Space Mission Concept Development Using Concept Maturity Levels
(Paper 1665457)

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AIAA Space 2013 Conference
Absent: a Common Language for Concepts

- How mature is your concept?
CML Scale is Based on the Structure of the TRL Scale

Cocktail Napkin
Initial Feasibility
F=ma
Initial Design
Preferred Design
Point within Trade Space
Trade Space
Preliminary Design Review (PDR)
Concept Baseline
Mission Definition Review
Proposal / MCR

Step 1

System Test, Launch & Operations
System/Subsystem Development
Technology Demonstration
Technology Development
Research to Prove Feasibility
Basic Technology Research
TRL 1
TRL 2
TRL 3
TRL 4
TRL 5
TRL 6
TRL 7
TRL 8
TRL 9
CML 1
CML 2
CML 3
CML 4
CML 5
CML 6
CML 7

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CMLs: A Powerful Communication Tool
CONCEPT MATURITY LEVELS (CML)
for NASA Competed and Assigned Projects
Early CMLs Provide the Greatest Value to Mission Architects

- Mission concept development has limited guidance prior to Phase A
- As such, CML Matrix and checklists have their largest utility during CML 1 – 4
  - At the start of Pre-Phase A, there is no NASA guidance
  - At the end of Pre-Phase A (CML 5) guidance is provided by:
    - NASA’s Announcement of Opportunity (Competed Projects)
    - NASA’s Procedural Requirements 7120.5E (Assigned Projects)
CML Matrix is the Key for Measuring Maturity

- CML Matrix contains
  - 7 Columns (CML 1 – 7)
  - 24 Rows (attributes)
    - Science rows (2)
    - Technical rows (13)
    - Management rows (5)
    - Cost row (1)
    - “Other” rows (3)
- Rows organized by the way NASA holds technical reviews
  - Science Review
  - TMCO Review
The Science Rows of the CML Matrix

<table>
<thead>
<tr>
<th>Lifecycle Phase</th>
<th>Pre-Phase A</th>
<th>Phase A</th>
<th>Early Formulation</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Advance Studies</td>
<td>Concept Development</td>
<td></td>
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<tr>
<td>CML</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Name</td>
<td>Cocktail Napkin</td>
<td>Initial Feasibility</td>
<td>Trade Space</td>
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<td>Lifecycle Gate</td>
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</table>

### Science

<table>
<thead>
<tr>
<th>Attribute</th>
<th>P4 Section</th>
<th>Science Objectives &amp; System Requirements</th>
<th>Science Data System</th>
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<tbody>
<tr>
<td></td>
<td>5.3</td>
<td>Science objectives described in one sentence</td>
<td>Identify science data drivers</td>
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<td></td>
<td></td>
<td>Science objectives described to levels that allow comparison with previous investigations and NASA science community documents</td>
<td>Science data rates and volume included in trade space analysis</td>
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<td></td>
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<td>Objectives linked to investigations and measurements; Science return as a function of cost, risk and programmatic quantified</td>
<td>Science data system sizing</td>
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<td></td>
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<td>Produce draft Science Traceability Matrix; Initial Level 1 requirements considered; Specifying one Baseline and one Threshold Science Investigation; Key Performance Parameters listed</td>
<td>Science data processing architecture, release and archive approach defined</td>
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<td></td>
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<td>Science Traceability Matrix (or equivalent) produced; Preliminary PLRA produced (assigned projects)</td>
<td>Science data management approach (includes Level 0, 1, 2 data products) defined</td>
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<td>Proposed Level 1 requirements documented Level 2 &amp; 3 driving requirements listed; Full and minimum success criteria defined; Baseline PLRA submitted @ SRR (assigned projects)</td>
<td>Same as for CML 6</td>
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<td>Update PLRA if necessary; Preliminary Level 2 &amp; 3 requirements listed</td>
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Checklist Derived from CML Matrix to Measure Concept Maturity

CML 3 Assessments

15 science & technical attributes
9 programmatic attributes

30-min interviews by objective assessor yield consistent assessments

Check List

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Strengthen and Weakness of CML Checklists

**Strengths:**
- Provides a systematic approach for measuring a mission concept’s maturity in Pre-Phase A
- Provides study team guidance about where to allocate their limited resources for the biggest benefit
- Assessment is quick and repeatable

**Weaknesses:**
- Does not measure the quality of the items produced, just their level of completeness
- No attempt to weight relative value of one attribute over another
- Study teams are too optimistic as self-assessors
CML Assessment Process is Continuously Being Evaluated

- Comparing results provides the ability to “tune” the checklists
  - If a particular attribute is all "red” and “yellow,” 1) study teams need training in that area or 2) attribute should be moved one CML later
  - Results are compared with results from an all-day JPL review prior to the start of Step 1

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<tr>
<th>Functional Area</th>
<th>Criteria</th>
<th>Proposal 1</th>
<th>Proposal 2</th>
<th>Proposal 3</th>
<th>Proposal 4</th>
<th>Proposal 5</th>
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How CMLs are Used at JPL to Advance Concept Design Maturity

• JPL’s A-Team (CML 1 – 3)
  – Idea generation, feasibility assessment, architecture trade space evaluation, science traceability, technology infusion, and strategic evaluation

• JPL’s Team X (CML 4)
  – Initiated in 1995 and pioneered the collaborative engineering capability within NASA
  – Conducted over 1000 studies
  – Collaborative design sessions to generate a specific mission design, spacecraft design, mission cost range and associated risks

• JPL’s Proposal Effort (CML 5 – 6)
Future Plans

• CMLs are not the entire answer to measuring concept maturity

• Other factors that can impact concept maturity are:
  – Complexity
  – Design Maturity
  – Technology Readiness

• JPL has begun work on identifying factors that are known in Pre-Phase A that can measure a concept’s complexity
  – Initial results indicate that a concept’s complexity level can be used to predict future cost growth
Conclusion

• CMLs are catching on at:
  – JPL
  – NASA Planetary Science Directorate
    • (based on application during Planetary Science Decadal Survey)

• 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
  – Most compelling science identified for a given cost class
  – Detailed trade space exploration has been performed
  – Mission concepts are complete (no omissions)