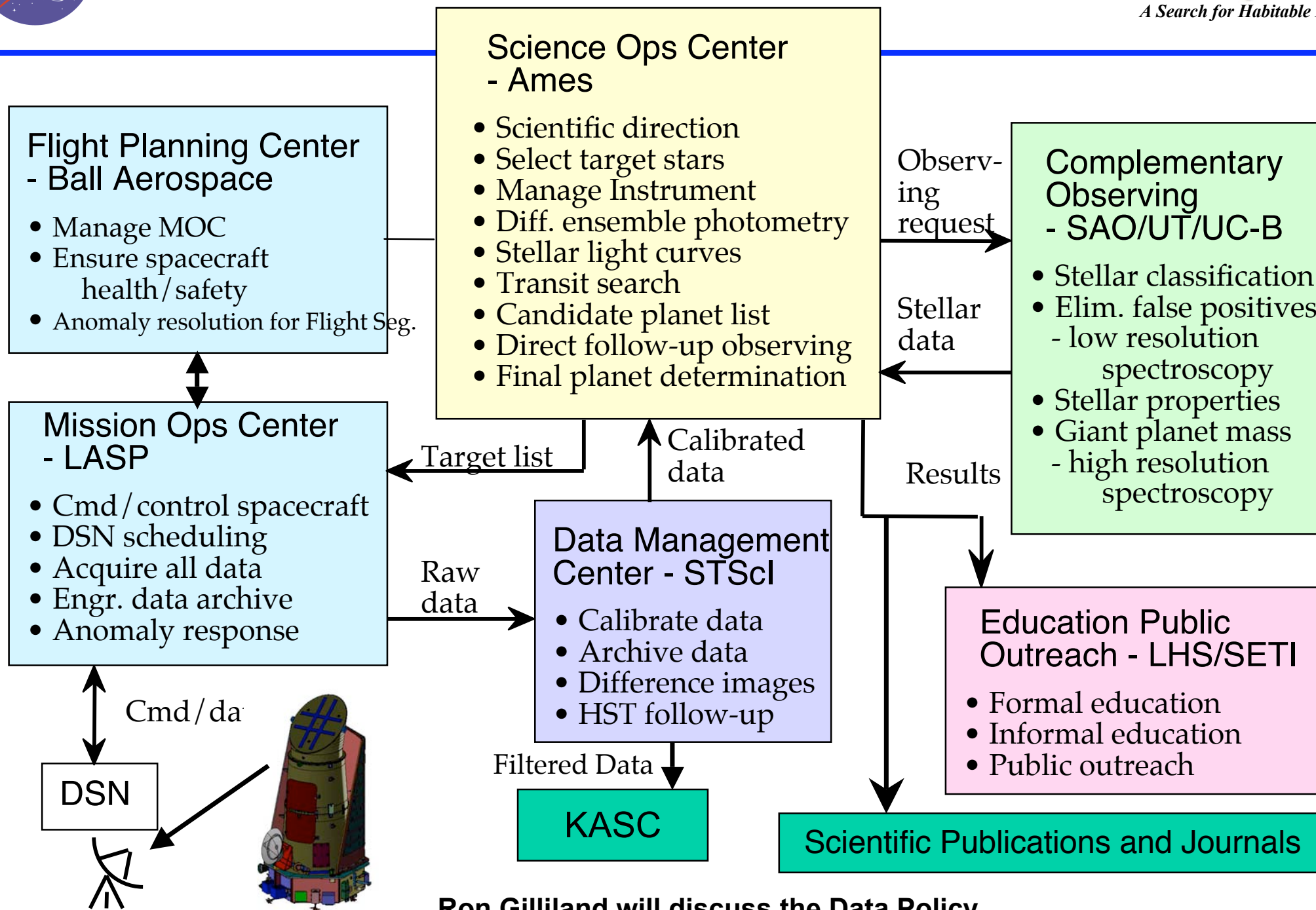
- **SNR > 7 to rule out statistical fluctuations**
- **Three or more transits to confirm orbital characteristics**
- **Light curve depth, shape, and duration**
- **Image subtraction to identify signals from background stars**
- **Radial velocity**
 - Medium resolution to rule out stellar companions**
 - High resolution to measure mass of giant planets**
- **High spatial resolution to identify extremely close bkgd stars**
- **Color change during transit?**



OPERATIONS ORGANIZATION



A Search for Habitable Planets



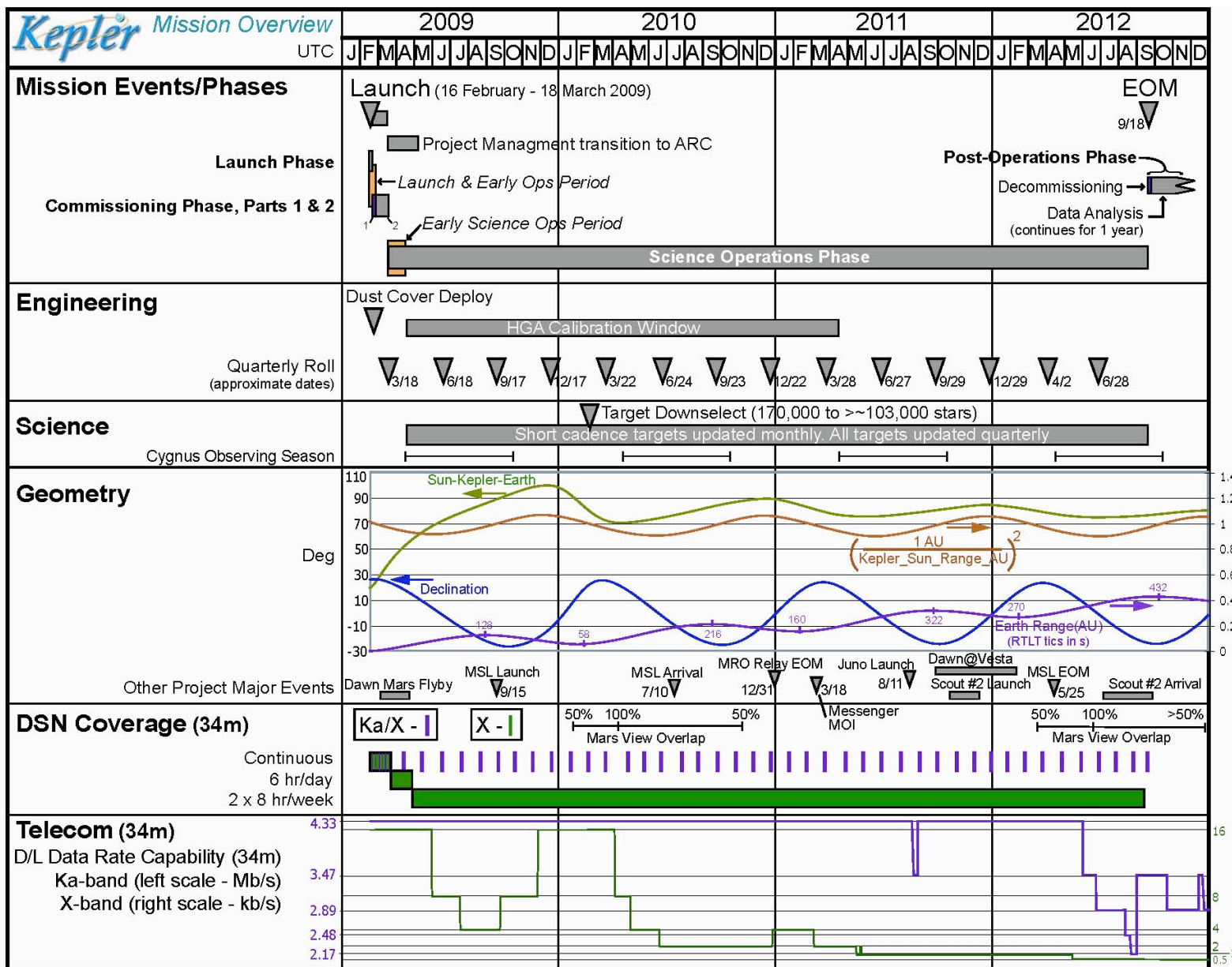
Ron Gilliland will discuss the Data Policy



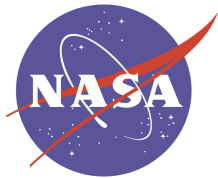
MISSION SCHEDULE



A Search for Habitable Planets



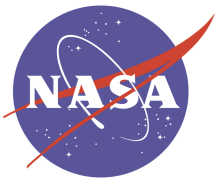
JL - 19 Oct 2007



SCIENCE COMMUNITY PARTICIPATION



- Participating Scientist Program (PSP)
 - The PSP funds investigators whose research program is directly concerned with the detection, characterization, or understanding of extrasolar planets. Such research programs complement those developed by the PI and Co-Is.
- Guest Observer Program
 - The GOP will function similar to facilities instrument such as HST. Approximately 3% of the downlink bandwidth will be available for astrophysical investigations by the GO. Observations of up to 3000 stars at the 30 minute cadence can be requested and/or 25 stars at a 1 minute cadence. Any type of object in the Kepler FOV will be observed upon request by a successful proposer.
- Astrophysics Data Program
 - This program funds investigators who wish to data mine the Kepler observations.



SUMMARY

- Kepler Input Catalog will be available for choosing appropriate targets
- A cadence of 1/minute is available for a maximum of 512 stars
- The number of short cadence asteroseismic targets will decrease to 240 at the end of mission
- Targets can be changed quarterly (Possibly monthly)
- At least 100 long cadence targets will always be available to the KASC. (More as resources permit.)
- Accurate values of stellar diameters are needed to determine the size of transiting planets. Mass and age are also important.

MOST & COROT are the pioneers. Kepler will continue the discoveries.