CONCEPT MATURITY LEVEL (CML)

Establishing A Shared Language To Articulate Maturity Of a Space-Science Mission Concept and Cost Uncertainty in the Early Formulation Phase

Presentation to the Planetary Science Decadal Survey Steering Group

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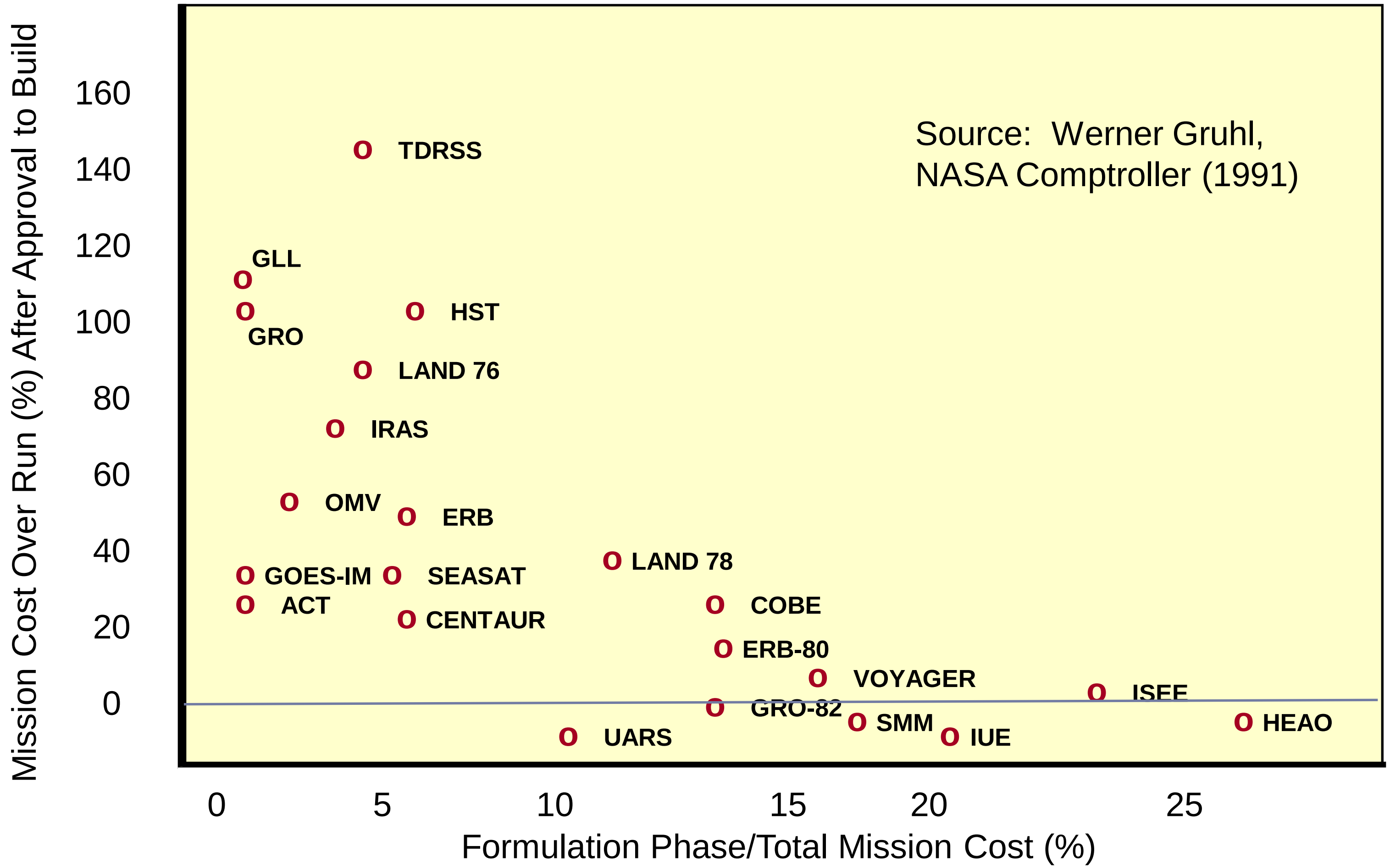
Key Challenge Facing the Planetary Science Decadal Survey (PS-DS)

- Translate "An inventory of the top-level scientific questions" into (1) "the optimum balance among small, medium, and large missions," (2) "a prioritized list of major flight investigations in the New Frontiers and larger classes," and (3) "a list of important science goals which could be achieved by small spacecraft (Discovery and Scout class) missions"
  - To achieve objectives (1), (2) and (3) above, members of the Survey will have to create and sort through scores of mission concepts
  - A successful outcome REQUIRES that the concepts be at similar levels of maturity because ***cost uncertainty scales directly with concept maturity***
  - ***Hence, the Survey needs a tool for assessing the concept maturity level of every Decadal Survey mission concept***

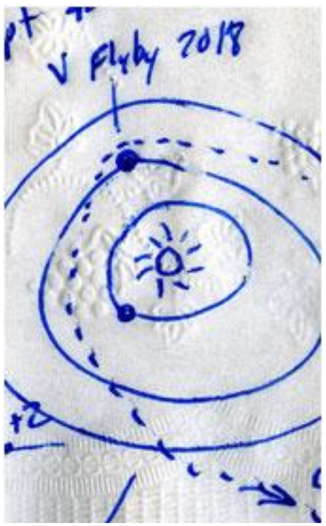
Mission Concept Maturity at "Approval" *vs* Subsequent Mission Implementation Cost Over Run



Key Messages for the PS-DS, NRC and NASA

1. An investment of 10-15% of total mission cost is required to reach 10-30% cost-estimate uncertainty
2. There is *no way* that the PS-DS or NASA can support such a level of investment for scores of mission concepts
3. Hence, NASA and the PS-DS must temper their expectations for what the Survey will produce
4. Focus instead on: Achieving a similar level of concept maturity and therefore cost uncertainty for ALL concepts to be consider.
    - ***Concept Maturity Level (CML) is enabling***

Absent a Common Language and a Yardstick, One Person's Concept is Another's Doodle



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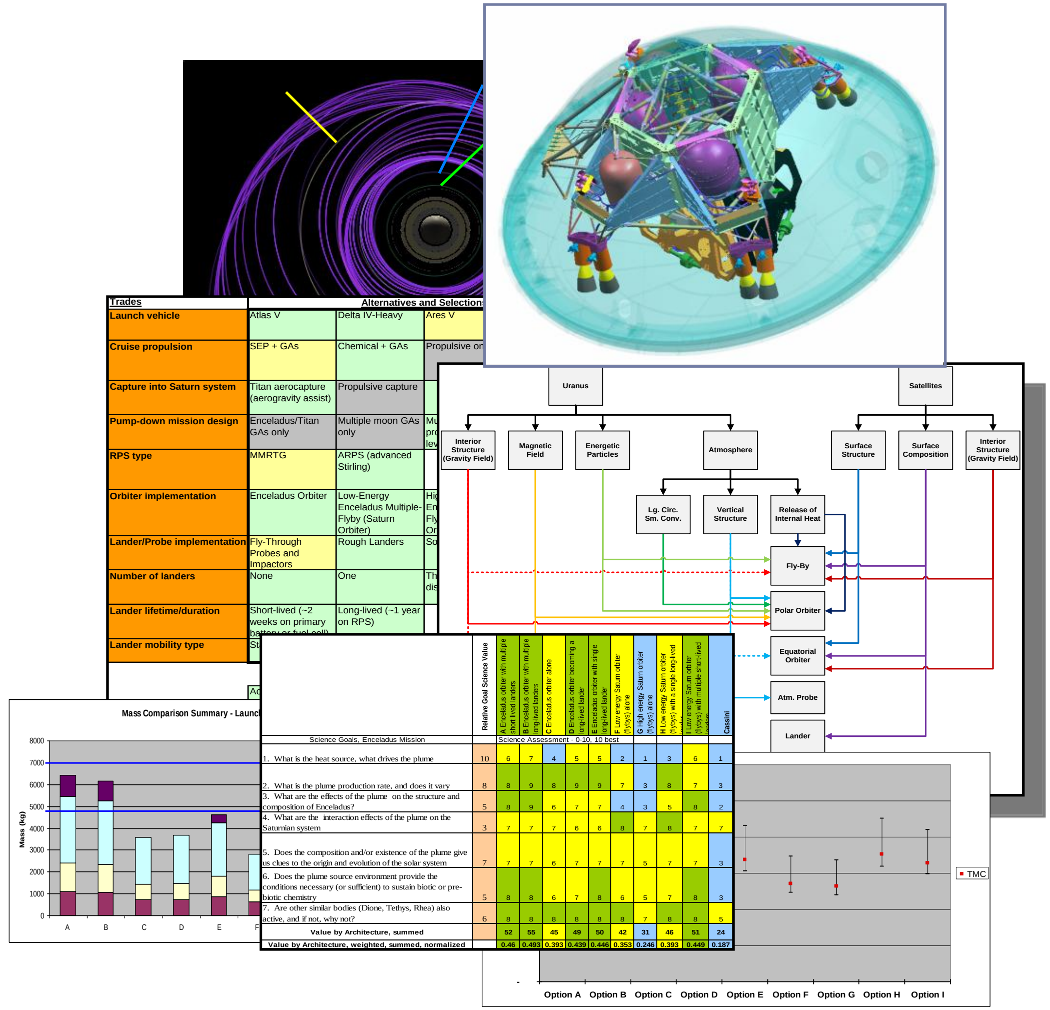
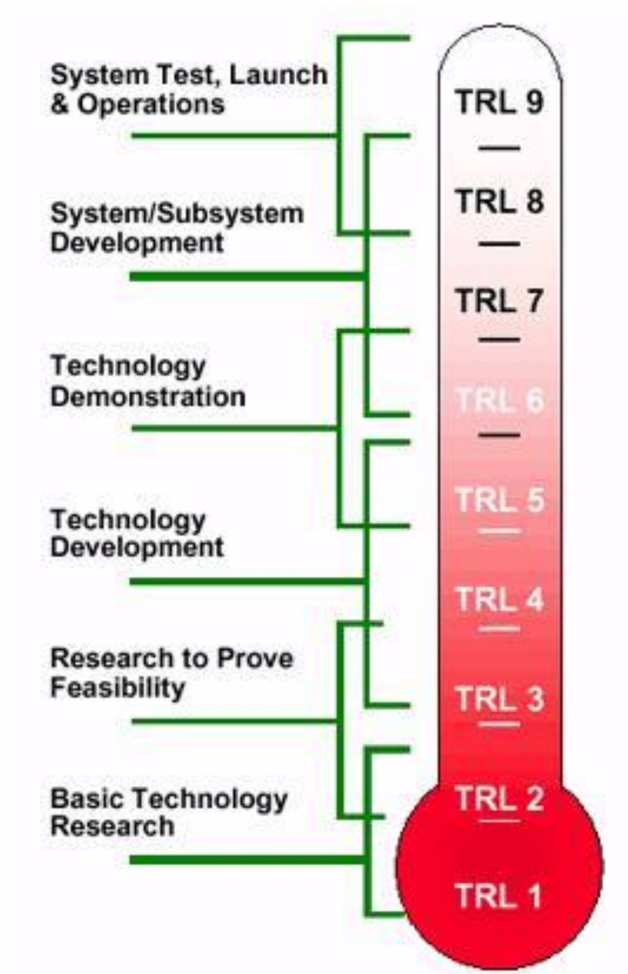


HIGH Cost Uncertainty

LOWER Cost Uncertainty

We Need a Language or a Yardstick – Just Like TRL… It Has Become a Powerful Communications Tool



- TRL has become a universal language
  - Commonly used in AOs, briefings, conference sessions, peer-reviewed literature
  - NPR 7120.8 defines NASA-wide standard
  - "TRL 6 by PDR"
- ***TRL sets expectations despite variations in interpretation***

Defining TRL Through Attributes

H/SW Both	Ques Catgry	% Complete		TRL 6 (Check all that apply or use sliders)
B	T	78	☐	Cross technology issue measurement and performance characteristic validations completed
H	M	100	☑	Quality and reliability levels established
B	M	100	☑	Frequent design changes occur
H	P	100	☑	Draft design drawings are nearly complete
B	T	100	☑	Operating environment for eventual system known
B	P	100	☑	Collection of actual maintainability, reliability, and supportability data has been started
B	P	100	☑	Design to cost goals identified
H	M	100	☑	Investment needs for process and tooling determined
B	T	100	☑	M&S used to simulate system performance in an operational environment
B	P	100	☑	Final Test & Evaluation Master Plan (TEMP)
H	T	100	☑	Factory acceptance testing of laboratory system in laboratory setting
B	T	100	☑	Representative model / prototype tested in high-fidelity lab / simulated operational environment
B	T	100	☑	Realistic environment outside the lab, but not the eventual operating environment
B	P	100	☑	Final Systems Engineering Master Plan (SEMP)
S	T	100	☑	Inventory of external interfaces completed
B	P	100	☑	Technology Transition Agreement has been updated
B	P	100	☑	Scaling issues that remain are identified and supporting analysis is complete
S	T	100	☑	Analysis of timing constraints completed
S	T	100	☑	Analysis of database structures and interfaces completed
B	P	100	☑	Have begun to establish an interface control process
H	P	100	☑	Draft production planning has been reviewed by end user and developer
H	M	100	☑	Critical manufacturing processes prototyped
H	M	100	☑	Most pre-production hardware is available
B	P	100	☑	Technology Transition Agreement has been coordinated and approved by end user
S	T	100	☑	Prototype implementation includes functionality to handle large scale realistic problems
S	T	100	☑	Algorithms parially integrated with existing hardware / software systems
H	M	100	☑	Materials, process, design, and integration methods have been employed
S	T	100	☑	Individual modules tested to verify that the module components (functions) work together
B	P	100	☑	Technology "system" specification complete
H	M	100	☑	Components are functionally compatible with operational system
S	T	100	☑	Representative software system or prototype demonstrated in a laboratory environment
B	T	100	☑	Laboratory system is high-fidelity functional prototype of operational system
B	P	100	☑	Formal configuration management program defined to control change process
B	M	100	☑	Integration demonstrations have been completed
B	P	100	☑	Final Technical Report
H	M	100	☑	Production issues have been identified and major ones have been resolved
S	T	100	☑	Limited software documentation available
S	P	100	☑	Verification, Validation and Accreditation (VV&A) initiated
H	M	100	☑	Process and tooling are mature
H	M	100	☑	Production demonstrations are complete
S	P	100	☑	"Alpha" version software has been released
B	T	100	☑	Engineering feasibility fully demonstrated
B	P	100	☑	Final Transition Plan with Business Case
B	P	100	☑	Acquisition program milestones established
B	P	100	☑	Value analysis includes business case
B	P	100	☑	Technical alternatives include "do nothing case"
B	P	100	☑	Formal requirements document available

- USAF scores 47 attributes for TRL 6

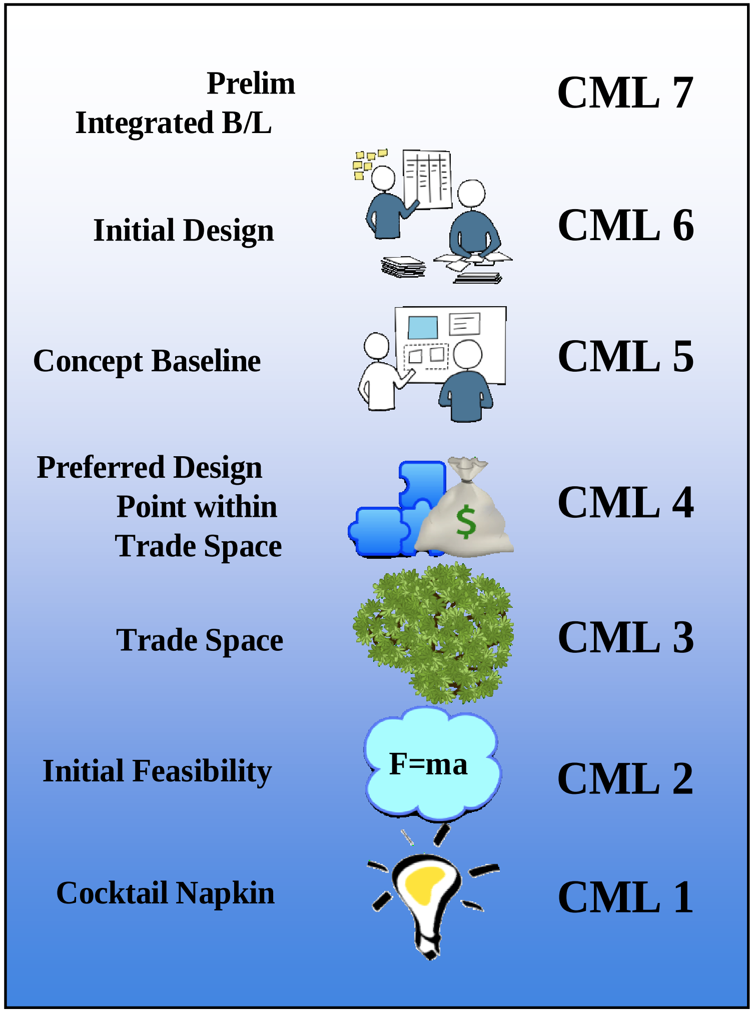
Draft design drawings are nearly complete

Draft production planning has been reviewed by end user and developer

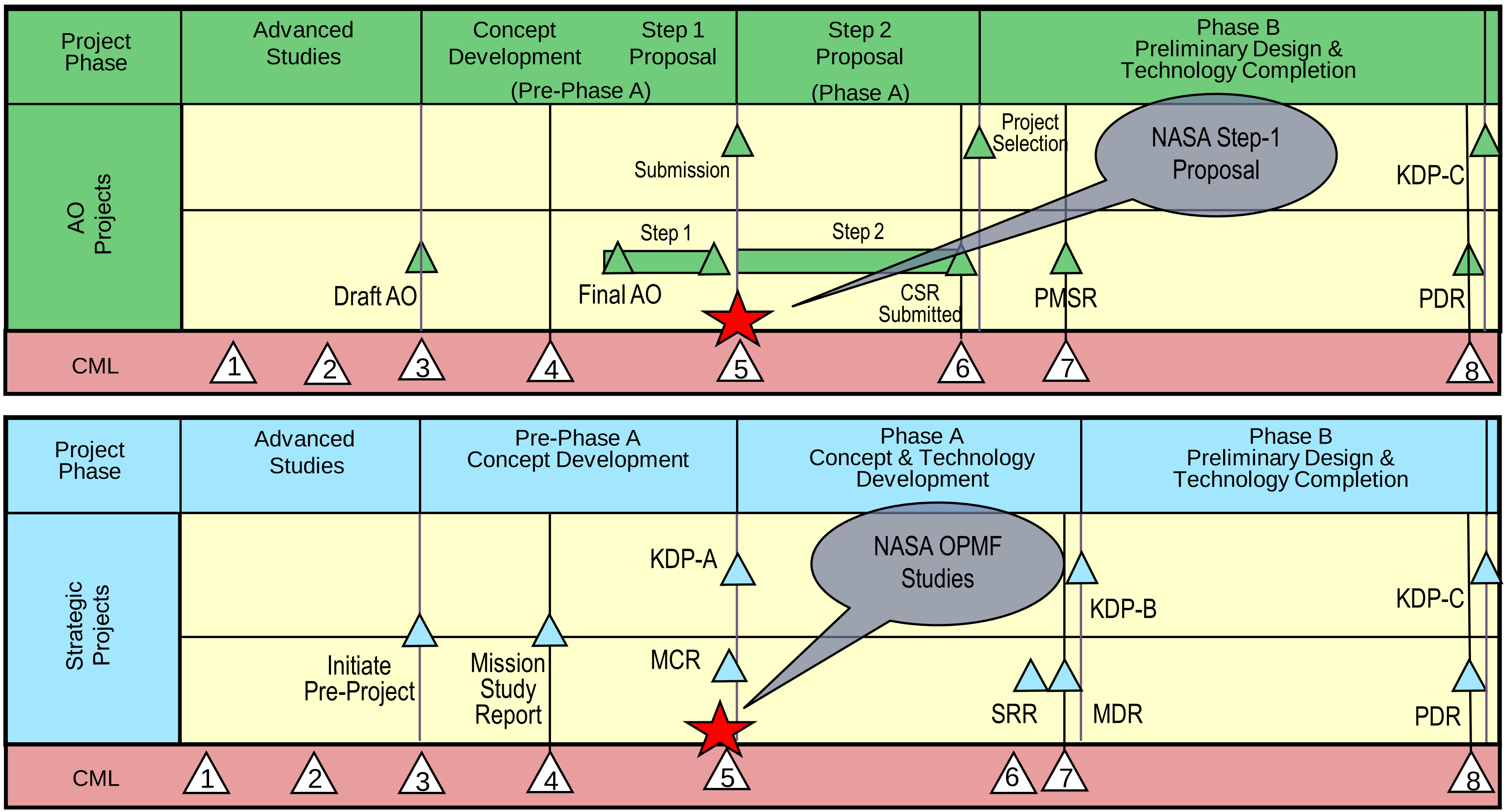
"Alpha" version SW has been released

Concept Maturity Level: CML

- Created by Mark Adler, JPL
- Inspired by TRL scale
- Covers the phase of mission concept formulation from "cocktail napkin" to NASA PDR
  - ***PDR = CML 8***
- Embraced by NASA PSD and now an integral part of JPL's formulation approach



CML and NASA Project Phase



Attributes of a Mission Concept

Technical Attributes (13)

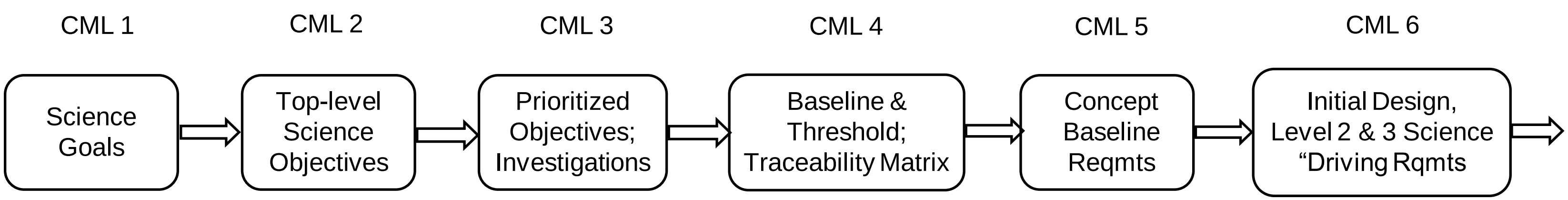
- Requirements
- Mission Design
- S/C System Design
- Ground System Design
- Risk
- Technology
- Master Equipment List
- Technical Margins
- Explored Trade Space
- Mission Assurance Approach
- Modeling & Simulation Approach
- Launch Vehicle
- Planetary Protection

Programmatic Attributes (10)

- Acquisition Approach and Make-Buy Decisions
- Project Organization
- Proposed Inheritance (value)
- Schedules
- Cost
- Documentation
- Work Breakdown Structure
- Test beds & Models
- Study Team Staffing
- Integrated Baseline

Requirements: Increasing depth with increasing CML

5.1.3 Science Objectives & Driving Requirements

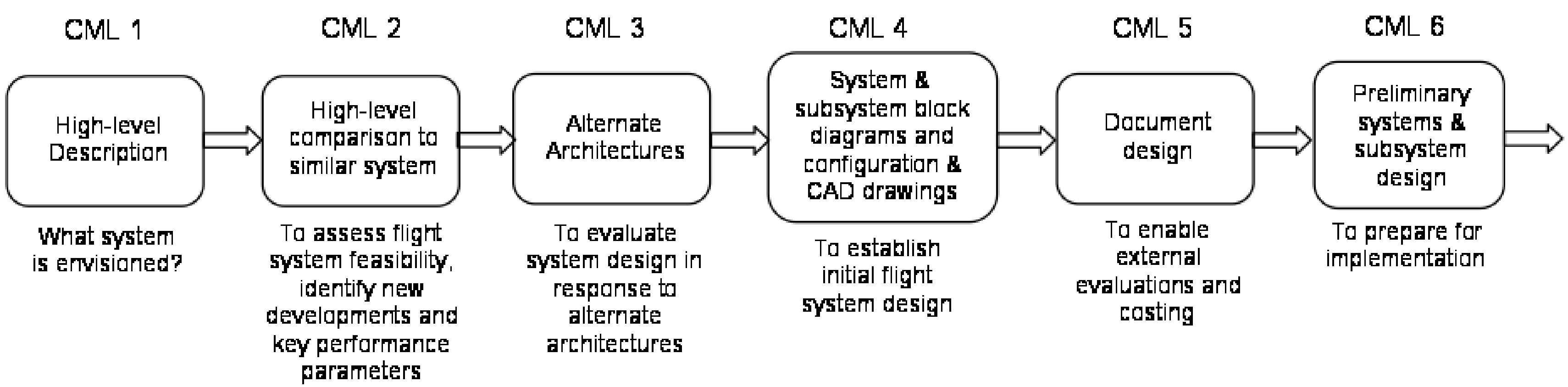


CML 1	CML 2	CML 3	CML 4	CML 5	CML 6
What does the mission intend to accomplish?	**Quantify objectives in order to allow validation of physical feasibility**	**Explore multiple architectures for achieving objectives; evaluate science value, mission cost bin, mission risk for each architecture**	**Document selected design: Traceability matrix (science, to instruments, to data products, to key mission features); baseline and threshold mission attributes**	**Detailed Traceability Matrix will all top-level science requirements (mission drivers) identified**	

Spacecraft Design: Increasing depth and detail with increasing CML

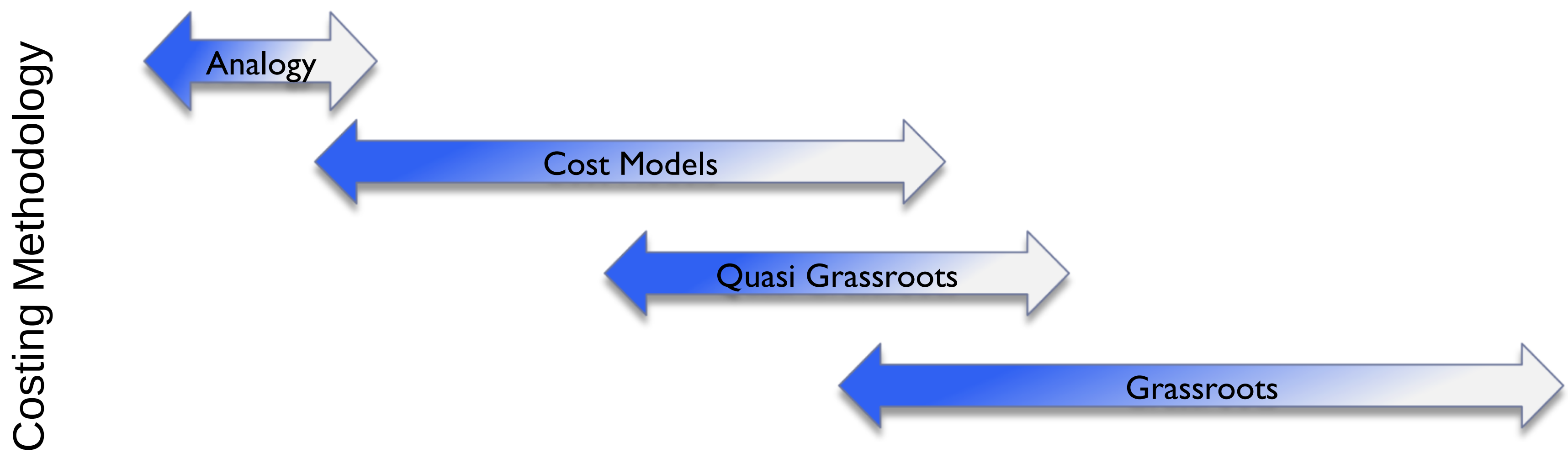
5.5 Spacecraft & Instrument System Design

Spacecraft & instrument system design is based on Level 3 and 4 requirements. It is defined through a series of trade studies and continues to mature from a high level architecture to detailed design through the System Critical Design Review in Phase C.



Appropriate Costing Methods at Each CML

Competed	Adv Studies	Adv Concept	Step 1 Proposal	Step 2 Proposal	Phase B
Assigned	Adv Studies	Pre-Phase A		Phase A	Phase B
CML	1 2	3 4	5	6	7



Summary

1. Cost uncertainty scales with mission concept maturity (and mission complexity)

2. Use of CML *alone* does not *directly* decrease cost uncertainty

3. It *does* enable a much more confident comparison and ranking of concepts within a given mission cost bin, by establishing that each concept is at a similar level of maturity, including the level of understanding of the mission complexity

4. ***Use of CML*** **indirectly** ***will decrease cost uncertainty by leading to more mature, better-understood mission concepts and…***

5. ***Markedly reduce the risk of prioritizing one immature, high-cost-uncertainty concept over another that is more mature and therefore has lower cost uncertainty.***