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**
  - **Cover robotic science spacecraft projects (unmanned)**
  - Contracting Fees/Burdens/Taxes, Contributions, Full Cost Accounting, External Impacts, and other characteristics affect cost data from past missions in different ways
  - For cost modeling, a data set reflecting a common set of assumptions is needed
- **Other significant requirements**
  - Provide mapping to the most current NASA standard WBS
  - Provide visibility into the assumptions affecting the normalized data
  - Build on the experience from NAFCOM and resources in REDSTAR

NASA STANDARD WBS	
WBS #	*Item*
1.0	Program Management
2.0	Systems Engineering
3.0	Mission Assurance
4.0	Science
5.0	Payload
6.0	Spacecraft
7.0	MOS
8.0	Launch Services
9.0	GDS
10.0	System Level IAT
11.0	E/PO

CADRe Data Normalization Approach & Products

Engineering Cost Office

APPROACH

- **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

PRODUCTS

- **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

	MISSION	Launch Date	Lead Org PM	Lead Org Flt Sys	NASA Program
1	TDRSS K-L	1/23/14	GSFC	Boeing	Space Comm
2	MAVEN	11/18/13	GSFC	LMA	Planetary
3	LADEE	9/6/13	GSFC	ARC	Planetary
4	IRIS	6/27/13	GSFC	LMMS	Astrophysics/SMEX
5	Van Allen Probes	8/30/12	GSFC	APL	Heliophysics/LWS
6	NuSTAR	6/13/12	JPL	OSC	Astrophysics/Explorer
7	MSL	11/26/11	JPL	JPL/LMA	Planetary/Mars Expl
8	GRAIL	9/10/11	JPL	LMA	Planetary/Discovery
9	Juno	8/5/11	JPL	LMA	Planetary/New Frontiers
10	Glory	3/4/11	GSFC	OSC/Swales	Earth Sciences
11	GOES (-P)	3/4/10	GSFC/NOAA	Boeing/SGT	Earth Sciences
12	SDO	2/11/10	GSFC	GSFC	Heliophysics
13	WISE	12/14/09	JPL	BATC	Astrophysics/Explorer
14	LCROSS	6/18/09	ARC	NG	Planetary/Discovery
15	LRO	6/18/09	GSFC	GSFC	Planetary
16	KEPLER	3/6/09	JPL	BATC	Astrophysics/Discovery
17	OCO	2/24/09	JPL	OSC	Earth Science
18	IBEX	10/19/08	SwRI	OSC	Astrophysics/Explorer
19	DAWN	9/27/07	JPL	OSC/JPL	Planetary/Discovery
20	Phoenix	8/4/07	JPL	LMA	Planetary
21	AIM	4/25/07	LASP	OSC	Heliophysics
22	THEMIS	2/17/07	UCB	Swales	Astrophysics/Explorer
23	STEREO	10/26/06	GSFC	APL	Heliophysics
24	CLOUDSAT	4/28/06	GSFC	BATC	Earth Sciences
25	NEW HORIZONS	1/19/06	APL	APL	Planetary/New Frontiers
26	MRO	8/12/05	JPL	LMA	Planetary/Mars Expl
27	DEEP IMPACT	1/12/05	JPL	BATC	Planetary/Discovery
28	Swift	11/20/04	GSFC	Spectrum Astro	Astrophysics/Explorer
29	MESSENGER	8/3/04	APL	APL	Planetary/Discovery
30	Spitzer	8/25/03	JPL	LMA	Astrophysics
31	MER	6/10/03	JPL	JPL	Planetary/Mars Expl
32	GALEX	4/28/03	JPL	OSC	Astrophysics/Explorer
33	RHESSI	2/5/02	UCB	Spectrum Astro	Heliophysics
34	TIMED	12/7/01	APL	APL	Earth Sciences
35	GENESIS	8/8/01	JPL	LMA	Planetary/Discovery
36	Mars Odyssey	7/7/01	JPL	LMA	Planetary/Mars Expl
37	WMAP	6/30/01	GSFC	GSFC	Astrophysics/Explorer
38	WIRE	3/5/99	GSFC	GSFC	Astrophysics/Explorer
39	TRACE	4/2/98	GSFC	GSFC	Astrophysics/Explorer
40	Cassini	10/15/97	JPL	JPL	Planetary/Outer Planets
41	Mars Global Surveyor	11/7/96	JPL	LMA	Planetary/Mars Expl
42	NEAR	2/17/96	APL	APL	Planetary/Discovery
		Group 1	Group 2	Group 3	

CADRe Data Normalization
Normalization Process Steps Summary

Engineering Cost Office

START
Raw (Unadjusted) Project Data

STEP 1
Inflate 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*

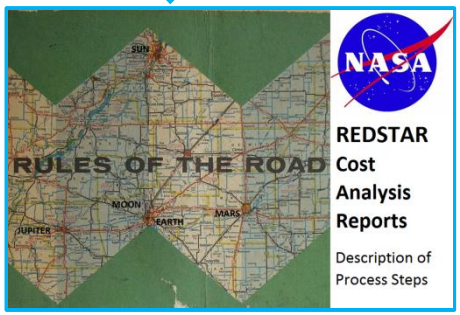
STEP 7
Removal of Costs for Multiple Units

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"



CADRe Data Normalization
Step 1) Inflation

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

CADRe Data Normalization
Step 2) Fees & Burdens

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**
  - This table allows input of applicable fees, taxes, and burdens associated with each organization, which are removed on the "Mgmt & Fee Table" worksheet

CADRe Data Normalization
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**
  - CS labor costs are replaced with a "composite" labor rate when the CS labor rate is substantially different
  - 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**

CADRe Data Normalization
Step 4) Contributions

GOAL – Add Costs for Contributed Elements

- **Contribution cost values for instrument and/or key project elements can often be found in CSR documentation**
  - 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**

CADRe Data Normalization
Step 5) NASA WBS Mapping

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

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

CADRe Data Normalization
Step 6) NRC/RC Splits

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
  - <u>Development Schedule Phases:</u>

NRC
1) **Design** = Phase B start to CDR

RC
2) **Fabrication** = CDR to SIR
3) **Integration & Test** = SIR to Ship (to launch site)
4) **Launch Operations & On-orbit CheckOut** = Ship to End of On-orbit C/O

CADRe Data Normalization
Step 7) Multiple Units

GOAL – Determine Adjustments for Single Unit Cost

- **Cost details for multiple units is identified in the Project WBS**
  - This does not ever seem to happen
- **Use details of the implementation approach to account for lower-level WBS impacts**
  - Adjustments can be applied independently to the NRC and RC portion of each WBS element, since multiple units have less sensitivity to NRC
  - 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
  - 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:**
  - Schedule delays due to Launch Vehicle availability/technical issues
  - Schedule delays due to funding availability shortfalls
  - Schedule delays due to Natural Disasters
- **Best Approach – Reviewed External Impacts identified in the Project WBS**
  - Some (but not many) projects include this in their reported cost data
- **Alternate Approaches**
  - Find costs for External Impacts in non-CADRe project documentation and/or related studies
  - Develop tailored estimating approaches to develop a rough estimates of associated impacts

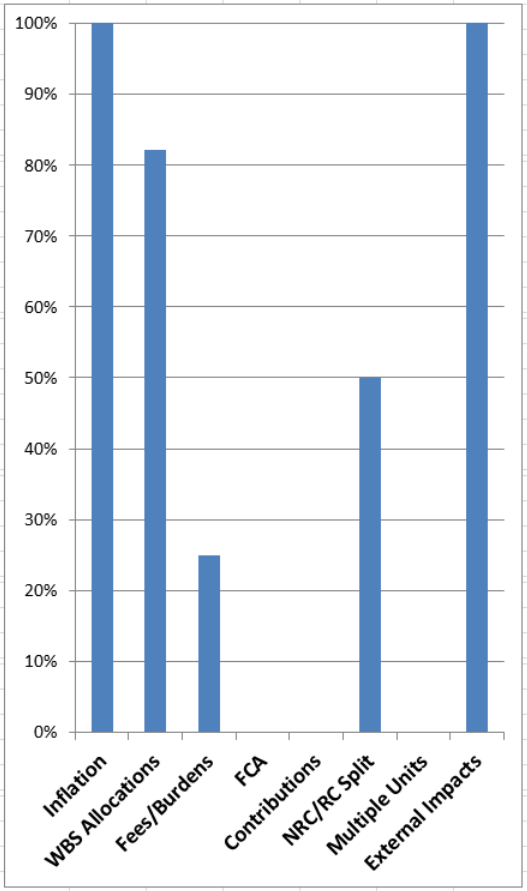
CADRe Data Normalization
Cost Analysis Figures-of-Merit (FOMs)

- **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**
  - 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**
  - 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**
  - This rating captures prototype/spare quantities and prototype utilization plan details.
- **Parts & Redundancy Assessment**
  - This rating captures the quality and type of parts and redundancy within each subsystem

CADRe Data Normalization FOM: Data Quality

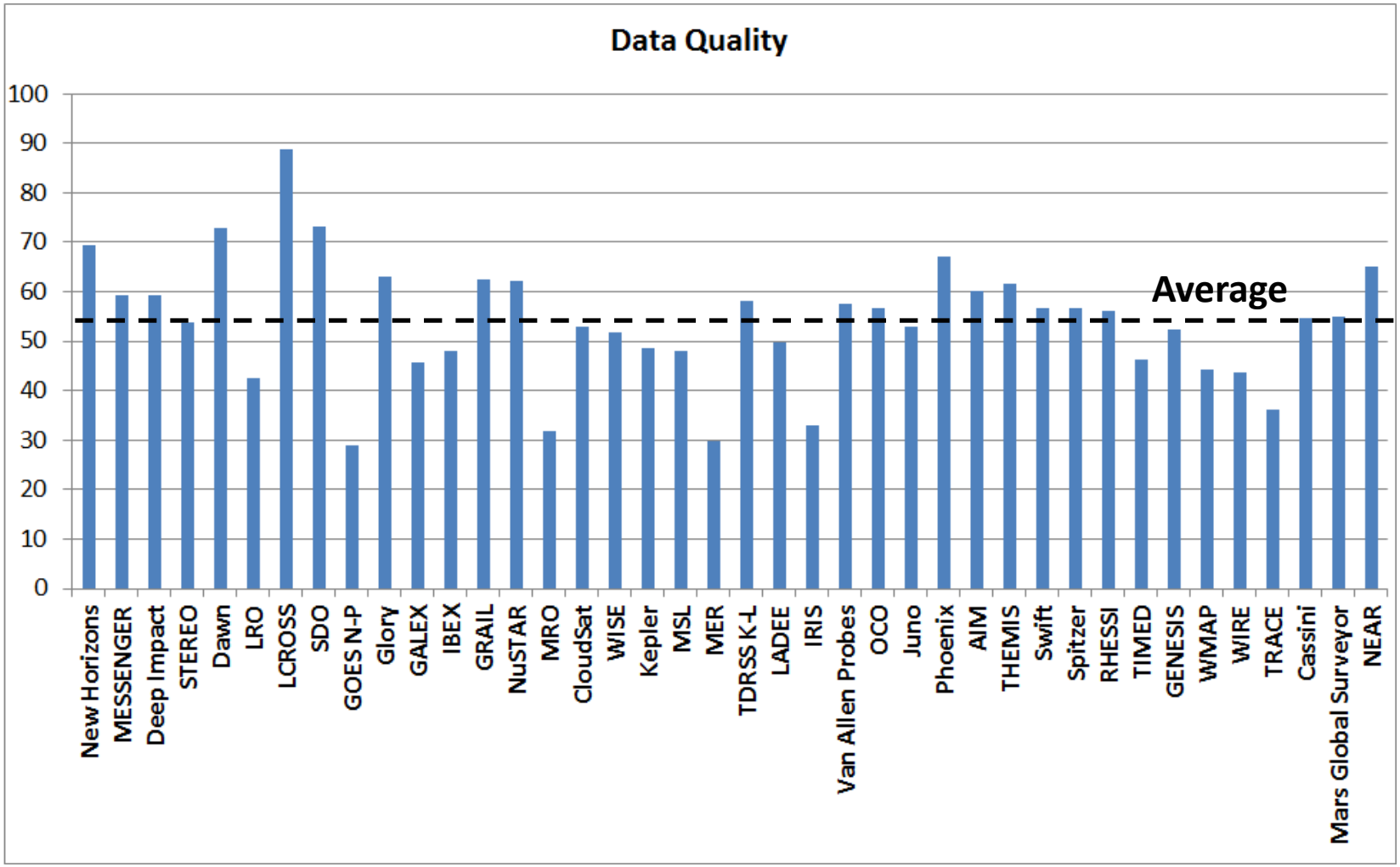
Data Quality Assessment for Data Normalization		Points Total =	69 (Max=100)
	New Horizons	Score	Points
Y=Yes, N=No, E=Estimated			
1 Inflation		100%	8
Costs by WBS Level 1	Y		
Costs by WBS Level 2 (S/C)	Y		
Costs by WBS Level 3 (S/C)	Y		
Costs by WBS Level 2 (Pyld)	Y		
Costs by WBS Level 3 (Pyld)	Y		
2 Allocations to NASA WBS		82%	23
Project WBS maps to NASA Lvl1	Y		
Project WBS maps to NASA Lvl2 (S/C)	E		
ProjWBS maps to NASA Lvl3 (S/C)	Y		
ProjWBS maps to NASA Lvl2 (Pyld)	E		
ProjWBS maps to NASA Lvl3 (Pyld)	Y		
3 Fees/Burdens		25%	5
Fees/Burdens Applicable	Y		
Fees Easily Separable	N		
Fee Data Available	E		
Burdens Easily Separable	N		
Burden Data Available	E		
4 FCA		n/a	
Civil Service Costs Applicable	N		
Civil Service Costs Identified	n/a		
CS Costs allocated by WBS	n/a		
5 Contributions		n/a	
Contributions Included	N		
Value Available by WBS	n/a		
6 NRC/RC Split		50%	11
NRC/RC Split Provided	N		
Monthly Costs by WBS Provided	N		
Schedule Detail Provided	Y		
Long Lead Items Identified	Y		
7 Multiple Units		n/a	
Number of S/C	1		
Costs per Unit Tracked	n/a		
Defined Multiple Unit Build/Test Plan	n/a		
8 External Impacts		100%	22
External Impacts Applicable	Y		
External Impacts < $10M?	Y		
Defined & Reviewed Set Available	Y		

NORMALIZATION DATA QUALITY SCORE SUMMARY



- **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

CADRe Data Normalization
Data Quality FOM –Results



CADRe Data Normalization FOM: Spacecraft Heritage

New Horizons

Spacecraft Heritage Rating

(blue = inputs)	S/S Heritage Rating 0-10	MASS-BASED HERITAGE ASSESSMENT *Mass Allocations from MEL details (kg)* TRL < 7	New	Major Mod	Minor Mod	Exact Copy	Total	Mass-based S/S Rating	IMPLEMENTATION APPROACH HERITAGE ASSESSMENT Same Provider? (Y/N/P)	Similar App? (Y/N)	Yrs Since Last Use < 5 yrs	< 10 yrs	Approach Adj	Implementation Notes	FY2014 RC (RC uses Ouput D)
Structure Subsystem	2.8	0.0	95.4	63.5	0.0	22.9	181.7	2.8	Y	Y	Y	Y	100%	Mods for RTG & 3rd stage	9,550
Thermal Control	7.0	0.0	13.4	0.0	25.8	27.6	66.8	7.0	Y	Y	Y	Y	100%		1,274
Electrical Power & Distr	4.6	0.0	36.8	0.0	27.6	58.8	123.2	6.6	N	Y	Y	Y	70%	RTG-powered	79,115
Attitude Deter & Control	8.1	0.0	0.0	1.7	8.1	9.7	19.6	8.1	Y	Y	Y	Y	100%		6,692
Reaction Control	6.4	0.0	5.7	0.0	22.4	106.6	134.6	9.1	N	Y	Y	Y	70%	Boeing custom 3rd stage	27,800
RF/Communication	7.0	0.0	2.7	0.0	31.0	5.4	39.0	7.0	Y	Y	Y	Y	100%		10,303
Command & Data	8.6	0.0	1.1	0.0	10.6	17.2	28.9	8.6	Y	Y	Y	Y	100%		20,781
Overall S/C Heritage Scor *(RC-adjusted combined rating)*	**5.7**	**0.0**	**155.1**	**65.2**	**125.4**	**248.2**	**593.9**	**7.0**					**81%**	CONTOUR-derived APL s/c	**155,516**

SLOC Summary	Re-Used	Re-Eng	New	Total
Flight Software				0

Rating Key:
- *0 = all items @ TRL< 7*
- *1 = New, but standard practice*
- *3 = Major Modification*
- *7 = Minor Modification*
- *10 = Exact Repeat (copy)*

- **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?*

CADRe Data Normalization
Spacecraft Heritage FOM Example

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.

Overall Score weights s/s ratings based on RC

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

Dawn

Spacecraft Heritage Rating

(blue = inputs)	S/S Heritage Rating 0-10	MASS-BASED HERITAGE ASSESSMENT — *Mass Allocations from MEL details (kg)* TRL < 7	New	Major Mod	Minor Mod	Exact Repeat	Total	Mass-based S/S Rating	IMPLEMENTATION APPROACH HERITAGE ASSESSMENT (Yes/No/ Partial (Y/N/P)) Same Provider?	Similar App?	Yrs Since Last Use (Y/N) < 5 yrs	< 10 yrs	Approach Adj	Implementation Notes	FY2014 RC
Structure Subsystem	3.1	0.0	14.8	88.9	29.0	0.0	132.7	3.6	Y	P	Y	Y	85%	OSC heritage EO s/c; 1st OSC deep space msn	6,782
Thermal Control Subsystem	1.5	0.0	38.5	0.0	5.4	0.0	44.0	1.7	Y	P	Y	Y	85%	OSC heritage EO s/c; 1st OSC deep space msn	3,467
Electrical Power and Distr Group	3.5	0.0	85.4	21.2	183.6	0.0	290.1	4.9	Y	N	Y	Y	70%	OSC heritage EO s/c; 1st OSC deep space msn; HighV bus	26,107
Attitude Deter & Control S/S	5.6	0.0	0.0	0.0	24.1	12.4	36.5	8.0	Y	N	Y	Y	70%	OSC heritage EO s/c; 1st OSC deep space msn	9,811
Reaction Control	2.5	0.0	30.1	84.5	2.7	31.6	149.0	4.2	P	N	Y	Y	60%	EP w/ JPL/OSC (vs JPL/SA on DS1)	25,577
CC&DH Group															
RF/Communication	7.1	0.0	0.0	0.0	14.7	11.6	26.3	8.3	P	Y	Y	Y	85%	JPL/OSC tcm s/s; 1st OSC deep space msn	8,590
C&DH Subsystem	4.9	0.0	0.0	0.0	21.0	0.0	21.0	7.0	Y	N	Y	Y	70%	OSC heritage EO s/c; 1st OSC deep space msn	9,002
Overall S/C Heritage Score *(RC-adjusted combined rating)*	**3.8**	**0.0**	**168.9**	**194.6**	**280.5**	**55.6**	**699.5**	**5.4**					**70%**	OSC LEOStar-2 w/ JPL SEP	**89,33(**

(EO = Earth orbiting)

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

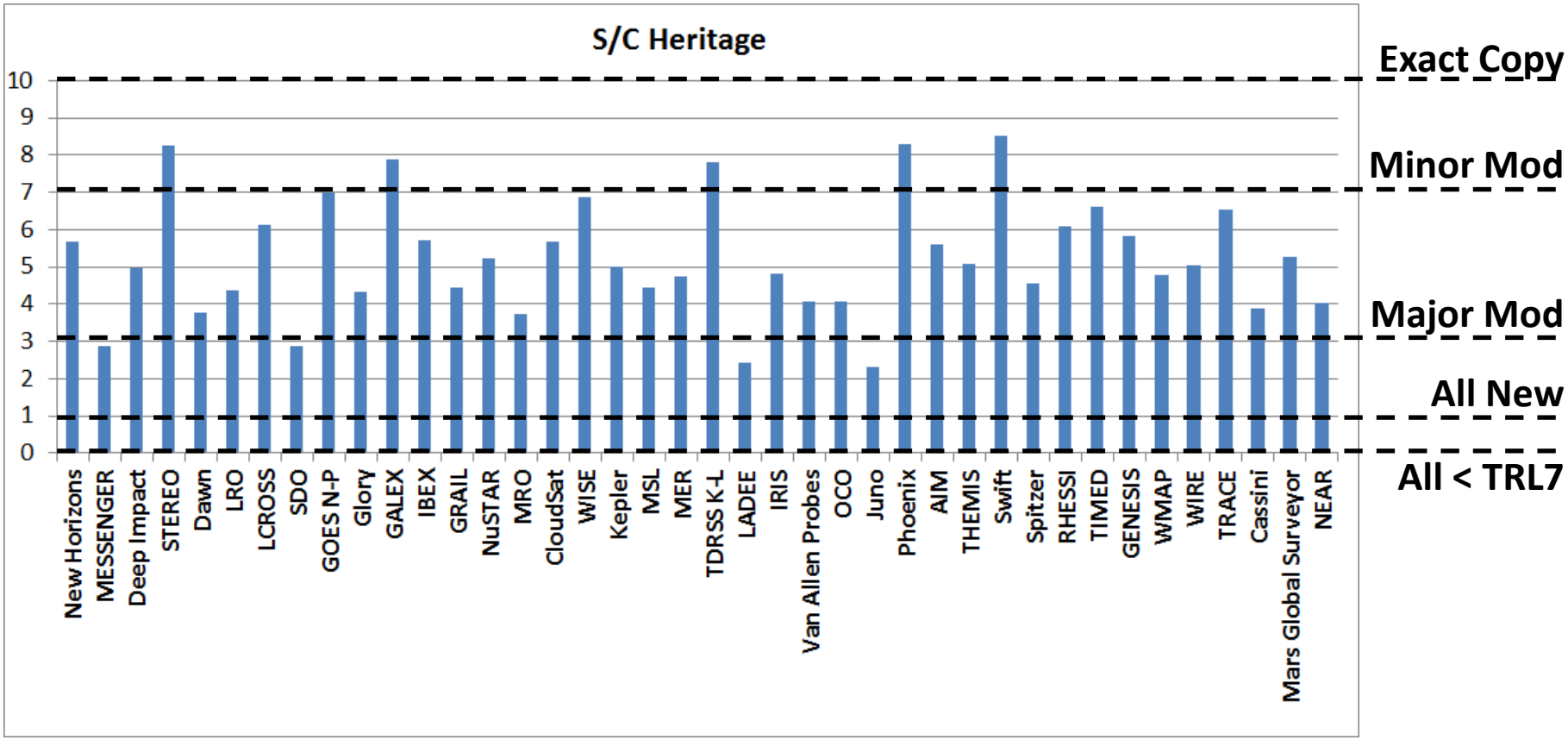
SLOC Summary	Re-Used	Re-Eng	New	Total	
Flight Software	58,700	7,600	16,700	**83,000**	Heritage from OSC LEOStar-2 (*CSR*)
	71%	*9%*	*20%*		

Rating Key:
- *0 = all items @ TRL< 7*
- *1 = New, but standard practice*
- *3 = Major Modification*
- *7 = Minor Modification*
- *10 = Exact Repeat (copy)*

Implementation Adj Assumptions (% reduction)			
Provider	App	< 5 yrs	< 10 yrs
30%	30%	20%	20%

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



CADRe Data Normalization FOM: Prototypes & Spares

New Horizons

Prototypes and Spares Rating

(blue = inputs)	Prototype Rating 0-10	Spare Rating 0-10	PROTO/SPARE QUANTITY ASSESSMENT – *PROTOTYPES*				*SPARES*				PROTOTYPE USAGE ASSESSMENT						
			Protos by Mass, kg	Proto% of Prod$	Equiv # of Protos	S/S Rating	Spares by Mass, kg	Spare% of Prod$	Equiv # of Spares	S/S Rating	Retrofit for flight	Extended life test	Serve as test surrogate	Starting TRL<5	Use for Grnd Test/Sim	Proto Usage Adj	Notes
Structure Subsystem	0.0	0.0	0.0	0%	0.0	0.0	0.0	0%	0.0	0.0	N	N	N	N	Y	90%	
Thermal Control	0.0	0.0	0.0	0%	0.0	0.0	0.0	0%	0.0	0.0	N	N	N	N	Y	90%	
Electrical Power & Distr	0.2	0.6	27.6	6%	0.3	0.2	27.6	17%	0.3	0.6	N	N	Y	N	Y	113%	Proto SRU (capacitors)
Attitude Deter & Control	0.0	0.0	0.3	0%	0.3	0.0	0.3	1%	0.3	0.0	N	N	Y	N	Y	113%	
Reaction Control	0.0	0.0	0.0	0%	0.0	0.0	0.0	0%	0.0	0.0	N	N	N	N	Y	90%	
RF/Communication	0.0	0.7	0.0	0%	0.0	0.0	7.9	15%	0.4	0.7	N	N	Y	N	Y	113%	Spare USO, SSPA
Command & Data	7.7	0.1	39.4	34%	2.0	6.8	1.6	4%	0.2	0.1	N	N	Y	N	Y	113%	Proto IEM
Overall Proto/Spares Score *(Prod$-adjusted combined rating)*	**1.1**	**0.3**	67.2	7%	0.4	1.0	37.3	10%	0.2	0.3						113%	

Rating Key:
- *0 = No Protos/Spares*
- *1 = Minimal Protos/Spares*
- *3 = Moderate Protos/Spares*
- *7 = Significant Protos/Spares*
- *10 = Full Flight Proto/Spare*

- **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

CADRe Data Normalization
FOM: Parts Quality & Redundancy

New Horizons

Parts Quality/Type and Redundancy Rating

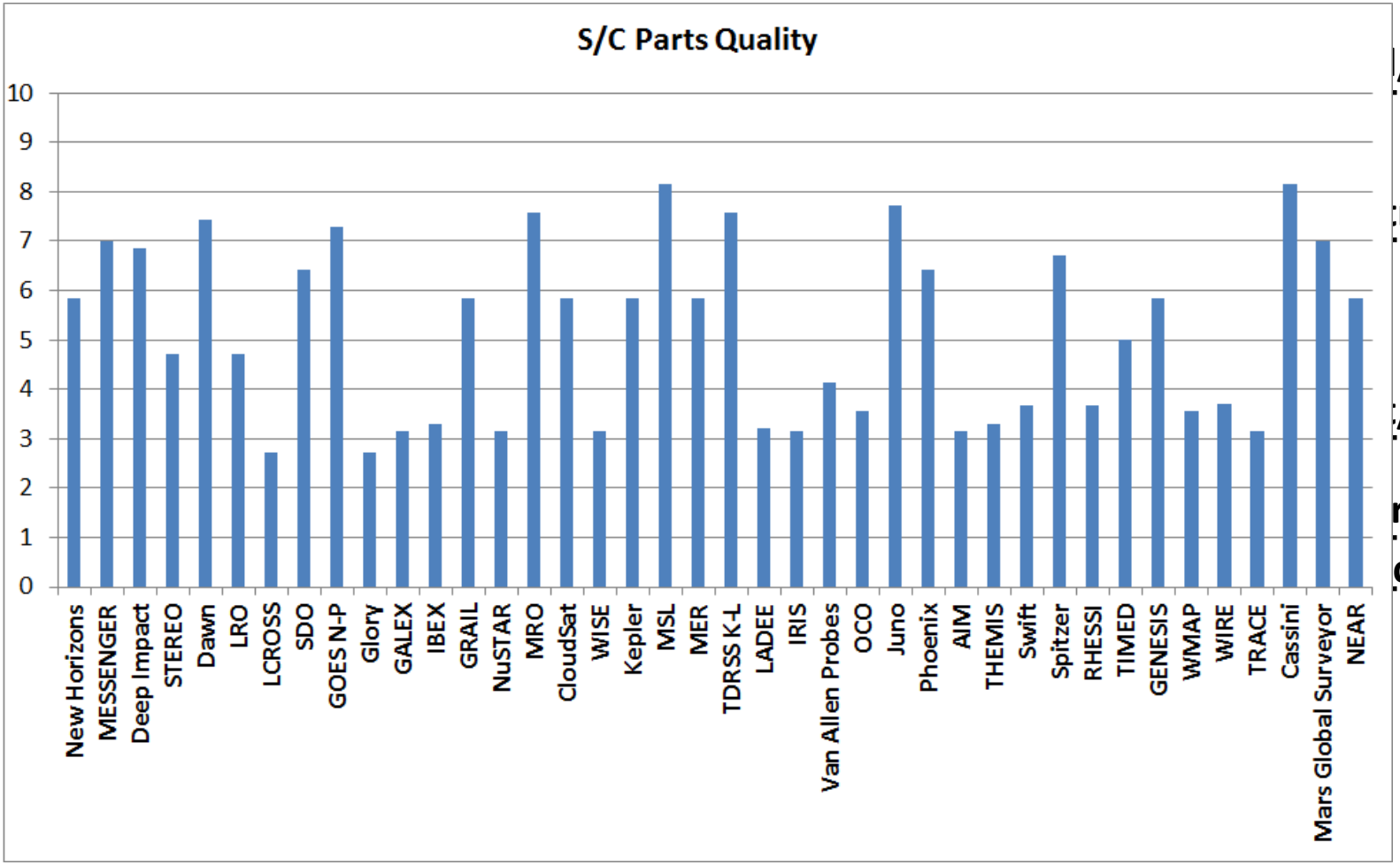
(blue = inputs)	*PARTS QUALITY/TYPE*							*REDUNDANCY*			
	% Flagship Class	% Disc/Mars Expl	% Explorer Class	% <Explorer Class	% < Space Qual	Type (for str/thm/rcs)	**Parts Rating**	% Redundant	% Replication	**Redund Rating**	Notes
Structure Subsystem						Al/Al-hnycmb	3.0				
Thermal Control						Passive/MLI+htrs+Rad	7.0				
Electrical Power & Distr	0%	100%	0%	0%	0%		7.0	0%	10%	0.1	No Redund/Battery, RTG-pwrd
Attitude Deter & Control	0%	100%	0%	0%	0%		7.0	41%	10%	3.8	Redund Star Tracker
Reaction Control						3-axis/Mono	3.0	27%	20%	2.6	Redund Thrusters, Valves, Cmn misc
RF/Communication	0%	100%	0%	0%	0%		7.0	43%	5%	3.9	Redund USO, SSPA, LGA, misc
Command & Data	0%	100%	0%	0%	0%		7.0	100%	15%	9.2	Redund IEMs, Cmn Board-lvl devices
Overall Score	0%	100%	0%	0%	0%		5.9	42%	12%	3.9	

PARTS QUALITY/TYPE Rating Key:
- *0 = Not Space Quality/Al or SS, No THM/RCS*
- *1= Lower Quality/Al, Passive-MLI, Spinner-Mono*
- *3 = Med Quality/Al-honeycomb, Passive-MLI+htrs, 3-axis-Mono*
- *7 = Higher Quality/Composite, Passive-MLI+htrs+Rad, 3-axis-Biprop*
- *10 = Highest Quality/Adv Mat'ls/RCS, Active-Cryo*

REDUNDANCY Rating Key:
- *0 = No Redund/Common Parts*
- *1 = Select/Min Redund/CmnPrts*
- *3 = Moderate Redund/CmnPrts*
- *7 = Significant Redund/CmnPrts*
- *10 = Full Redund/Sign 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

CADRe Data Normalization
S/C Parts Quality FOM –Results



l/Adv Mat'ls

truct/Biprop

t/Monoprop

rop/Spinner

ce Qualified

CADRe Data Normalization
Next Steps

- **Continue expanding the data set with new projects**
  - Prioritize incorporating new projects as launch CADRe's are completed
  - Go back to older projects as time allows, focusing on candidates with good data
- **Implement enhancements/fixes to the process with user feedback**
  - New data may allow enhancements to some data points (particularly those with a low Data Quality FOM score)
  - Minor errors might be identified by the user community
  - A process to collect this feedback needs to be established (similar to RFAs)
- **Refine approaches used for Figure-of-Merit (FOM) analyses**
  - 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**
  - Currently in use supporting development of a PM/SE/MA/I&T model