Kepler Lessons:

Dealing with Resource Challenges—Managing Partners, Managing Contingency, De-scope Philosophy

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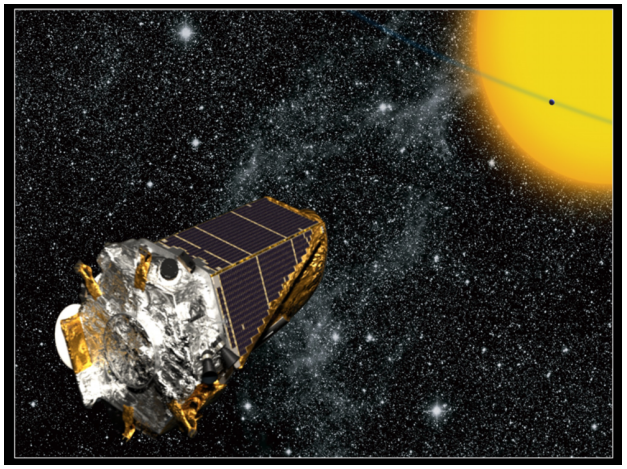
Kepler

Mission Goal: Determine what fraction of stars in our galaxy harbor potentially habitable, earth-size planets

With a 1.5 m primary mirror and a 0.95-m aperture, the Kepler photometer monitored 170,000 stars continuously over 4 years seeking the telltale dimming of a transiting planet.



Planned (Actual):

Cost:	Phase B	$38M	
	Phase C/D	$164M	
	Phase E	$33M	
	Launch	$64M	
	Total (FY01$)	$299M	(~$620M RY$)
Sch:	Phase B		
	Phase C//D		
	Launch	10/06	(3/09)

- Launch Vehicle: Delta II
- Earth trailing, heliocentric orbit
- X-band up/down, Ka-band down, DSN
- Dual string
- Solar power
- Reaction wheels for attitude control
- Monopropellant hydrazine for momentum management
- Ball Aerospace – Single contractor for the spacecraft, instrument and operations

Key Lessons

Things *will* go wrong…

(your problems will be different from ours)

1. Maintain good partnerships
2. Always have an escape hatch
3. Leverage reserves

Maintain Good Partnerships

Partners are there for a reason…

1. Advocacy
2. Expertise
3. Resources

- Maintain openness and respect within the team
- Include partners upward, downward and laterally
- Build strong, *personal* relationships

Maintain Good Partnerships

Kepler Examples:

1. Kepler had an executive Council with the directors of the three primary partners
   - No personal connections
   - Represented institutions rather than the mission
   - ➢ Was never convened!
2. Kepler held early, externally facilitated, team-building exercises
   - Created cross-partner relationships
   - Team was invested in the mission
   - Relationships were critical when problems arose
3. Ball Aerospace retained a scientist on-staff to help its team weigh options
4. Discussions were open and largely badgeless

Escape Hatches

Events *will not* unfold as planned…

1. Budgets are never secure
2. Vendors will have problems with some deliveries
3. The system will fail some aspects of test
4. Key personnel will leave

Plans cannot be laid for every contingency, but knowing your flexibility is critical.

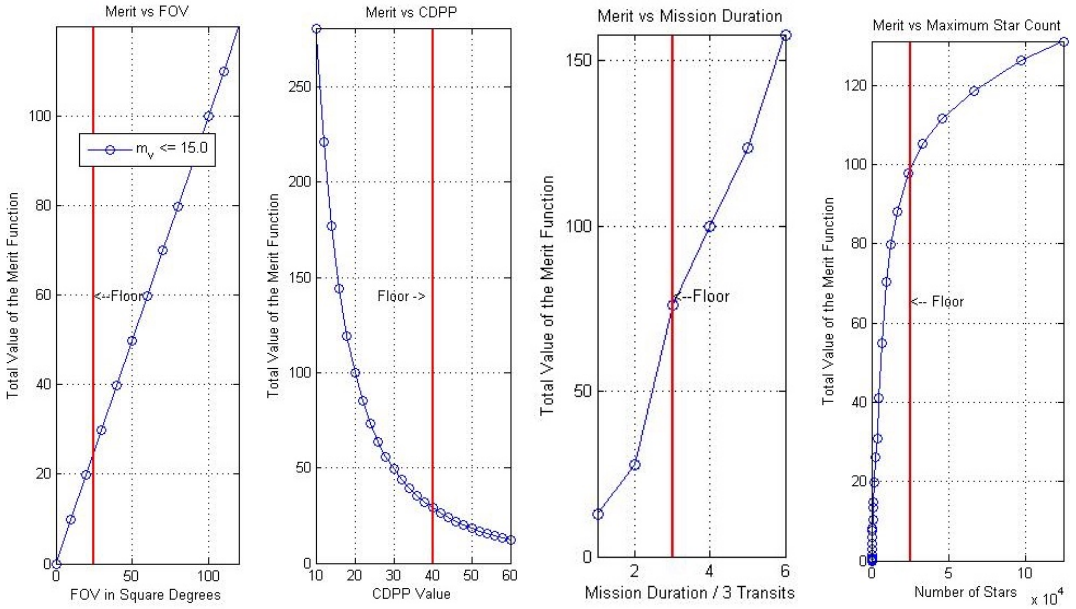
- Understand how the mission science will degrade when requirements are not met
- Build in back-ups for key suppliers
- Maintain an investment priority list

Escape Hatches

Kepler Example 1:

In response to early advice from a review board, the Kepler PI invested significant resources in developing a mission Merit Function

- Partial derivatives of the mission success score over a range of parameters
  - Field of view
  - SNR
  - Etc.
  - Data completeness
  - Mission duration
- A tool to quickly score the impact of potential descopes, in particular:
  - Quantified the impact of abandoning a gimbal on the high gain antenna

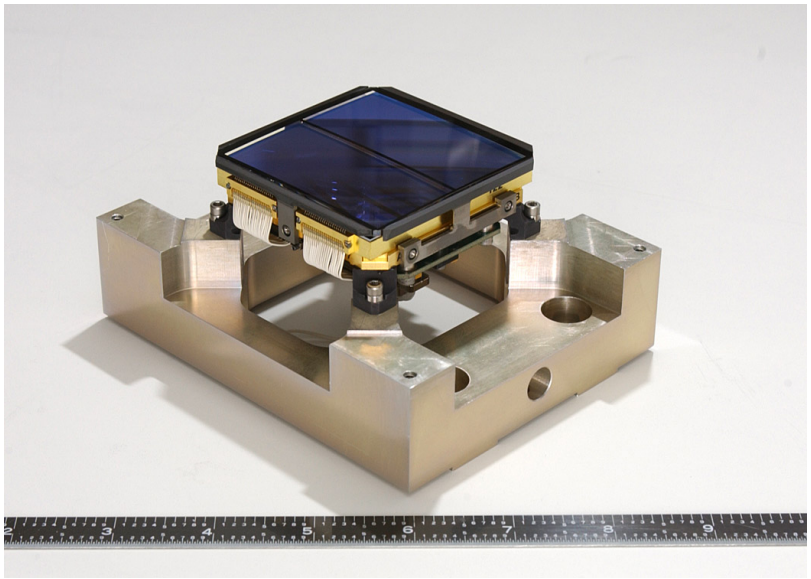


Escape Hatches

Kepler Example 2:

Detectors were identified as a high risk item in the selection review.

- Two vendors were selected to provide half of the flight set each, each with an option to supply the full set.
- When one vendor failed to consistently provide quality parts its contract was terminated and the option exercised with the other vendor.



Escape Hatches

Kepler Example 3:

An End-to-End test of the full system was seen to be imperative (post-Hubble), but understood to be challenging.

- The development testbed was preserved, and when the full test proved to be cost prohibitive, a single-string test of the flight hardware was done at Ames.

Leverage Reserves

Reserves lose value over time:

1. Schedule $\propto$ Cost^2 !
   - Use reserves early! $10M will buy you nothing the week before launch.
2. Avoiding a problem is much less expensive than solving one (apologies to Ben Franklin…)

A corrollary: Don't trust a good spending curve

- Anyone can spend to a plan, but spending must be reflected in progress
- The concept behind Earned Value