CADRe Data Normalization to Support Cost Modeling & Analyses

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CADRe Data Normalization
Primary Objective

• Provide a set of normalized cost data to support NASA cost modeling efforts and future versions of the PCEC
  o Cover robotic science spacecraft projects (unmanned)
  o Contracting Fees/Burdens/Taxes, Contributions, Full Cost Accounting, External Impacts, and other characteristics affect cost data from past missions in different ways
  o For cost modeling, a data set reflecting a common set of assumptions is needed

• Other significant requirements
  o Provide mapping to the most current NASA standard WBS
  o Provide visibility into the assumptions affecting the normalized data
  o Build on the experience from NAFCOM and resources in REDSTAR
CADRe Data Normalization
Approach & Products

• Developed an approach for a revised data normalization process
  - Past approaches lacked clear visibility into how data points were normalized
  - Plans for a Normalization Study were reviewed/approved by the MSFC ECO lead
  - Selected 20 projects to include to assess the credibility and impact of a revised data normalization approach and developed a quick turn-around schedule (~6wks)
  - Selected projects were split into 2 Groups; Interim results covering the first group (12 projects) were provided on 10/21/13 and process adjustments implemented
  - The revised process was then applied to 42 projects

• Cost Assessment Reports (CARs)
  - CARs document assumptions associated with each step of the normalization process and provide normalized results that can be used for cost modeling
  - Each CAR has a corresponding Excel workbook with additional details

• Figure-of-Merit (FOM) Analyses
  - Four FOM analyses are included with each CAR: Data Quality, S/C Heritage, Prototypes/Spares, Parts Quality/Redundancy
  - The Data Quality FOM captures the degree to which the raw cost data provided visibility into each step of the normalization process
  - The other FOM analyses attempt to capture technical characteristics that affect cost
CADRe Data Normalization
Challenges

• Many items complicate using the cost data for modeling and making fair comparisons between projects; Examples include:
  ➢ Fee/Burden/Tax arrangements for major contracts vary by project
  ➢ Full Cost Accounting changes add uncertainty/error
  ➢ Schedules are continually changing at all WBS levels
  ➢ Impact from Long Lead procurements can skew NRC/RC splits
  ➢ PM/SE/MA/I&T is impacted by Contributed (uncosted) items
  ➢ Changing NASA culture over past 10-20 years
  ➢ Projects have varying approaches to parts quality, prototyping, etc.
  ➢ Flight heritage significantly affects most cost elements
  ➢ Costs are often affected by “External Impacts”
  ➢ And More
**CADRe Data Normalization**

**Current Project Data Set**

- **Groupings are based on Launch Dates and Data Availability**

- **Group 1 (12 projects)**
  - Represents the initial data set used
  - These missions were re-analyzed after reviewing results and incorporating feedback from other reviewers

- **Group 2 (8 projects)**
  - Represents the 2nd data set normalized
  - Used the refined process after completing the Group 1 analysis

- **Group 3 (30 projects)**
  - An additional 30 projects have been identified to be added
  - Candidates include several recently launched projects
  - Projects shown here include the 22 of 30 that have been completed
CADRe Data Normalization
Normalization Process Steps Summary

START Raw (Unadjusted) Project Data →

STEP 1 Inflated to Common Fixed Year $ →

STEP 2 Allocate to NASA WBS →

STEP 3 Account for Mgmt, Fees, & Burdens →

OUTPUT A NASA WBS by Yr w/o Fees or Burdens

STEP 4 Full Cost Accounting Adjustments →

STEP 5 Account for Contributions →

OUTPUT B NASA WBS by Yr w/ FCA & Contributions but w/o Fees or Burdens

STEP 6 Development Profile Phasing - Schedule & Long Lead Items →

STEP 7 Removal of Costs for Multiple Units →

OUTPUT C NASA WBS by Phase (normalized to a single protoflight unit)

STEP 8 Removal of Costs from External Impacts →

OUTPUT D NASA WBS by Phase w/o External Impacts

Additional detail covering each process step is documented in the “Rules of the Road”
GOAL – Convert Project Real Year dollars to Fixed Year

• The 1st worksheet in each file is the Raw Data
  ● The primary source for this information is the Launch CADRe
  ● For some projects, this data can be augmented with additional details from other non-CADRe data sources (which will be clearly noted on the Raw Data worksheet)

• Each relevant cost element is inflated
  ● Uses the latest NASA New Start Inflation Indices
  ● Worksheet allows user input of desired Fixed Year (currently set to FY14)
  ● Links to the Raw Data worksheet need to be setup and verified
GOAL – Remove System/Instrument Contractor Fees & Burdens

• For contracted s/c and instruments, fees and burdens can vary by organization, project, and time period

• Best Approach – Fees/Burdens are identified in the Project WBS

• Alternate Approach – Management & Fee Table
  o This table allows input of applicable fees, taxes, and burdens associated with each organization, which are removed on the “Mgmt & Fee Table” worksheet
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Step 3) Full Cost Accounting

GOAL – Adjust Costs for Civil Service Labor (FCA)

• Primarily affects projects in Implementation during FY04-08
• Many organizations did not apply a burden for contracting during this time period
• Best Approach – Civil Service (CS) labor and associated labor costs are identified in the Project WBS
  o CS labor costs are replaced with a “composite” labor rate when the CS labor rate is substantially different
  o Basis for “Composite” labor rate comes from analysis of cost details from 3 major aerospace contractors and includes a mix of labor categories
• Alternative Approach – Distribute summary CS labor costs based on CS staffing details
GOAL – Add Costs for Contributed Elements

• Contribution cost values for instrument and/or key project elements can often be found in CSR documentation
  o Although these values are typically not validated, the perception is they are initially high (conservative) values but might capture experienced cost growth

• Contributions are allocated to each WBS element
GOAL – Map Project WBS to NASA WBS (7120.5)

- Each Project WBS element is allocated to a WBS element
  - WBS adds a 2nd level for WBS 5&6 (Payload & S/C)
  - Provisions are included to capture multiple instruments and flight elements

- PM/SE/MA and I&T functions are captured at the Project, Payload, and Spacecraft WBS Levels
  - For the S/C and Payload, these functions represent system contractor efforts and/or relevant functions provided by the Project Management organization

### NASA (augmented) WBS

<table>
<thead>
<tr>
<th>WBS #</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Program Management</td>
</tr>
<tr>
<td>2.0</td>
<td>Systems Engineering</td>
</tr>
<tr>
<td>3.0</td>
<td>Mission Assurance</td>
</tr>
<tr>
<td>4.0</td>
<td>Science</td>
</tr>
<tr>
<td>5.0</td>
<td>Payload</td>
</tr>
<tr>
<td>5.1</td>
<td>P/L PM</td>
</tr>
<tr>
<td>5.2</td>
<td>P/L SE</td>
</tr>
<tr>
<td>5.3</td>
<td>P/L MA</td>
</tr>
<tr>
<td>5.4</td>
<td>Instrument #1</td>
</tr>
<tr>
<td>5.xx</td>
<td>Instrument n</td>
</tr>
<tr>
<td>5.70</td>
<td>P/L Software</td>
</tr>
<tr>
<td>5.80</td>
<td>P/L IAT</td>
</tr>
<tr>
<td>5.90</td>
<td>P/L GSE</td>
</tr>
<tr>
<td>6.0</td>
<td>Spacecraft</td>
</tr>
<tr>
<td>6.1</td>
<td>S/C PM</td>
</tr>
<tr>
<td>6.2</td>
<td>S/C SE</td>
</tr>
<tr>
<td>6.3</td>
<td>S/C MA</td>
</tr>
<tr>
<td>6.4</td>
<td>Structure &amp; Mech. (SC 1)</td>
</tr>
<tr>
<td>6.5</td>
<td>Thermal (SC 1)</td>
</tr>
<tr>
<td>6.6</td>
<td>Power (SC 1)</td>
</tr>
<tr>
<td>6.7</td>
<td>C&amp;DH (SC 1)</td>
</tr>
<tr>
<td>6.8</td>
<td>Communications (SC 1)</td>
</tr>
<tr>
<td>6.9</td>
<td>ACS (SC 1)</td>
</tr>
<tr>
<td>6.10</td>
<td>Propulsion (SC 1)</td>
</tr>
<tr>
<td>6.11</td>
<td>Harness (SC 1)</td>
</tr>
<tr>
<td>6.12-6.43</td>
<td>Repeat 6.4-6.11 for each Flt Element</td>
</tr>
<tr>
<td>6.70</td>
<td>S/C Software</td>
</tr>
<tr>
<td>6.80</td>
<td>S/C IAT</td>
</tr>
<tr>
<td>6.90</td>
<td>S/C GSE</td>
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<tr>
<td>7.0</td>
<td>MOS</td>
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<td>8.0</td>
<td>Launch Services</td>
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<td>9.0</td>
<td>GDS</td>
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<tr>
<td>10.0</td>
<td>System Level IAT</td>
</tr>
<tr>
<td>11.0</td>
<td>E/PO</td>
</tr>
</tbody>
</table>
GOAL – Identify Non-Recurring & Recurring Costs by WBS

• **Best Approach – NRC/RC identified in the Project WBS**
  - This split is not typically provided for the “as-launched” status
  - Costs for all identified Long-Lead items moved to “Fabrication” phase

• **Alternate Approach – Use schedule and cost details to determine NRC/RC splits**
  - Monthly data (at least for the year the Mission CDR occurs in) should be used when available
  - Annual cost details can be used to roughly approximate splits using schedule details
  - Development Schedule Phases:
    - **NRC**
      1) **Design** = Phase B start to CDR
      2) **Fabrication** = CDR to SIR
    - **RC**
      3) **Integration & Test** = SIR to Ship (to launch site)
      4) **Launch Operations & On-orbit CheckOut** = Ship to End of On-orbit C/O
GOAL – Determine Adjustments for Single Unit Cost

• Cost details for multiple units is identified in the Project WBS
  o This does not ever seem to happen

• Use details of the implementation approach to account for lower-level WBS impacts
  o Adjustments can be applied independently to the NRC and RC portion of each WBS element, since multiple units have less sensitivity to NRC
  o Adjustments are made at the NASA (augmented) WBS level 2 to account for less sensitivity to multiple units for items like Project-level PM/SE/MA
  o GSE costs needs to account for whether Fabrication and I&T were performed serially or in parallel
CADRe Data Normalization
Step 8) External Impacts

GOAL – Identify Costs Associated with External Impacts

• External Impacts capture occurrences beyond the project’s control and include:
  o Schedule delays due to Launch Vehicle availability/technical issues
  o Schedule delays due to funding availability shortfalls
  o Schedule delays due to Natural Disasters

• Best Approach – Reviewed External Impacts identified in the Project WBS
  o Some (but not many) projects include this in their reported cost data

• Alternate Approaches
  o Find costs for External Impacts in non-CADRe project documentation and/or related studies
  o Develop tailored estimating approaches to develop a rough estimates of associated impacts
• Developed four supplemental analyses to facilitate using data analysis results for cost modeling - Objective is to provide analysts with additional details that can be used to improve cost models

• Data Quality Assessment
  o A score sheet has been included to capture uncertainty related to data interpretation due to lack of details - this provides a measure of confidence in the results and provides direction for future improvements

• Spacecraft Heritage Assessment
  o A rating sheet has been included to capture the level of spacecraft heritage associated with each project. The rating uses in-depth knowledge of the “as-launched” spacecraft configuration as the heritage basis (which is often less than pre-Phase B predictions)

• Prototypes & Spares Assessment
  o This rating captures prototype/spare quantities and prototype utilization plan details.

• Parts & Redundancy Assessment
  o This rating captures the quality and type of parts and redundancy within each subsystem
### CADRe Data Normalization

**FOM: Data Quality**

- **Data Quality Assessment**
  - A score (0-100) is determined for each project to capture the availability of needed data details and the amount of assumptions required for the cost analysis.
  - Scores are based on details covering each cost analysis process step.
  - The process steps are not equally weighted and steps that are “not applicable” are not considered in the points result.

<table>
<thead>
<tr>
<th>Data Quality Assessment for Data Normalization</th>
<th>Points Total: 69 (Max:100)</th>
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<tbody>
<tr>
<td><strong>New Horizons</strong></td>
<td><strong>Score</strong></td>
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<tr>
<td>1 Inflation</td>
<td>100%</td>
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<tr>
<td>Costs by WBS Level 1</td>
<td>Y</td>
</tr>
<tr>
<td>Costs by WBS Level 2 (S/C)</td>
<td>Y</td>
</tr>
<tr>
<td>Costs by WBS Level 3 (S/C)</td>
<td>Y</td>
</tr>
<tr>
<td>Costs by WBS Level 2 (Pylid)</td>
<td>Y</td>
</tr>
<tr>
<td>Costs by WBS Level 3 (Pylid)</td>
<td>Y</td>
</tr>
<tr>
<td>2 Allocations to NASA WBS</td>
<td>82%</td>
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<tr>
<td>Project WBS maps to NASA Lv1</td>
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</tr>
<tr>
<td>Project WBS maps to NASA Lv1 (S/C)</td>
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<td>ProjWBS maps to NASA Lv3 (S/C)</td>
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<tr>
<td>ProjWBS maps to NASA Lv2 (Pylid)</td>
<td>E</td>
</tr>
<tr>
<td>ProjWBS maps to NASA Lv3 (Pylid)</td>
<td>Y</td>
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<td>3 Fees/Burdens</td>
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<td>Fee Data Available</td>
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<tr>
<td>Burdens Easily Separable</td>
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<td>Burden Data Available</td>
<td>E</td>
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<td>4 FCA</td>
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<td>Civil Service Costs Applicable</td>
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<td>5 Contributions</td>
<td>n/a</td>
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<tr>
<td>Contributions Included</td>
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<tr>
<td>Value Available by WBS</td>
<td>n/a</td>
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<td>6 NRC/RC Split</td>
<td>50%</td>
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<td>NRC/RC Split Provided</td>
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<td>Monthly Costs by WBS Provided</td>
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<tr>
<td>Schedule Detail Provided</td>
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<tr>
<td>Long Lead Items Identified</td>
<td>Y</td>
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<tr>
<td>7 Multiple Units</td>
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<tr>
<td>Number of S/C</td>
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<tr>
<td>Costs per Unit Tracked</td>
<td>n/a</td>
</tr>
<tr>
<td>Defined Multiple Unit Build/Test Plan</td>
<td>n/a</td>
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<tr>
<td>8 External Impacts</td>
<td>100%</td>
</tr>
<tr>
<td>External Impacts Applicable</td>
<td>Y</td>
</tr>
<tr>
<td>External Impacts &lt; $10M?</td>
<td>Y</td>
</tr>
<tr>
<td>Defined &amp; Reviewed Set Available</td>
<td>Y</td>
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</tbody>
</table>
CADRe Data Normalization
Data Quality FOM – Results

Data Quality

Average

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**Spacecraft Heritage Assessment**

- The rating combines a mass-based and implementation approach-based assessment.
- The mass-based analysis uses a roll-up of component-level heritage assignments using heritage information representing the “as flown” configuration.
- The mass-based results are adjusted based on details of the implementation approach – *Similar provider and application? How long since last used?*
Results of the Dawn test case appear reasonable. A rating of 3.8 has a little more heritage than a “Major Modification”. The Dawn bus was based on the OSC LEOStar-2 RSDO bus but modified for deep space application using solar electric propulsion, which seems major.

These values are based on roll-ups from lower-level detail on the MEL worksheet in the Normalization file.

Overall Score weights s/s ratings based on RC.

These values are based on the analyst’s understanding of the implementation details.

This % reduction is applied to the mass based heritage associated with a “N” entry. These are based on expert judgment and should be further reviewed.
CADRe Data Normalization
S/C Heritage FOM – Results

S/C Heritage

Exact Copy
Minor Mod
Major Mod
All New
All < TRL7

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**CADRe Data Normalization**  
**FOM: Prototypes & Spares**

### Prototypes & Spares Assessment
- Prototype/Spare quantities are assigned based on data typically provided in a detailed project Master Equipment List (MEL) and represent the portion of the subsystem (s/s) being prototyped/spared.
- The portion of s/s costs covering prototypes/spares is estimated assuming a non-flight quality prototype is ~25% of a flight unit and a typical spare is ~75% (these percentages are only applied to flight unit fabrication costs).
- Intended prototype usage is used to adjust the results based on 5 inputs.
### Parts Quality/Type and Redundancy Rating

<table>
<thead>
<tr>
<th>PARTS QUALITY/TYPE</th>
<th>RATING</th>
<th>REDUNDANCY</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Flagship Class</td>
<td>% Disc/Merlin Class</td>
<td>% Explorer Class</td>
<td>% &lt; Explorer Class</td>
</tr>
<tr>
<td>Structure Subsystem</td>
<td>3.0</td>
<td>7.0</td>
<td>Al/Al-honeycomb</td>
</tr>
<tr>
<td>Thermal Control</td>
<td>7.0</td>
<td>7.0</td>
<td>Passive/MLI+htrrs+Rad</td>
</tr>
<tr>
<td>Electrical Power &amp; Distr</td>
<td>7.0</td>
<td>7.0</td>
<td>Al/Al-honeycomb</td>
</tr>
<tr>
<td>Attitude Deter &amp; Control</td>
<td>3.0</td>
<td>7.0</td>
<td>Passive/MLI+htrrs+Rad</td>
</tr>
<tr>
<td>Reaction Control</td>
<td>3.0</td>
<td>7.0</td>
<td>3-axis/Mono</td>
</tr>
<tr>
<td>RF/Communication</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Command &amp; Data</td>
<td>7.0</td>
<td>7.0</td>
<td>3-axis/Mono</td>
</tr>
<tr>
<td>Overall Score</td>
<td>5.9</td>
<td>42%</td>
<td>12%</td>
</tr>
</tbody>
</table>

**Parts Quality/Type Rating Key:**
- 0 = Not Space Quality/Al or SS, No THM/RCS
- 1 = Low Quality/Al, Passive-MLI, Spinner-Mono
- 2 = Med Quality/Al-honeycomb, Passive-MLI+htrrs, 3-axis-Mono
- 3 = High Quality/Composite, Passive-MLI+htrrs+Rad, 3-axis-Biprop
- 4 = Highest Quality/Adv Mat’ls/RCS, Active-Cryo

**Redundancy Rating Key:**
- 0 = No Redund/Common Parts
- 1 = Select/Min Redund/CmnPrts
- 2 = Moderate Redund/CmnPrts
- 3 = Significant Redund/CmnPrts
- 4 = Full Redund/Sgn CmnPrts

### Parts & Redundancy Assessment
- Parts Quality/Type covers electronics classifications for devices in the Power, Attitude Control, Communication, and Command & Data s/s’s – They are shown by program but represent various applicable Military Specs
- Parts Quality/Type for Structure, Thermal, and Reaction Control are s/s-specific
- Redundancy captures the portion of each s/s that is redundant and also captures contributions from common parts

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CADRe Data Normalization
S/C Parts Quality FOM – Results

S/C Parts Quality

- Highest Qual/Adv Mat’ls
- High Qual/Composite Struct/Biprop
- Med Qual/Al-honeycomb Struct/Monoprop
- Lower Qual/Al Struct/Monoprop/Spinner
- All < Space Qualified

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CADRe Data Normalization
Next Steps

• Continue expanding the data set with new projects
  o Prioritize incorporating new projects as launch CADRe’s are completed
  o Go back to older projects as time allows, focusing on candidates with good data

• Implement enhancements/fixes to the process with user feedback
  o New data may allow enhancements to some data points (particularly those with a low Data Quality FOM score)
  o Minor errors might be identified by the user community
  o A process to collect this feedback needs to be established (similar to RFAs)

• Refine approaches used for Figure-of-Merit (FOM) analyses
  o The FOM analyses provide good supporting detail to support modeling and comparisons; however, the approach used for each should be further reviewed and refined if needed

• Use the data to support cost model development
  o Currently in use supporting development of a PM/SE/MA/I&T model