Improved Cost and Technical Data Collection for Government Contractors

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Abstract

Audience feedback during the 2017 ICEAA Workshop "Lessons Learned in Leveraging Historical Cost, Schedule and Technical Data" suggested applying standardized CARD (Cost Analysis Requirements Description) structure to the presented data collection process. This paper provides lessons learned from adopting this enhanced approach to a large scale program. The authors show how contractors can leverage government standard process to improve their internal data collection and gain new insights on cost trends beyond model calibration.

Introduction

Contractors increasingly have the same motivation as our government customers to collect, analyze and apply historical program data that justifies proposals, budgets and trade study costs. However, even OEM (Original Equipment Manufacturers) Contractors have limited views of all the costs associated with their own past programs due to increased outsourcing to second and third tier suppliers as well as GFE content. During the 2017 ICEAA conference one of our government customers (Ranae Woods of AFCAA) suggested data collection can be improved by using the standardized CARD (Cost Analysis Requirements Description) structure. This paper looks at the current contractor data collection process and evaluates the benefits of using the CARD data collection structure to better capture program information used for internal cost analysis and to better understand the government customer position for cost and risk.

Typical OEM Data Collection for cost modeling and analysis

In our 2017 presentation "Lessons Learned in Leveraging Historical Cost, Schedule and Technical Data" we presented a data collection sheet that, while capturing much of the essence of the CARD, focused primarily on programmatic and system/subsystem level data for structural, electronic, and system attributes that drive costs.

For each WBS element/ subsystem, we captured key attributes of each subsystem that can be used to create Cost Estimating Relationships (CERs) and calibrate complex commercial cost models. These attributes included system descriptions, part numbers, supplier information (name, agreements delivery schedule, cost improvement (learning) curves for assemblies or parts), parts per assembly weight, volume, design location, percent new design, # drawings/3D models, development schedules, development tooling, and TRL/MRL (Technical Readiness/Manufacturing Readiness) levels at program initiation. For each WBS, we also captured planned or operational production information including production schedules, projected new program quantities, prior (or similar) production quantities, planned or actual production schedules, automation, and projected learning curves for labor and materials.

Our approach for data collection emulated the parametric cost worksheets often used for calibrating commercial parametric models. Data was categorized into General, Development, Production, Supplemental, Contact Info and other notes for each Structural, Electronic, Software and System level data types. The following embedded worksheet provides an example.

Microsoft Excel
97-2003 Worksheet

While this approach generally provides the information needed to calibrate the parametric models, additional information that may be useful for future analysis is suggested by the CARD.

Cost Analysis Requirements Description (CARD)

According to the Defense Acquisition University (DAU), the Cost Analysis Requirements Description (CARD) contains "…a description of the salient features of the acquisition program and of the system itself. It is the common description of the technical and programmatic features of the program". The government cost teams use this information to prepare Life Cycle Cost Estimates (LCCE), Component Cost Estimates (CCE), and Independent Cost Estimates (ICE) for ACAT "I" and "1A" programs

We found that the CARD data, while there is some overlap with our current process, adds significant additional information that would also be useful to the contractor developing estimates of their own systems. Sikorsky has emulated some of the CARD methodology by initiating development of "BlueBooks" for several programs including MH-60S, S-76®, S-92®, and UH/MH-60M.

The CARD used by government teams is based on the Defense Acquisition Guidebook. The following embedded Word document is a blank version of a CARD.

Microsoft Word 97
- 2003 Document

Key Elements of the CARD, most relevant to our discussion of cost analysis, CER development and model calibration, include the following:

- System Overview – this section provides high level view of overall system including:
    - System Characterization – System description, diagrams, functional relationships, a WBS table to identify configurations of equipment (both hardware and software), Government Furnished Equipment (GFE)
    - System Characteristics – Performance, technical descriptions, physical design parameters, software description, human performance, safety, survivability (see below for examples)
    - Subsystem Descriptions and characteristics - describes the major equipment (hardware/software) WBS components of the system including Subsystem overview, performance parameters and characteristics, technical and physical description, standard or commercial parts, manufacturing, commonality, software elements
    - Quality – Reliability, Maintainability, Availability, Portability
    - Security - Physical, information, and operations security descriptions
    - Predecessor/derivative systems - similarity to other systems, prior problems, commonality with replaced system as well as any analogous systems
- Risks – Technology, TRL, MRL, test, funding, related external projects from program, manager assessment and external technology programs
- Logistics /Support Concepts - force structure elements associated with the operation, basing and deployment plans, deployment method, maintenance and repair levels, hardware support

concept, Repair versus Replacement, Standard Support Equipment, software upgrade plans, location of system stocks and the methods of resupply, training Plans
- Quantities – matrix of systems developed, tested, produced, and deployed by year. This information may also include a count development or production items of other systems that are similar or common to the design under consideration.
- Acquisition Plan – type of contracts, suppliers and schedules to system or subsystem considered. This plan should be understood from both the customer and OEM supplier perspectives.
- Development Plan – DEM/VAL and EMD plans, schedules, testing during development, number, type, location, and expected duration of hardware and software tests, responsible organizations for test and operational test plans
- Facilities – type and number of hardware and software test and production facilities, type and number of hardware and software facilities for deployment, operation and support, and common facilities to other programs
- Changes – tracks changes in design, schedule and program direction (objectives)
- Program Reporting requirements – induces CCDR plans (e.g. 1921 reports)

Note that there is significant overlap on both OEM and government approaches – but the differences may add value to either OEM or government data collection efforts.

Below are examples of Key System and Subsystem Characteristics and Performance Parameters that are captured in the CARD. These "technical" parameters may provide insight to the cost drivers when analyzed against various cost metrics including development and unit cost.

Aircraft: Airframe Unit Weight (AUW); breakdown of AUW by material type; empty weight; structure weight; length; wingspan; wing area; wing loading; combat weight; maximum gross weight; payload weight; internal fuel capacity; useful load; maximum speed (knots at sea level (SL)/maximum altitude); combat ceiling; combat speed; wetted area. Note that for other systems like helicopters, UAVs, etc. There could be other information that might be useful including number of rotor blades, type of vertical lift and primary technologies (e.g. Single Main Rotor, Tilt Rotor, X2, pusher prop), etc.

Engines: Maximum thrust at sea level; specific fuel consumption; dry weight; turbine inlet temperature (degrees Rankine) at maximum value and maximum continuous value; maximum airflow.

Missiles: Weight, length, width, height, type propulsion, payload, range, sensor characteristics (e.g., millimeter wavelength(s) for MMW sensors).

Ships: Length overall (LOA) (ft); maximum beam (ft); displacement (full) (T); draft (full load) (ft) [Note appendages, such as sonar dome]; propulsion type (nuclear, gas turbine, conventional steam, etc.); number of screws; shaft horsepower (SHP) (HP); lift capacity (troops, vehicles, (KSqFt), cargo (KCuFt), bulk fuel, (K Gal), LCAC, AAAV, VTOL L/L and VTOL M/S).

Tanks and Trucks: Weight, length, width, height, engine horsepower, and payload (i.e., ammunition loads and tonnage ratings).

Data Automation/ADPE (Automatic Data Processing Equipment): Type (mainframe, mini, micro); processor (MIPS, MPLOPS, MOPS, SPECMARKS); memory (size in megabytes); architecture (monolithic, distributed).

Electronic Systems

Electronic systems naturally require a view of different characteristics and attributes from structures to best represent the drivers of development, production and support costs. The CARD outlines many of the Electronics Characteristics and Performance Parameters that at are used to estimate costs in CERs and commercial cost models.

Examples of Key Electronics Characteristics and Performance Parameters that are captured in the CARD

TYPE SYSTEM	PERFORMANCE MEASURES	TECHNOLOGY	OTHER
Radar	Output Power	MIMIC	Phased Array
	Range	TWT	Type Scan
	Resolution	VHSIC	Reliability
	Classification Capable	Stealth	Waveform
	Frequency	SOS, etc	Quantity
	Number Phase	Software	
	Shifters		
	Number of Elements		
Communications	Frequency	MIMIC	Tactical/Strategic
	Power	Antenna Type	Secure
	Number Channels	SOS, etc.	ANTI-Jam
	Interoperability	Stealth	User Community
	LPI	Software	Data/Voice
	Range/LOS/NLOS		
Satellite	Quantity	Size/Weight	Purpose
	Orbit	Launch Vehicle	Coverage
	Number of Users	Processors	Design Life
	Power	Bus	
	Waveform	Software	
EW	Classification Capable	MIMIC/TWT	Purpose
	Active/Passive	On/Off Board	Expendable
	Automatic/Manual	VHSIC	Installation
	Programmable	Integration	Platforms
	Power/Frequency	Stealth	
		Packaging	
		Software	

Predecessor data

In addition to the specific system to be estimated, it's important to understand predecessor or "similar to" systems that may be the foundation for the new or modified design. Many CERs and commercial cost models account for benefits of prior work impacting factors including percent new design, experience of design team, prior production quantity (learning), design and production commonality across programs, and reliability, maintainability and logistics support. Often OEMs will have the detail level information and understanding of "commonality" (by weight or by drawing) that the government would not normally receive in their CDRL program reports received from the contractor. OEM/

contractors should ensure they include this information in their own data collection efforts that may extend beyond CARD guidance.

At minimum, the following characteristics can/should be captured for Predecessor or Reference Systems depending on scope of work for the new system estimate:

Examples of Predecessor or Reference System to Proposed System contained in CARD data

- System Designation and Name
- Manpower Requirements
  - Flight Crew Composition
- Performance
  - Speed (max)
  - Speed (sustained)
  - Range
  - Payload
- Configuration
  - Key technologies (lifting mechanisms, materials by subsystem
  - Weight (Airframe Unit)
  - Weight (empty)
  - Weight (gross)
  - Dimensions
  - Height
  - Weight
  - Length
- Acquisition
  - Unit Cost (Prototype/100th Prod. Unit)
  - Number of Systems
    - Acquire(d)
    - Deploy(ed)
  - Operating Concept
  - No. of Equipped Deployable Units (sqd/companies)
  - Average No. Systems/Unit
  - Operating Hours or Miles/Year/System
- Maintenance Concept
  - Interim Contractor Support
  - Contractor Logistics Support
  - In-House Support
  - Number of Maintenance Levels
- Performance Goals
  - Operational Ready Rate (%)
  - System Reliability (Mean Time Between Failures)
  - Maintenance Manhours Per Flying/Operating Hour/Miles
  - Major Overhaul Point (flying hrs/oper hrs/m/miles)

Note: The elements under each category should be expanded, deleted, or revised to capture the level of detail needed. For example, a WBS level breakdown might be appropriate if specific subsystems are new or modified on larger systems. Aircraft level data may be sufficient in other cases.

Most contractors/OEMs do not drill to this level of detail in collecting data on past programs since their focus has been primarily to develop estimates for development, recurring costs and sometimes portions of sustainment costs. Also the government teams have access to a broader set of data across contractors for similar programs and technologies. However, there may be a great opportunity to emulate the OEM in the government customer position to better understand the impacts of design requirements on cost and to calibrate past program cost models to these cost driving parameters.

NASA's Cost Analysis Data Requirement (CADRe)

The DoD CARD is one example. Another collection process and template example is NASA's CADRe. Here the reporting requirements are met by one document in three separate Parts: A, B & C, as defined by NASA's NPR 7120.5E "Space Flight Program and Project Management Requirements" standard. The goal is to allow NASA estimators visibility to cost/schedule/technical/programmatic data, collected in a consistent and quality-enforced manner, for defendable estimating of current and future missions. This three Part document is completed for each milestone (System Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Systems Integration Review (SIR), Launch and End of Mission (EOM)) per Figure 1 below, from the NASA Cost Estimating Handbook:

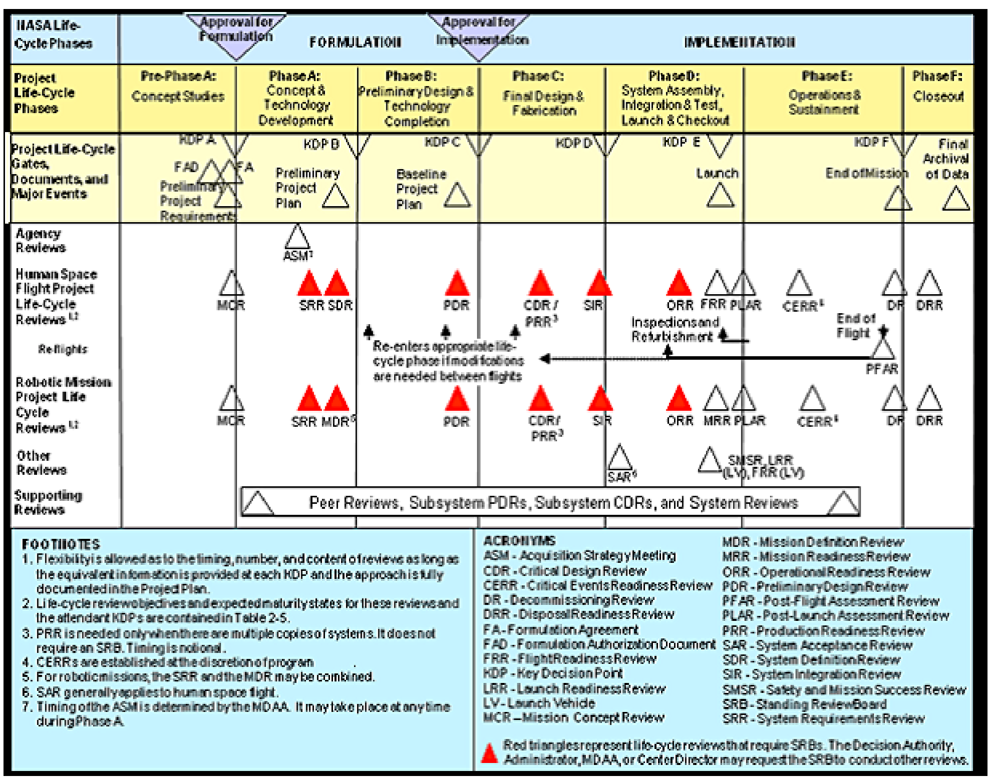

Figure 1: NASA Life Cycle Phases and Milestones

To date, NASA has collected over 150 completed CADRes, hosted on their ONCE database portal. The first section, Part A, captures programmatics and narrative descriptions of significant changes that have occurred, per Figure 2 below again from the NASA Handbook.

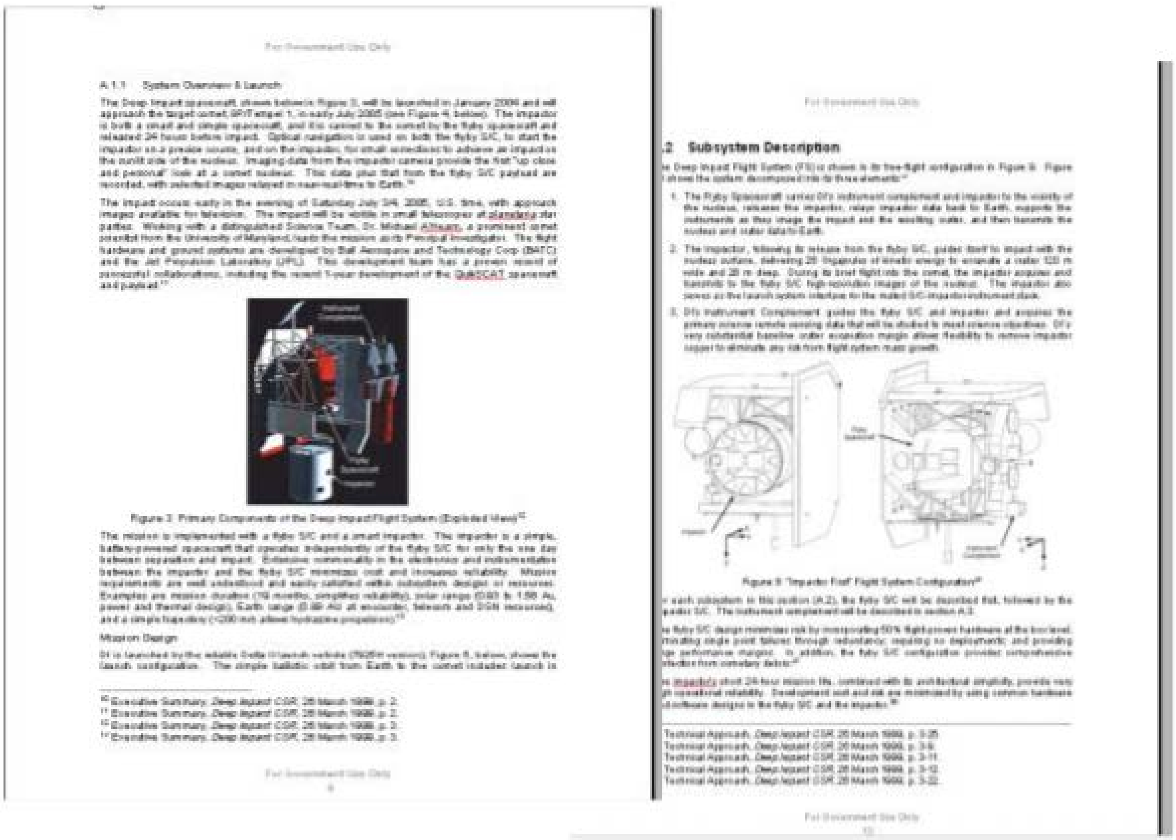
A.1.1 System Overview & Launch

Figure 3: Primary Components of the Deep Impact Flight System (Exploded View)

2 Subsystem Description

Figure 2: CADRe Part A Example – Narrative Project Description

The second section, Part B, follows an Excel template and describes technical parameters at spacecraft-bus and payload-instrument component levels, typically WBS-2 level. Parameters for consideration as cost-drivers can include mass (weight), power, data rates and software metrics. The NASA Handbooks shows this Excel-based template example in Figure 3 below:

Figure 3: CADRe Part B Example – Key Technical Parameters

The third section, Part C, also follows an Excel template and describes both project estimated and actual costs, to a WBS-2 or lower level. Part C also collects associated project schedule, risks and GR&A. The NASA Handbooks shows this Excel-based template example in Figure 4 below:

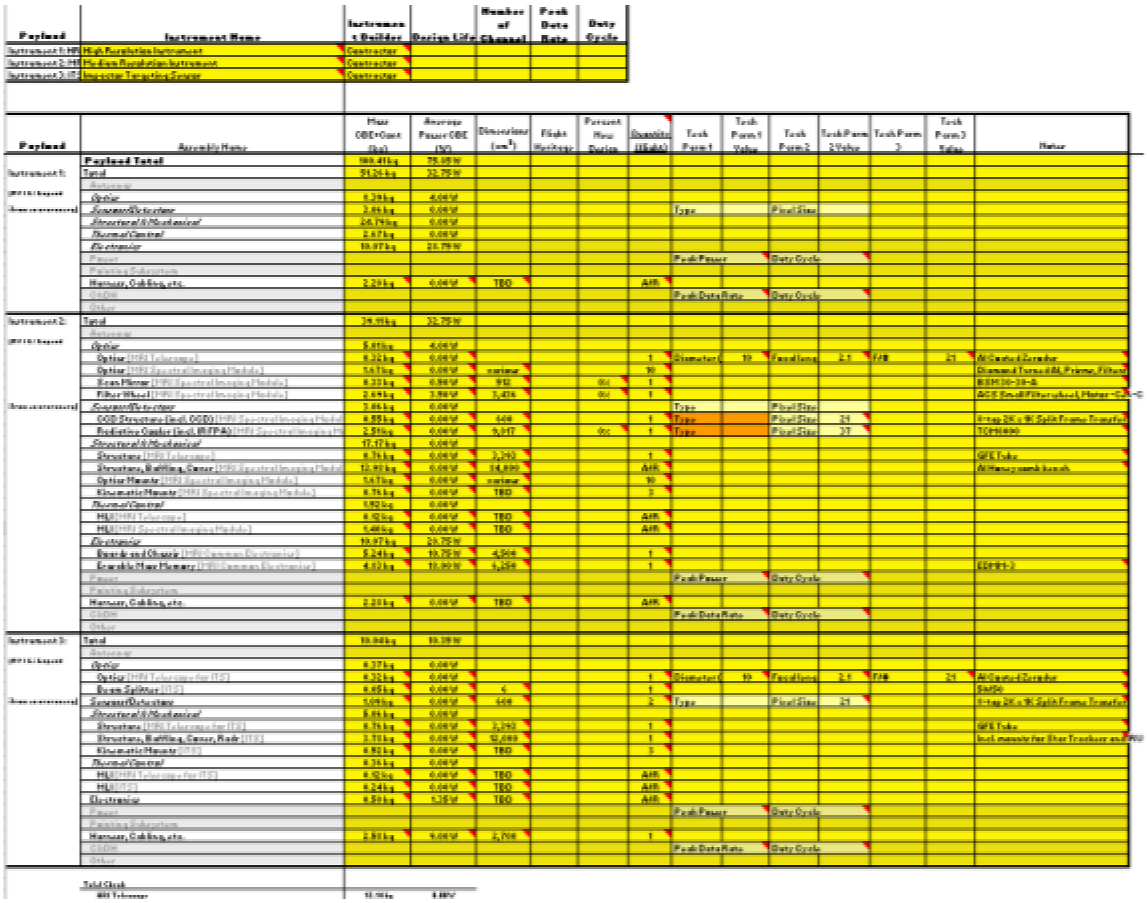

Figure 4: CADRe Part C Example – Estimated and Actual Costs

NASA's 3-Part CADRe document is offered here as an example, with customer-defined templates providing common structure based on "existing documents" so that no unique new documentation beyond NASA's standard project planning and reporting documentation is required.

Comparison of CARD to OEM data collection – Benefits of additional CARD data for OEM cost analysis

The following table provides some insight into the differences between OEM and Government data collection. While the objective of both groups is to develop a good preliminary estimate of proposed system costs, the focus and access to data for each group are somewhat different. For example, OEMs have access to many of the engineers that provide insight into why costs for some data elements are what they are (e.g. yield rate, level of experience, commonality to other systems, etc.). OEM focus is also primarily on the costs that they can control. As noted earlier, government teams have access to a broad set of similar programs not available to OEMs, but do not typically have data at levels below 4th level WBS that may better provide details that may better describe cost drivers in a system or subsystem.

From the perspective of the OEM, collecting and analyzing some of the characteristics that the government team requires in the CARD may provide a better understanding of government needs to meet higher level budget considerations. This effort may also provide OEM program teams with tools to better align cost and performance to government objectives increasing probability of proposal win.

General Information

The following provides a comparison between our current OEM data collection and those outlined in the CARD. This comparison may help the user to understand the differences in focus.

	In OEM	In CARD	Comments
WBS Number	Yes	Yes	OEMs may map parts to WBS
WBS Name/Description	Yes	Yes	
Alternate Name of System or Subsystem	Yes	Yes	
Part Number(s)	Yes	No	OEMs can evaluate part level costs not reported to government
Physical/Functional Description (brief descrip)	Sometimes	Yes at WBS level	Describes in general the purpose and technologies used for the part or system
If Purch - Supplier name	Yes	Yes	For subsystem – not in CARD or OEM summaries at part level.
Number of units per aircraft/assembly	Yes	No	Count of lower level parts (like rotor blades) per assembly is needed for cost evaluation and cost improvement curves
Names of Interfacing Units	Yes	Yes	For govt at system level only. OEMs may capture each level of integration
Weight of Unit (Structure)	Yes	Yes	Early design weights are parametric – mature designs are part based.
% Material Type	Yes	Yes	Available from technical mass properties data but not always captured for historical purposes – proposed CSDR report1921-T may help
Volume of Unit	No	No	May be helpful for electronics estimating—can usually be found in technical data. Cabin volume may be useful for high level CERs

WBS Weight (unit weight x # units per Aircraft/ assembly)	Yes	No	WBS weights are mapped by mass properties to the WBS standard – not generally provided to government teams
CAM Name/contact info	Yes	No	
Similar prior uses/ commonality	Not typically	Yes	Description at high level

Similarly, one can compare OEM and CARD elements useful for CER and cost model calibrations for various product types. Generally the OEM and CARD/CADRe align for data availability for each team.

Technical Information – by product type

Aircraft	In OEM	In CARD	Comments
Airframe unit weight (AUW)	Yes	Yes	
Breakdown of AUW by material type	Yes	Yes	
Empty weight	Yes	Yes	
Structure weight	Yes	Yes	
Common Weight or Drawing Count to prior program/product	Yes	No	Better understanding for cost impact on design and production
Length	Yes	Yes	
Wingspan	Yes	Yes	
Wing area	Yes	Yes	
Wing loading	Yes	Yes	
Combat weight	Yes	Yes	
Maximum gross weight	Yes	Yes	
Payload weight	Yes	Yes	
Internal fuel capacity	Yes	Yes	
Useful load	Yes	Yes	
Maximum speed (knots at sea level (SL)/maximum altitude)	Yes	Yes	
Combat ceiling	Yes	Yes	
Combat speed	Yes	Yes	
Wetted area.	Yes	Yes	

Engines	Yes	Yes	
Maximum thrust at sea level	Yes	Yes	
Specific fuel consumption;	Yes	Yes	
Dry weight	Yes	Yes	
Turbine inlet temperature (degrees Rankine) at maximum value and maximum continuous value	Yes	Yes	
Maximum airflow	Yes	Yes	

Other system attributes for various systems may useful when evaluating parameters driving cost. Below are some product types and their key attributes:

Missiles: Weight, Length, Width, Height, type propulsion, Payload, Range, Sensor characteristics (e.g. millimeter wavelength(s) for MMW sensors).

Ships: Length overall (LOA) (ft); Maximum beam (ft); Displacement (full) (T); Draft (full load) (ft) [Note appendages, such as sonar dome]; Propulsion type (nuclear, gas turbine, conventional steam, etc.); Number of screws; shaft horsepower (SHP) (HP); Lift capacity (troops, vehicles, (KSqFt), cargo (KCuFt), bulk fuel, (K Gal), LCAC, AAAV, VTOL L/L and VTOL M/S)

Tanks and Trucks: Weight: Length; Width; Height; Engine horsepower; Payload (i.e., ammunition loads and tonnage ratings)

Software: Size, functional requirements, Product requirements, Application, Operating Environment, etc.

Conclusion

Whether aligning with DoD's CARD or NASA's CADRe (or both), the OEM has an opportunity to codify a structured data collection methodology that also solves for reporting compliance. It would stand to reason that redundant effort is eliminated if an OEM's data collection/mapping is designed up-front to satisfy both internal and external requirements. Again, the value of standardized data collection is multi-fold. The OEMs have an opportunity to utilize the CARDs multi-dimensional views of programmatic, cost and technical data to standardize their cost analysis and modelling/calibration studies across comparable past projects.

There is government/industry support for the broader view that adds CARD/CADRe information to the OEM data set. It's clear from recent participation in government/ OEM Aviation Cost IPT meetings that new information (typically held by contractors) is being requested for new programs. These new reports using electronic "FlexFiles" and containing new data from 1921-T, Q, R and other reports provide additional detail as suggested in this paper.