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Concept Maturity Levels (CMLs)

Tony Freeman

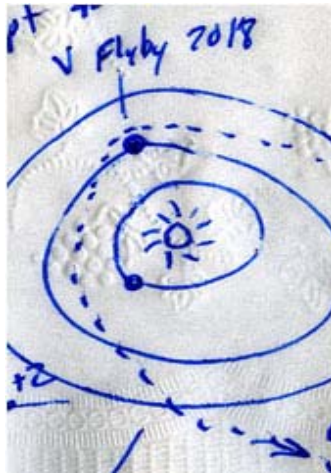
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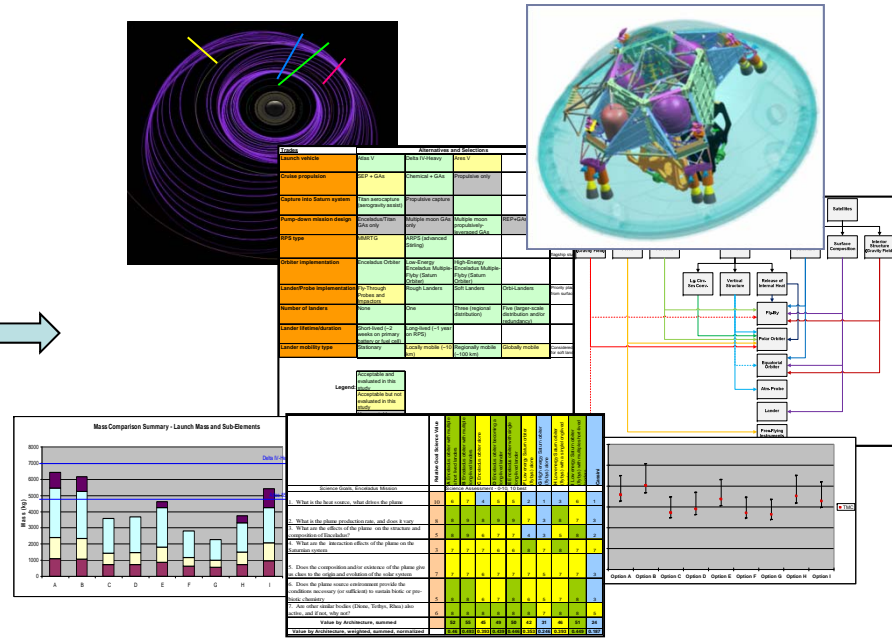
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Absent: a Common Language for Concepts

- How mature is your concept?



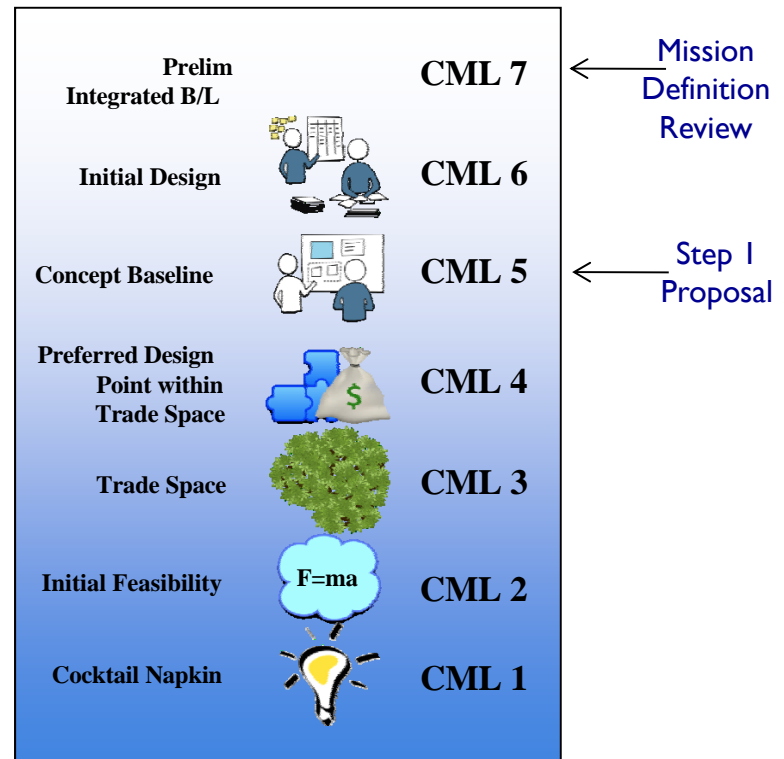
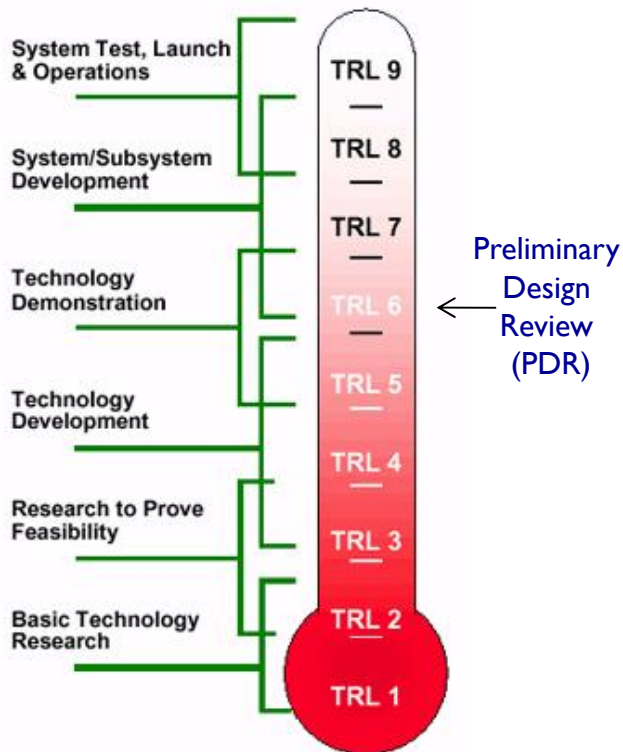
← This or that? →





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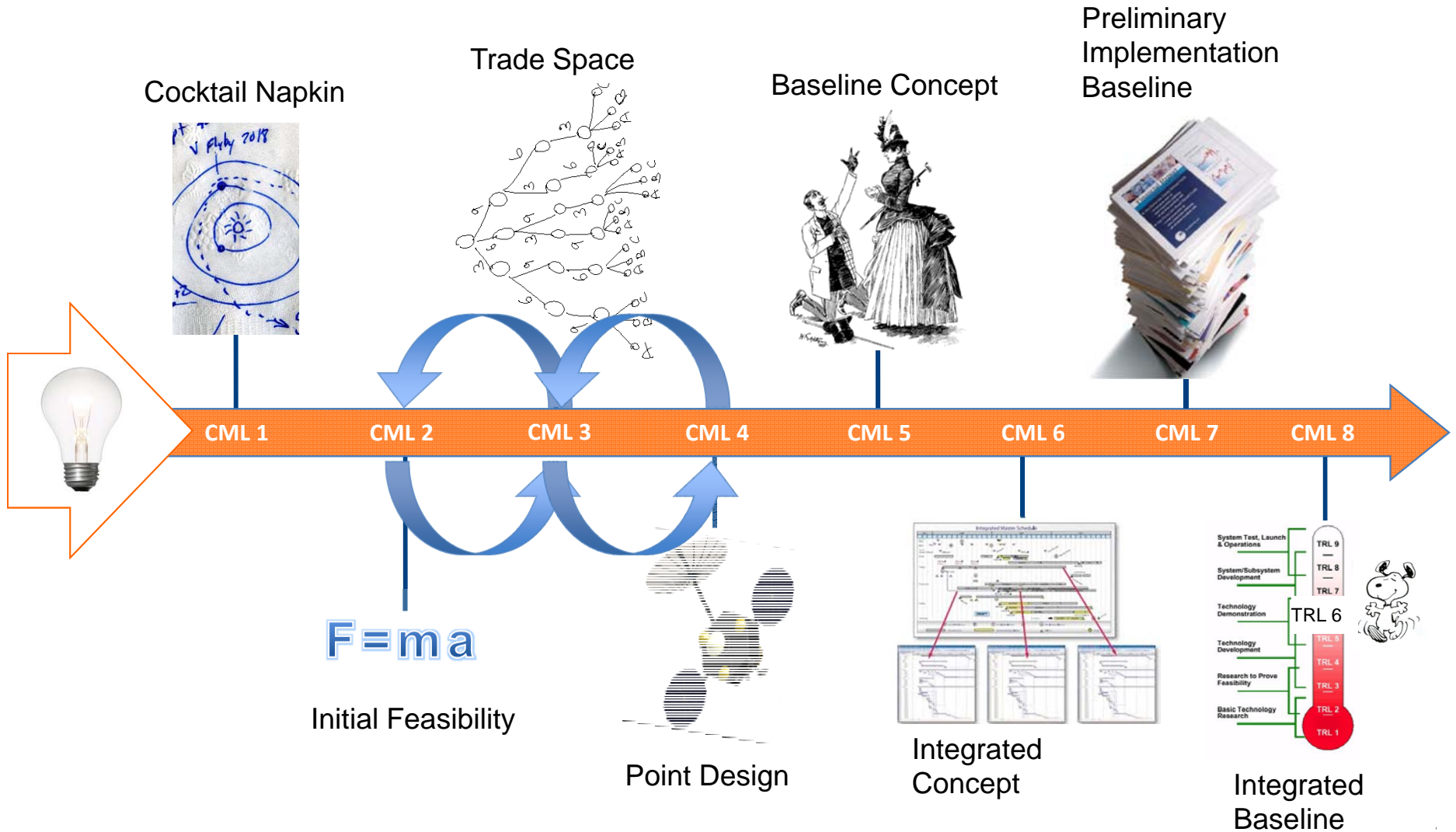
CML Scale is Based on the TRL Scale





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CMLs: A Powerful Communication Tool

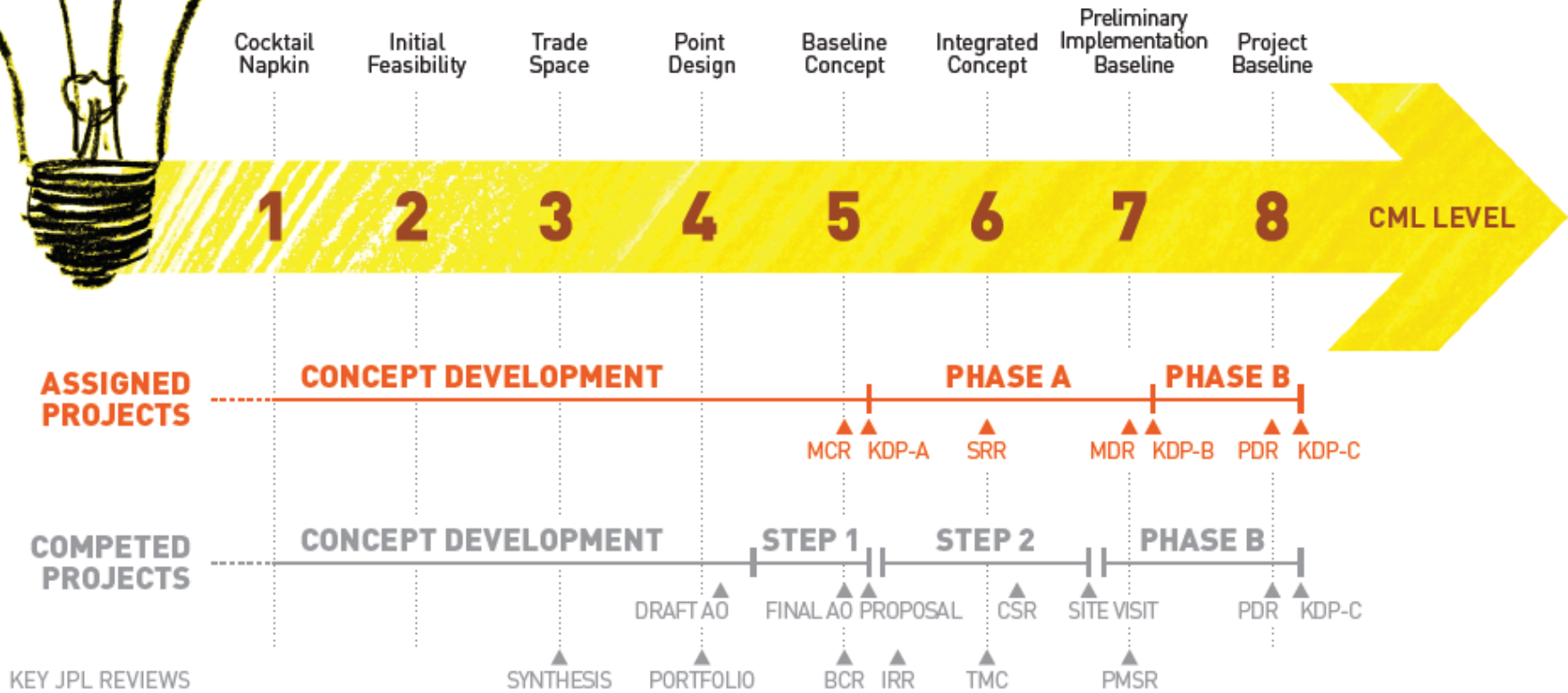
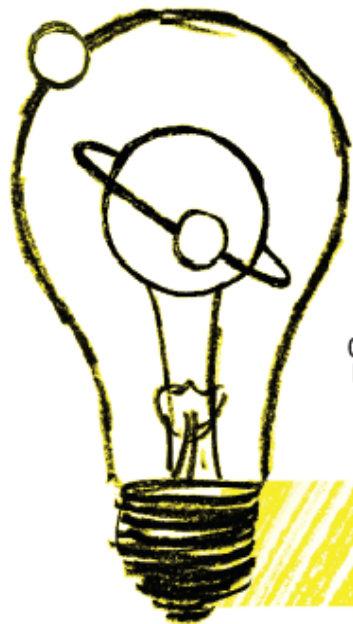




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CONCEPT MATURITY LEVELS (CML)

for NASA Competed and Assigned Projects





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From Communication to Concept Development

Lifecycle Phase		Pre-Phase A				Phase A		
		Advance Studies			Concept Development		Early Formulation	
CML		1	2	3	4	5	6	7
Name		Cocktail Napkin	Initial Feasibility	Trade Space	Point Design	Baseline Concept	Integrated Concept	Preliminary Implementation Baseline
Lifecycle Gate		-	-	-	Concept Gate (Draft AO Out / Mission Study Report)	Baseline Commitment Gate/ MCR	Step 2 Submittal	PMSR/MDR
Science								
Attribute	P4 Section							
Science Objectives & System Requirements	5.3	Science objectives described in one sentence	Objectives described to levels that allow comparison with previous investigations and NASA science community documents	Objectives linked to investigations and measurements; Science return as a function of cost, risk and programatics quantified	Produce draft Science Traceability Matrix; Initial Level 1 requirements considered; Specifying one Baseline and one Threshold Science investigation; Key Performance Parameters listed	Science Traceability Matrix (or equivalent) produced; Preliminary PLRA produced (assigned projects)	Proposed Level 1 requirements documented Level 2 & 3 driving requirements listed; Full and minimum success criteria defined; Baseline PLRA submitted @ SRR (assigned projects)	Update PLRA if necessary; Preliminary Level 2 & 3 requirements listed
Science Data System	5.4	-	Identify science data drivers	Science data rates and volume included in trade space analysis	Science data system sizing	Science data processing architecture, release and archive approach defined	Science data management approach (includes Level 0, 1, 2 data products) defined	Same as for CML 6



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Application to Discovery 2010 Proposals

CML=3

Lifecycle Phase		Pre-Phase A			Phase A	
CML	1	2	4	5	6	7
Name	Cocktail Napkin	Initial Feasibility	Joint Design	Baseline Concept	Integrated Concept	Preliminary Implementation Baseline
Lifecycle Gate	-	-	Concept Gate (Draft IO Out / Mission Study Report)	Baseline Commitment Gate (MCI)	Step 2 Submit	PMS/RM/RD
Attribute	P4 Section					
Science Objectives & System Requirements	5.3	Science objectives described in one sentence	Objectives described to levels that allow comparison with previous investigations and NASA science community documents	Produce draft Science Traceability Matrix; Initial Level 1 requirements considered; Specifying one Baseline and one Threshold Science Investigation; Key Performance Parameters listed	Science Traceability Matrix (for equipment) produced; Preliminary PLRA produced (assigned projects)	Proposed Level 1 requirements documented; Level 2 & 3 driving requirements listed; Full and minimum success criteria defined; Baseline PLRA submitted; SFR (assigned projects)
Science Data System	5.8	Identify science data drivers	Science data system architecture	Science data processing architecture, release and archive technology	Science data management approach	Science data management approach
Mission Development	6.1	Clear language description of unique mission & system characteristics	Quantified performance requirements documented; Preliminary load and delta-V budget determined; Power, telecom, data processing approach defined; Doses & backup options characterized of space environment	Proprietary load and delta-V budget determined; Power, telecom, data processing approach defined; Doses & backup options identified as needed	Collectible, viable & deliverable science objectives documented; Mission traceability matrix created; Resource allocation consistent with science and ops modes; A mission categorization and risk classification determined	Key driving mission elements, timelines and modes documented in detail
Spacecraft System Design	6.2	Key flight elements, design parameters & performance requirements listed; High-level comparison to similar flight systems documented	System architecture with mechanical configuration drawings, block diagrams & discope options compiled	Subsystem designs to enable external evaluation & costing documented; System contingencies & margins established	Major architectural trades complete and incorporated; All key LV, sic and payload IP qualitatively defined	System & subsystem designs and external IP defined; Plans for closing open design items finalized; Plans for maturing technology long-lead items, and prototyping engineering developments in place
		One sentence description of potential	Instrument design with mechanical configuration drawings	Instrument designs sufficient to enable external evaluation & costing developed (completed projects); Initial instrument accommodations	Major payload	

CML Matrix

CML 3 Assessments

Functional Area	Criteria	Proposal 1	Proposal 2	Proposal 3	Proposal 4	Proposal 5
Science Objectives, Driving Requirements & Dscope Options	<ul style="list-style-type: none"> 3. Prime objectives identified, qualified and documented (CML 1 & 2) 4. Broadened set of objectives defined to include acceptable alternatives 5. Major science drivers to cost & risk identified 6. Quantified cost & risk sensitive to varying levels of science return documented 	G	G	G	G	G
Mission Design	<ul style="list-style-type: none"> 1. Key mission parameters & performance requirements qualified (CML 2) 2. Alternative set of mission architectures evaluated against science objectives, cost & risk 3. Developed matrix of alternative architectures and implementation modes 	G	G	G	G	G
Spacecraft or Instrument System Design	<ul style="list-style-type: none"> 1. Key flight element design parameters & performance requirements identified (CML 2) 2. Alternate flight system architectures and concepts evaluated against mission objectives, cost & risk 3. Performance assessment completed for alternative architectures, implementation modes & risks 4. Key flight element design parameters & performance requirements identified (CML 2) 5. Key flight element design parameters & performance requirements identified (CML 2) 	G	G	G	G	G
Assessment & Mitigation Technology & Technical Margins	<ul style="list-style-type: none"> 1. Key flight element design parameters & performance requirements identified (CML 2) 2. Alternate flight system architectures and concepts evaluated against mission objectives, cost & risk 3. Performance assessment completed for alternative architectures, implementation modes & risks 4. Key flight element design parameters & performance requirements identified (CML 2) 5. Key flight element design parameters & performance requirements identified (CML 2) 	G	G	G	G	G
Major Trades	1. Performance-cost trade space varied by at least 20% of nominal design point	R	G	G	G	G
Mission Assurance Modeling & Simulations	1. Required modeling developments with major criteria input to cost or risk identified	G	G	R	G	G
Launch Vehicle	1. Candidate launch vehicle and trades identified	G	G	G	G	G
Planetary Protection	1. Expected Planetary Protection Classification and any variations across trade space documented	N/A	G	N/A	N/A	G
Project Plans	1. Followed the P4 Pre-Phase A & Formulation Phase Life Cycle (CML 2)	G	G	G	G	G
Organization, Partnering & Staffing	1. Partnering options identified (CML 2)	G	G	G	G	G
Schedules	1. Key flight element design parameters & performance requirements identified (CML 2)	G	G	G	G	G
Inheritance	1. Inheritance options, benefits and risks identified	G	G	G	G	G
Cost	1. Cost estimates generated using System 55 costing models (CML 2)	G	G	G	G	G
Cost Risk Assessment & Reserves	1. Cost Risk Subsystems from evaluated across trade space	G	G	G	G	G

30-min interviews yield consistent assessments

15 science & technical attributes
9 programmatic attributes

Check List

Developed a “check list” from the CML Matrix for concept evaluations



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Application to Discovery 2010 Proposals

- Evaluated the maturity of the Discovery mission concepts at their Cost Preview (prior to writing the Step 1 proposals)
 - Held interviews with each study team
- Results:
 - All proposal concepts were basically “green”
 - New proposals were not as mature as those resubmitted
 - Proposal teams need to expand their trade space exploration activities
 - Check list was very useful for finding concept weaknesses



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Conclusion

- CMLs are catching on at:
 - JPL
 - NASA
 - National Research Council's Planetary Science Decadal Survey Panels
- Many uses
 - communication tool
 - evaluating and sorting concepts
 - identifying areas that need strengthening
 - input to estimating cost uncertainty
- Will improve concept robustness prior to moving into Project Formulation