Technomics
Better Decisions Faster

A New Approach When Cost/Capability Trades Matter Most

ICEAA Professional Development & Training Workshop

May 14 – 17, 2019

Outline

- Background
- What Happens Pre-Milestone A in Acquisition and How Does it Impact Cost?
- Framing the Life Cycle Cost Estimate (LCCE)
- Data
- Analysis
- Ground Wheeled Vehicle Cost Model
- Summary and Conclusion

Background

- The current acquisition environment is not working effectively
- Work is performed linearly instead of concurrently and does not take advantage of modern tools and computing resources
- OSD recognized this and created a “Community of Interest” they called Engineered Resilient Systems (ERS) with the mission of solving the problem that “Acquisition is driven by a linear, process-heavy engineering environment”
- OSD gave the responsibility for this mission to the United States Army Corps of Engineers (USACE)
- USACE built a collection of tools and models (referred to as the toolset and composed of a mobility model, transportability model, design model, producibility model, software design model, etc.)
- The toolset lacked a critical capability -- cost estimating. This presentation describes our effort to develop a ground wheeled vehicle life cycle cost model that uses the design model outputs as direct inputs into estimating equations.

Ground Vehicles

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What Happens Pre-Milestone A in Acquisition and How Does it Impact Cost?

- The acquisition process starts with a validated “capability requirement” contained in a document usually called an Initial Capabilities Document (ICD)
- The ICD describes what the ultimate end user of a new system desires in performance terms (e.g. how fast, how survivable, how mobile, etc.)
- At this early stage (Pre-Milestone A) of a program the total LCC of the initial requirements is rarely estimated and therefore not considered.
- The entry point into the acquisition process for all defense acquisition products is the Materiel Development Decision (MDD). This marks the start of pre-MS A activities to analyze alternative solutions.
- There is no formal requirement for cost estimates Pre-MS A.
- The time between the MDD and MS A is when the USACE tools and models will provide a significant benefit to the acquisition framework—especially with the addition of a life cycle cost model

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Framing the LCCE (Cost Element Structure)

In addition to general DoD Guidance, the US Army Cost Manual prescribes the cost element structure (CES) for preparing the LCCE.

The five parent CES elements below each have ~ dozen standard CES child elements, as shown with Procurement as an example.

- CES 1.0 Research, Development, Test and Evaluation
- CES 2.0 Procurement →
  - CES 2.01 Non-recurring production
  - CES 2.02 Recurring production
  - CES 2.03 Engineering changes
  - CES 2.04 Systems engineering/program management
  - CES 2.05 System test and evaluation, production
  - CES 2.06 Training
  - CES 2.07 Data
  - CES 2.08 Support equipment
  - CES 2.09 Operational/site activation
  - CES 2.10 Fielding
  - CES 2.11 Training ammunition/missiles
  - CES 2.12 War reserve ammunition/missiles
  - CES 2.13 Modifications
  - CES 2.14 Other procurement
- CES 3.0 Military Construction
- CES 4.0 Military Personnel
- CES 5.0 Operations and Maintenance

Framing the LCCE (Vehicle WBS)

MIL-STD-881 prescribes the WBS for weapon commodities, including Surface Vehicles (ref. Appendix G)

Provides a standard organization for management, data reporting, and cost estimating
(primary vehicle hardware/software elements shown, support elements not shown)

- Primary Vehicle Integration, Assembly, Test and Checkout
- Hull/Frame/Body/Cab
- System Survivability
- Turret Assembly
- Suspension/Steering
- Vehicle Electronics
- Power Package/Drive Train
- Auxiliary Automotive
- Fire Control
- Armament
- Automatic Ammunition Handling
- Navigation and Remote Piloting
- Special Equipment
- Communications
- Primary Vehicle Software Release 1...n
- Other Vehicle Subsystems 1...n (Specify)

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Data

- The Cost Assessment Data Enterprise (CADE) is an Office of the Secretary of Defense Cost Assessment and Program Evaluation (OSD CAPE) initiative
  - to increase analyst productivity and effectiveness by **collecting, organizing and displaying data** in an integrated single web-based application, improving data quality, reporting compliance and source data transparency.
  - to provide the government analyst with a single, **authoritative** website utilizing data visualization methods to house source data which are easily searchable and retrievable.
  - to offer the analyst a reduction in the time spent on ad-hoc data collection and validation, allowing more time for in-depth, meaningful analysis in support of DoD's mission.

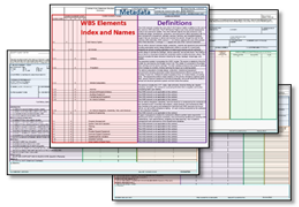
Data

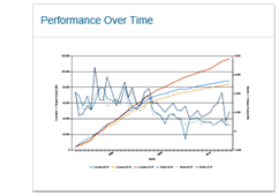
http://cade.osd.mil

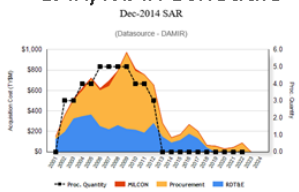
COST ASSESSMENT DATA ENTERPRISE

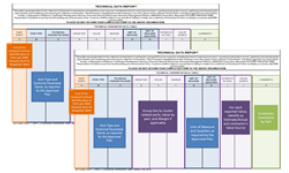
- Actuals: Cost & Technical Data
- Program and Data Situational Awareness
- Analysis-Ready Data Downloads
- Quick-Look Visualizations

Cost	Earned Value (EVM)	Acquisition	Technical	Library
› Analysis-Ready Data Downloads › Profit & Fee Visibility on FFP contracts › Insight into Prime and Subcontractor	› Aligned Cost-EVM allows for time-phased analysis › Early warning signs of program health	› Completes the story of a program lifecycle cost › Program Information › SAR/MAR › Annual Funding › SAR/MAR Schedule	› Only place in the DoD that ties cost & technical data › Software analysis at the CSCI level	› Searchable data for historical reference at your fingertips" – Cost Estimates – Funding Memos – Program Briefings – ICEs, SCPs – Research Studies









CADE is the authoritative data source for estimating & analyzing Major Defense Programs

300+ Programs | 3,000+ CSDR Submissions | 1,000+ EV Submissions

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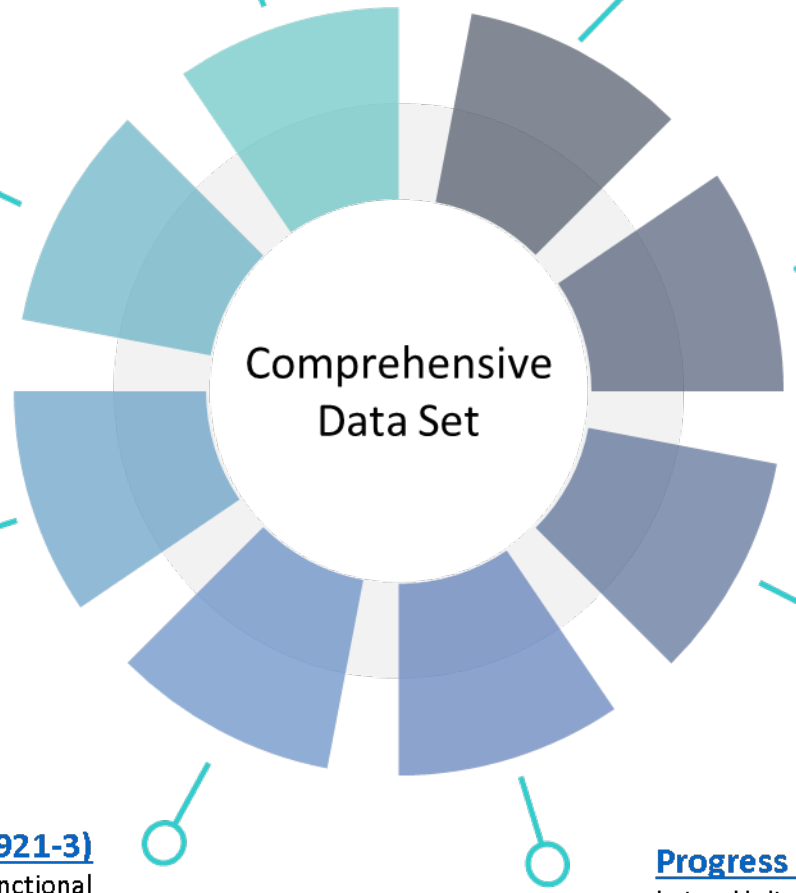
Data (Types of CSDRs)

CSDR Plan (DD 2794)
Defines WBS Structure and Schedule for reporting

Cost Data Summary Report (DD 1921)
Summary cost data for all elements on approved contract CSDR plan

Contract Work Breakdown Structure Dictionary (CWBS)
Lists all contract data reporting elements with definitions of technical, work, and cost content (recurring vs. nonrecurring by functional category)



Functional Cost-Hour Report (DD 1921-1)
Cost and hour data for specific elements broken down by functional category

Software Resource Data Reports (SRDRs)
Size, schedule & effort on data on software development

Sustainment Report (DD 1921-5)
Nonrecurring & recurring costs and hours reported against a sustainment cost element structure & functional categories

Contractor Business Data Report (DD 1921-3)
Direct & Indirect cost, hour & employee data by functional category for a Contractor Business Unit

Progress Curve Report (DD 1921-2)
Lot or Unit reporting of direct recurring costs to date for specific hardware elements

Data

PROPRIETARY

SECURITY CLASSIFICATION

Form Approved
OMB No.
0704-0188

COST DATA SUMMARY REPORT

1a. PROGRAM: STRYKER FAMILY OF VEHICLES		2. DOLLARS IN	3. TYPE ACTION: X CONTRACT NO: DAAE07-00-D-M051 DO #0019; LATEST AMENDMENT: 55	4. APPROPRIATION: RDT&E / X PROCUREMENT	5. REPORT AS OF *(MM/DD/YY)*: 12/31/2005
1b. APPROVED PLAN NUMBER: A-04-B-C1		WHOLE (NOTE 1)	RFP NO: / PROGRAM ESTIMATE	6 MULTI-YEAR CONTRACT: YES / X NO	7. FY FUNDED: 2003
8. CONTRACT TYPE: FR	9. CONTRACT PRICE ESTIMATE: $371,782,081	CONTRACT CEILING: N/A	11a CONTRACTOR TYPE: X PRIME/ASSOCIATE / SUBCONTRACTOR	11b. NAME/ADDRESS *(Include ZIP Code)*: GM GDLS DEFENSE GROUP LLC, JOINT VENTURE, 14920 23 MILE ROAD, SHELBY TOWNSHIP, MI 48315	12. NAME OF CUSTOMER: *(Subcontractor Use Only)*

CONTRACT LINE ITEM A	REPORTING ELEMENTS B	WBS ELEMENT CODE C	TO DATE: NUMBER OF UNITS D	TO DATE: COSTS INCURRED NONRECURRING E	TO DATE: COSTS INCURRED RECURRING F	TO DATE: COSTS INCURRED TOTAL G	AT COMPLETION: NUMBER OF UNITS H	AT COMPLETION: COSTS INCURRED NONRECURRING I	AT COMPLETION: COSTS INCURRED RECURRING J	AT COMPLETION: COSTS INCURRED TOTAL K
N/A	STRYKER LRIP	1.0								
0001	INFANTRY CARRIER VEHICLE (ICV)	1.1								
	HULL/STRUCTURE	1.1.1								
	SUSPENSION/STEERING	1.1.2								
	POWER PACKAGE/DRIVE TRAIN	1.1.3								
	AUXILIARY AUTOMOTIVE	1.1.4								
	TURRET ASSEMBLY	1.1.5								
	FIRE CONTROL	1.1.6								
	ARMAMENT	1.1.7								
	BODY/CAB	1.1.8								
	AUTOMATIC LOADING	1.1.9								
	AUTOMATIC/REMOTE PILOTING	1.1.10								
	NUCLEAR, BIOLOGICAL, CHEMICAL	1.1.11								
	SPECIAL EQUIPMENT	1.1.12								
	NAVIGATION	1.1.13								
	COMMUNICATIONS	1.1.14								
	INTEGRATION, ASSEMBLY, TEST & CHECK	1.1.15								

Data

- We started with the entire inventory of wheeled vehicle program cost reports and evaluated each one for its applicability and utility to this effort.
- CADE houses cost data on 7 wheeled vehicle programs
  - Joint Light Tactical Vehicle (**JLTV**): 40 records development phase, 4 records production phase
  - MRAP All Terrain Vehicle (**MATV**): 24 records production phase
  - Stryker: 254 records production phase
  - Family of Medium Tactical Vehicles (**FMTV**): 30 records production phase
  - Medium Tactical Vehicle Replacement (**MTVR**): 5 records production phase
  - Palletized Loading System (**PLS**): 1 record production phase
  - Heavy Expanded Mobility Tactical Truck (**HEMTT**): 1 record production phase

Data/Systems/Summary Tech Specs

	Crew	Pass	Length (m)	Width (m)	Height (m)	Weight (kg)	Config	Engine (hp)
JLTV	1	1-3	5.2-5.5	2.4	2.2	6,000	4X4	449
MATV	1	4	6.3	2.5	2.7	16,000	4X4	300
Stryker	1-3	0-9	6.9-7.6	2.7-2.9	2.6-2.7	16,500-18,000	8X8	350
LMTV	1	2	6.4	2.4	2.8	6,000-8,000	4X4	275
MTV	1	2	6.9-9.6	2.4	2.8-3.7	9,000-17,000	6X6	330
MTVR	1	2	8.0-9.8	2.5	3.2	13,000-14,000	6X6	425
HEMTT	1	2	8.9-10.8	2.4	2.8-3.7	15,000-23,000	8X8	445
PLS	1	2	11.2-11.3	2.4-2.5	3.3	24,000-25,000	10X10	500-600

We collected technical specifications for each variant for which we have cost data; more detail and more specs in our dataset.

Sources:

- Contractor websites and product brochures
- Program Office documentation (e.g., Cost Analysis Requirements Description (CARD))
- *Janes* reference books

Common to find conflicting information and different measures

- e.g., curb weight, transport weight, unladen weight, gross vehicle weight, laden weight

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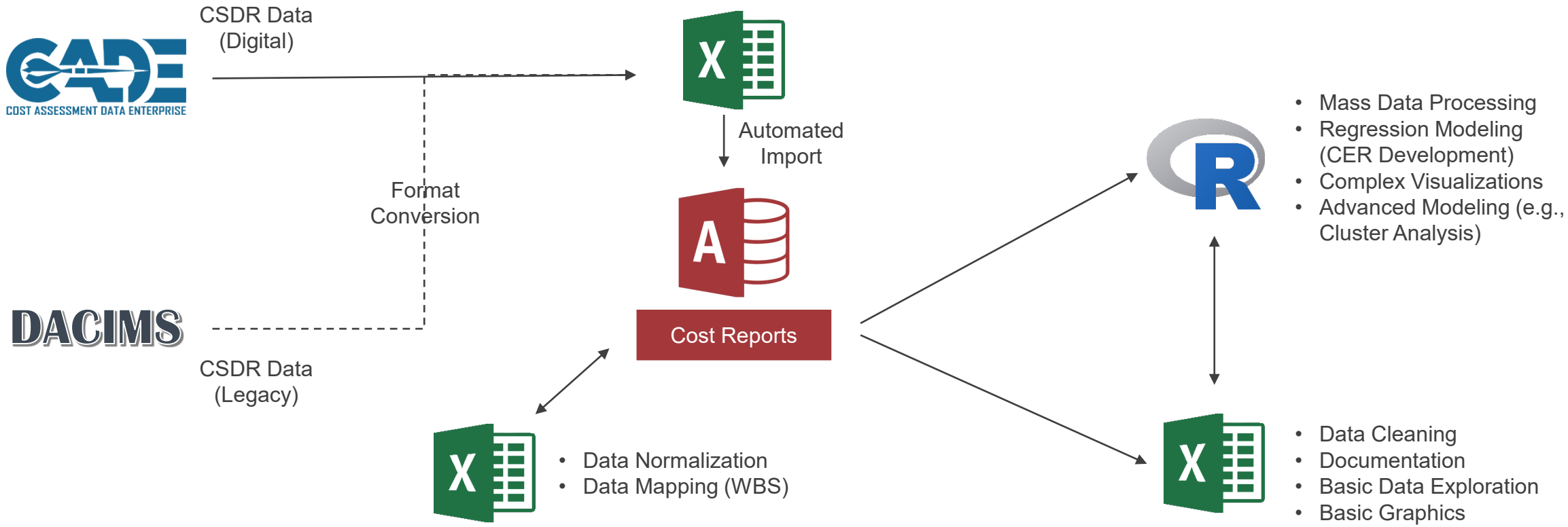
The Data Workflow



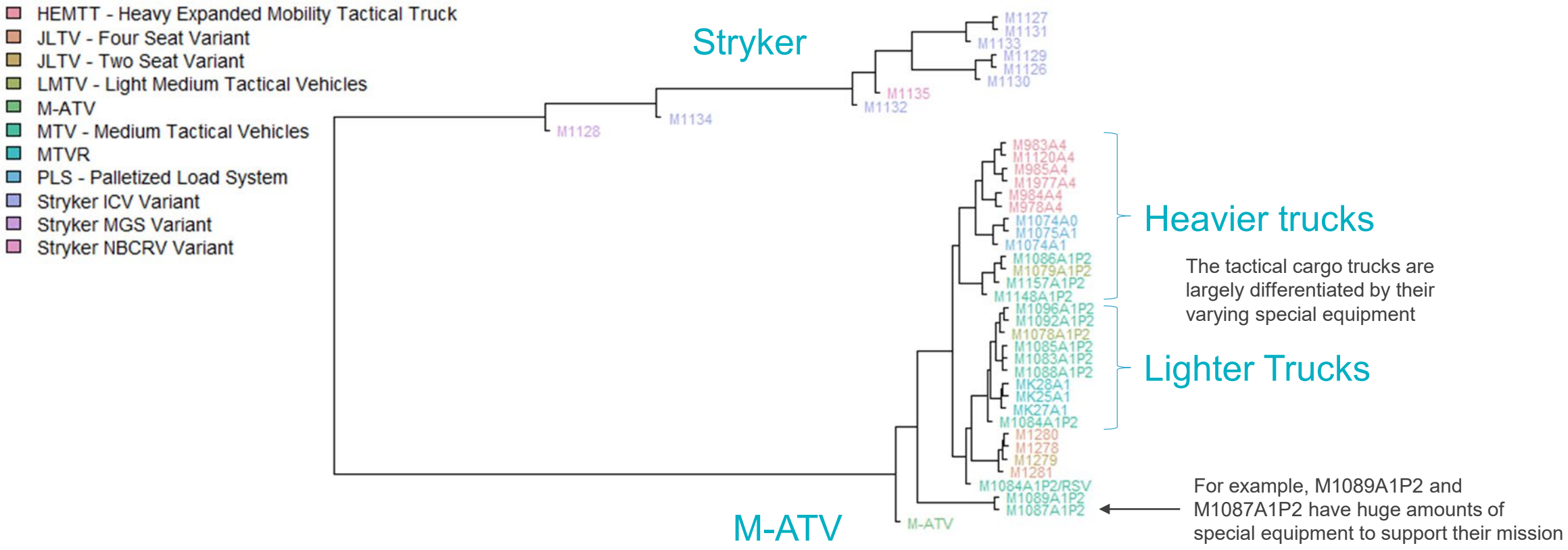
Cost data is exported from the CADE system and loaded into a “mapped and normalized” Access database which feeds data to both R and Excel for analysis

Data Normalizations

- Cost Report data from the CADE system requires careful cleaning before it can be used in a comprehensive model
  - Manually identify which reports to use (e.g., annual data or cumulative data reported annually, scope of report such as manufacturing or support services)
  - Normalize to a common WBS so that programs can be compared to each other
  - Apply surface vehicle escalation indices to compare like-dollars
- Bucketing of costs into WBS items can be subjective
  - Costs get assigned into overall vehicle integration creating “zero cost” items which are really “missing values”
  - For example, Power Package / Drive Train includes only the Engine and Transmission for some programs and items such as transfer case, drive shafts, axle differentials, cooling system, exhaust system for others

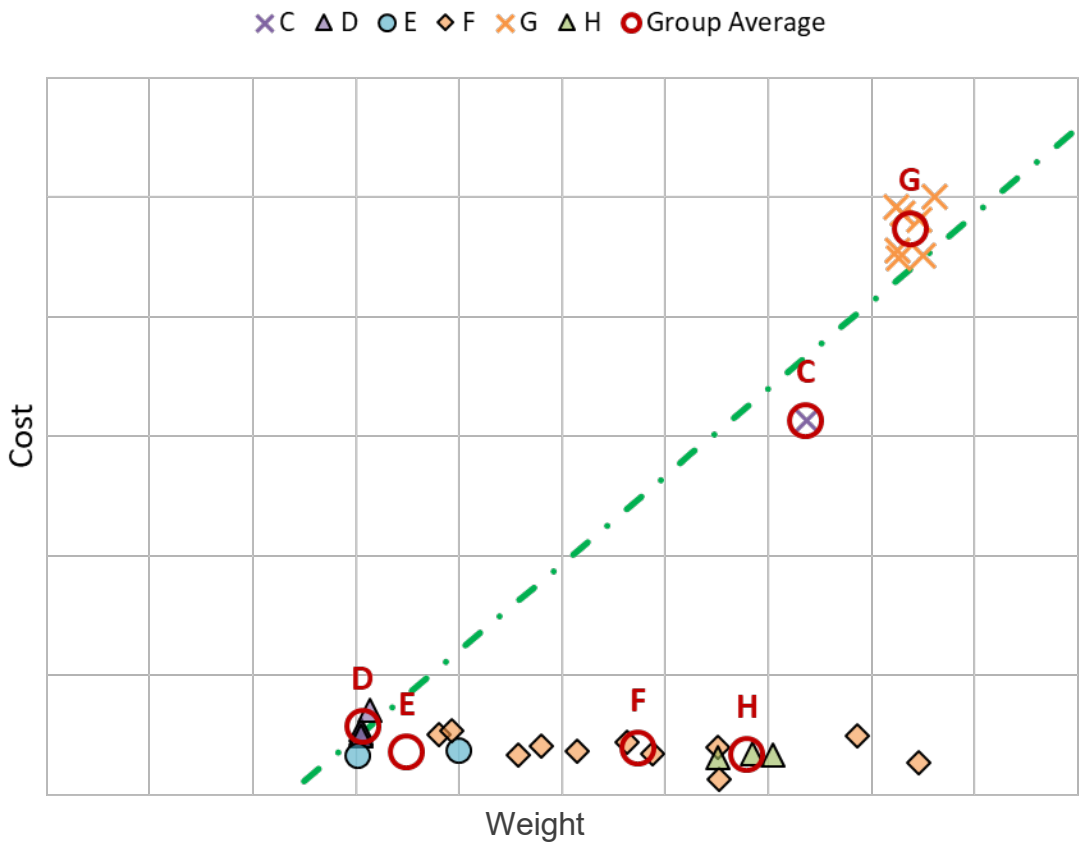
Clustering on Cost Data

- Performed hierarchical clustering on Cost (BY2018 $K) of WBS elements 1.1.1 – 1.1.15

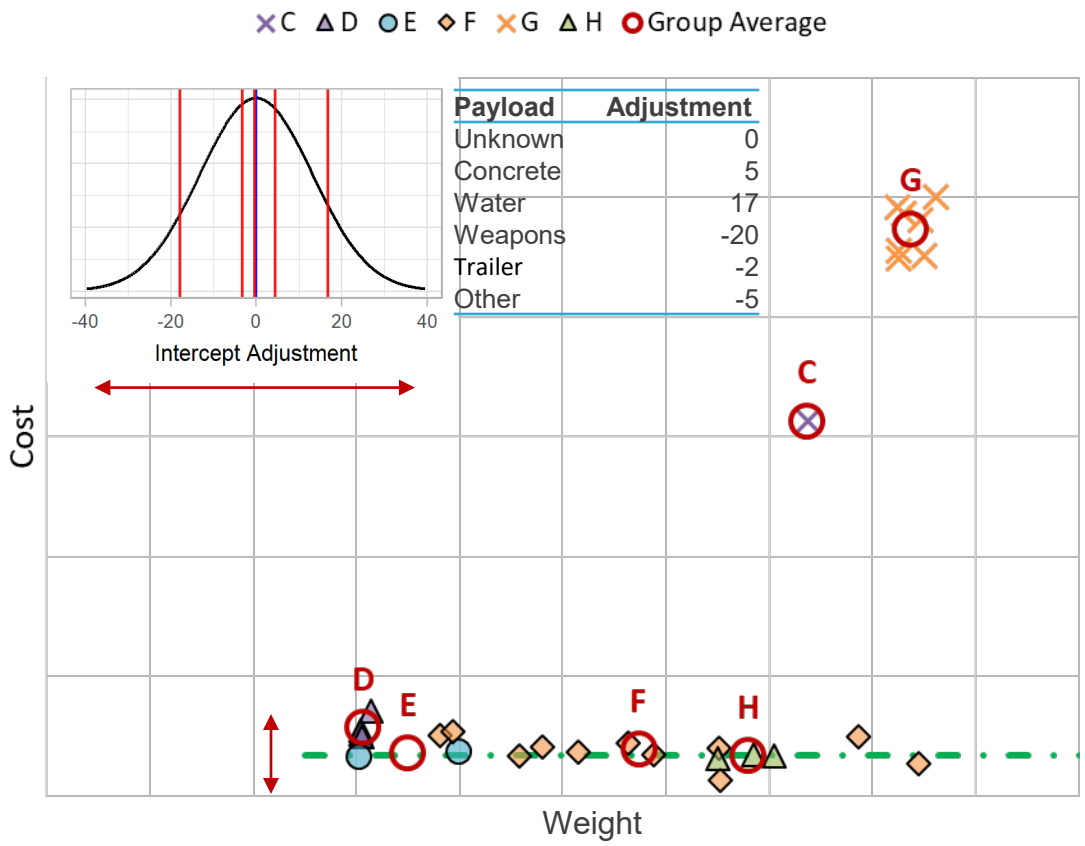


Example CER: Hull/Frame/Body/Cab

Personnel Vehicle Trend

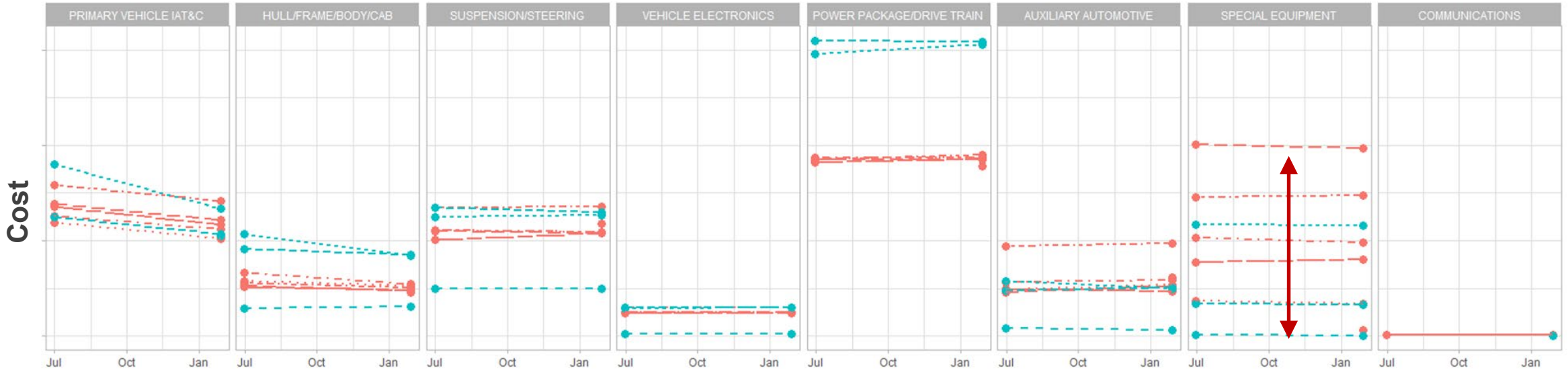


Cargo Trucks Trend



Example: Truck Costs over Time

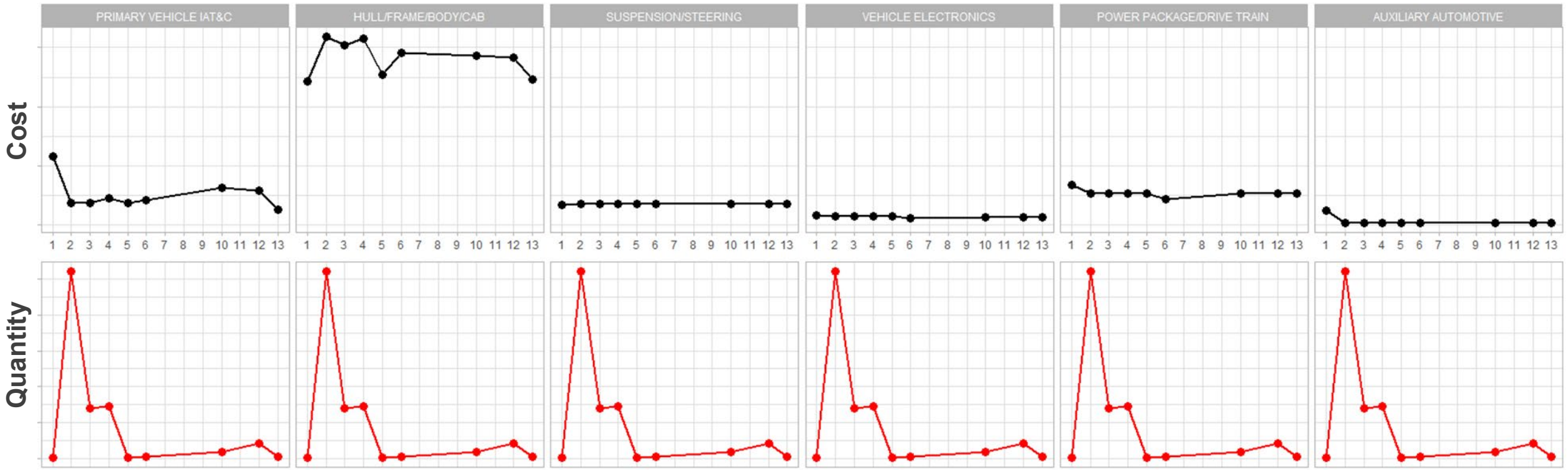
- Program A and B are differentiated by their Power Package / Drive Train
  - There is variation in other cost elements, but it is mixed between the two programs
  - Special Equipment is the largest cost differentiator of total cost



Program A Program B

Example: Costs over Time by Quantity

- Program X costs are consistent over time and do not vary by quantity



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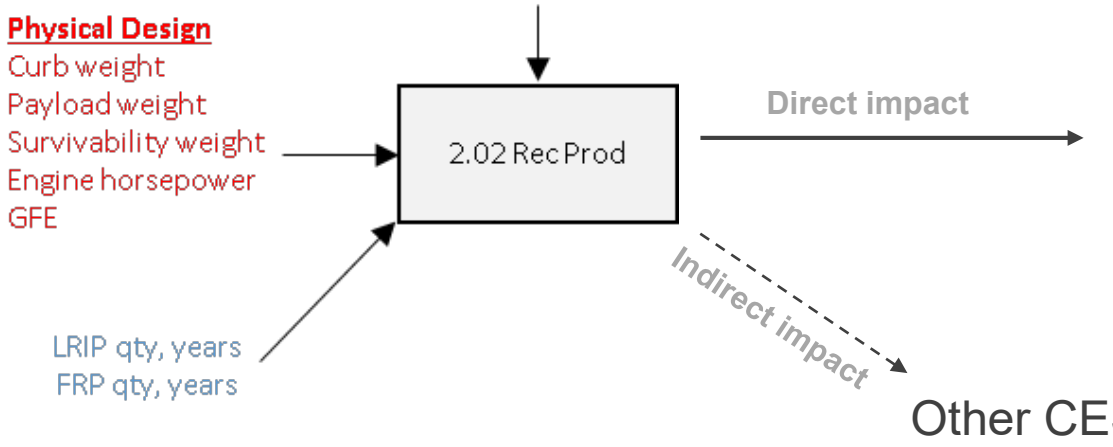
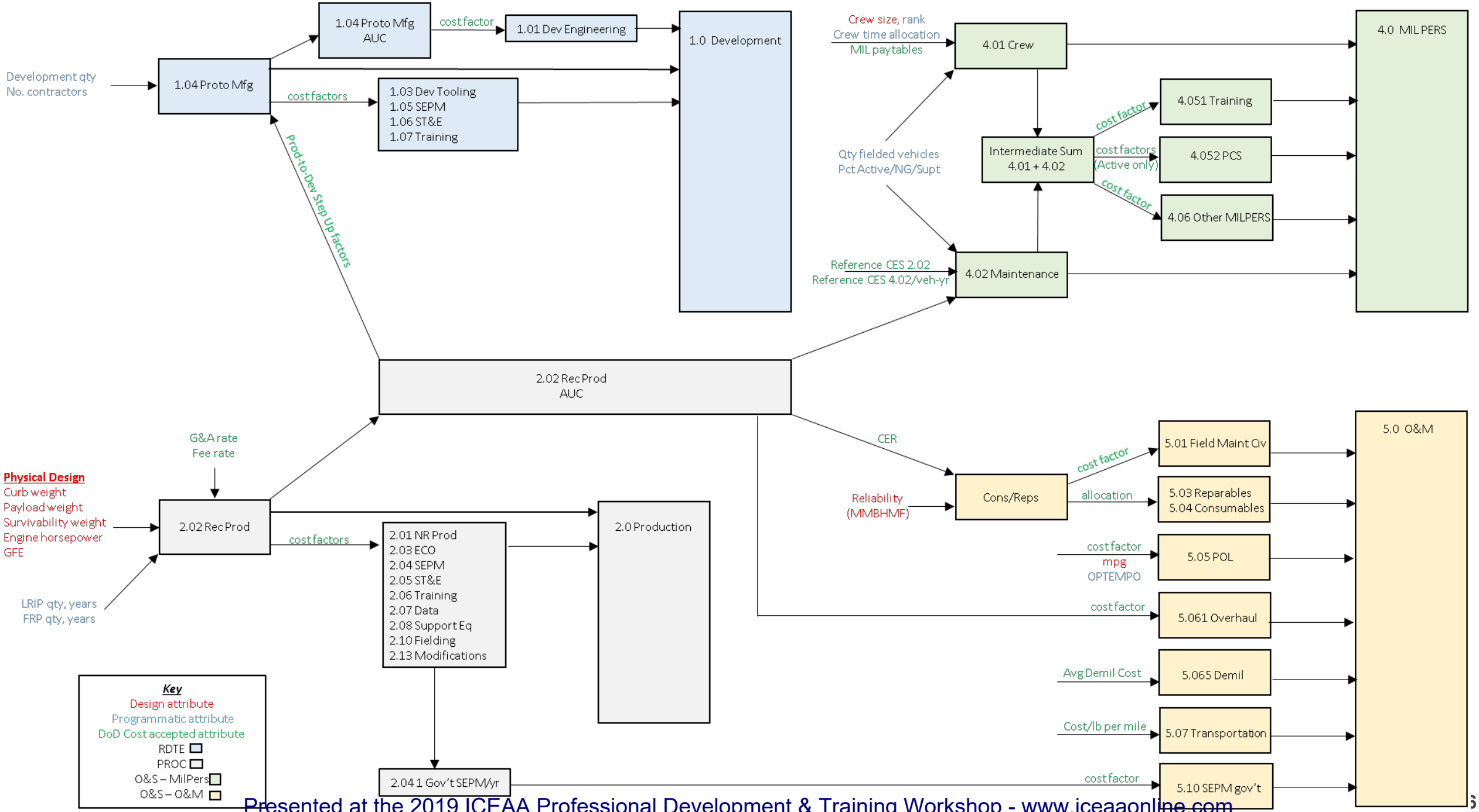
Cost Model Flow Chart

- Vehicle hardware production cost is driven by the vehicle design
- In turn, vehicle production cost is used to drive much of the LCCE



CES 1.04 Prototype Manufacturing
CES 2.XX many production costs
CES 4.02 Maintenance
CES 5.03 Consumables
CES 5.04 Reparables
CES 5.061 Overhaul

Summary, abbreviated view of calculation flow.
Detailed view next slide.


1.04 Proto Mfg AUC
cost factor
1.01 Dev Engineering
1.0 Development
Development qty
No. contractors
1.04 Proto Mfg
cost factors
1.03 Dev Tooling
1.05 SEPM
1.06 ST&E
1.07 Training
Prod-to-Dev Step Up factors
Crew size, rank
Crew time allocation
MIL paytables
4.01 Crew
4.0 MIL PERS
4.051 Training
cost factor
Qty fielded vehicles
Pct Active/NG/Supt
Intermediate Sum
4.01 + 4.02
cost factors
(Active only)
4.052 PCS
cost factor
4.06 Other MILPERS
Reference CES 2.02
Reference CES 4.02/veh-yr
4.02 Maintenance
2.02 Rec Prod
AUC
G&A rate
Fee rate
Physical Design
Curb weight
Payload weight
Survivability weight
Engine horsepower
GFE
2.02 Rec Prod
cost factors
2.01 NR Prod
2.03 ECO
2.04 SEPM
2.05 ST&E
2.06 Training
2.07 Data
2.08 Support Eq
2.10 Fielding
2.13 Modifications
2.0 Production
LRIP qty, years
FRP qty, years
CER
Reliability
(MMBHMF)
Cons/Reps
cost factor
5.01 Field Maint Civ
allocation
5.03 Reparables
5.04 Consumables
5.0 O&M
cost factor
mpg
OPTEMPO
5.05 POL
cost factor
5.061 Overhaul
Avg Demil Cost
5.065 Demil
Cost/lb per mile
5.07 Transportation
cost factor
5.10 SEPM gov't
2.04 1 Gov't SEPM/yr
Key
Design attribute
Programmatic attribute
DoD Cost accepted attribute
RDTE
PROC
O&S – MilPers
O&S – O&M

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Summary and Conclusions

- We achieved the overriding objective of developing a set of cost estimating relationships (CER's) driven by explanatory variable input values generated by the design model in the USACE toolset.
- We then utilized various techniques to develop a parametric life cycle cost model that generates life cycle costs for any ground wheeled vehicle concept developed from capability requirements.
- Our model enables cost/capability trades much earlier (Pre-MS A) in the acquisition framework.
- Life cycle costs are introduced at a point where they can have the greatest impact on program success.