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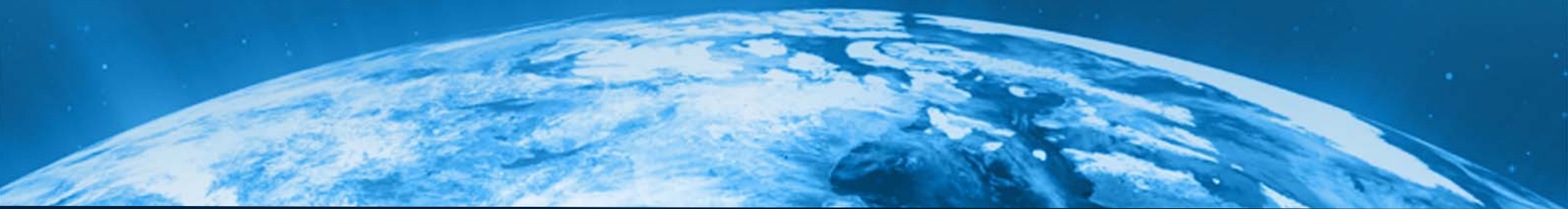
# FACT Enters the DoD Acquisition Process: *Amphibious Combat Vehicle Feasibility Study*

30 October 2013

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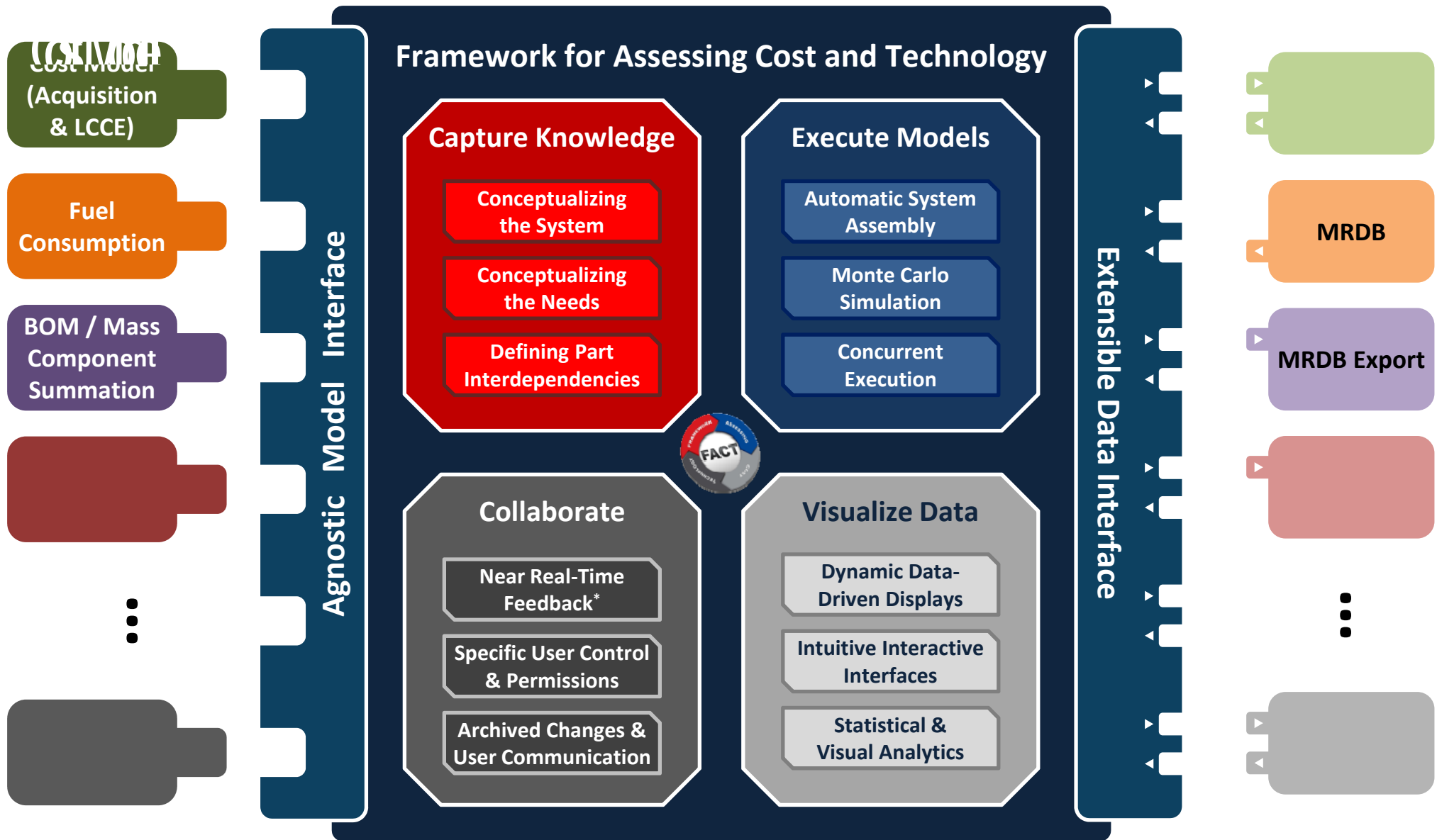
**“I don't foresee a grand slam on the first pitch where we're going to deliver a fixed capability for the life of the vehicle. We've got to be knowledgeable enough to recognize the environments change, threats change, new technology starts to come to pass, and we want to make sure this design will allow for that growth in the future.”**

**Dr. John Burrow, Executive Director, Marine Corps Systems Command & Director, USMC ACV Team**  
Interview with *Inside the Navy*, 25 March 2013

## Problem Statement

Using data provided by the ACV Team for a list of components, explore the design trade space for feasibility of an Amphibious Combat Vehicle while considering cost and capability requirements.

# FACT-ACV Capability Overview



\* Requires integrated models to be executable in near real-time

## Market Research Database (MRDB)

- Excel workbook listing available components
- Captures component SHWAP and BOM cost
- Incorporated into FACT by matching WBS and creating component in database for each entry

## Life Cycle Cost Estimate (LCCE)

- Provides estimate of Acquisition Cost based on BOM cost and competitive split
- Provides LCCE
- Logic converted from Excel to Python via automated script / code generator

## Fuel Consumption

- Estimates First Mission Day and Land Operations Required Fuel based on vehicle gross mass, op tempo and mission attributes
- Logic converted from Excel to Python
- Used to do single iteration on Gross Vehicle Weight based on fuel load to meet fuel required
- Automated fuel map query to remove human-in-the-loop from estimating fuel consumption

# Upgrades to FACT to Support ACV Team



- Capture part dependencies
  - Requires, Incompatible, Add-If relationships*
  - Front-end interface for managing rule set
  - Back-end logic to enforce rule set

**Part dependencies for [2.01.02.01-3] Option 3**

**Parts**

Filter:

- [2.01.02] Land Suspension System
  - [2.01.02.01] Track System
  - [2.01.02.02] Hydropneumatic Suspe
  - [2.01.02.03] Road Wheels
  - [2.01.02.04] Sprocket Carriers
  - [2.01.02.05] Support Rollers
  - [2.01.02.06] Track Tensioning System
  - [2.01.02.08] DEPRECATED
  - [2.01.02.07] Other Land Suspension
- [2.01.03] Hydrodynamic Appendages
  - [2.01.03.01] Bow System
    - [2.01.03.01.01] Structure Weldm
    - [2.01.03.01.02] Actuators
    - [2.01.03.01.03] Other Bow System
  - [2.01.03.02] Chine System
    - [2.01.03.02.01] Structure Weldm
    - [2.01.03.02.02] Actuators
    - [2.01.03.02.03] Other Chine Sys
  - [2.01.03.03] Transom System

**Options**

- [2.01.02.04-0] Option 0
- [2.01.02.04-1] Option 1
- [2.01.02.04-2] Option 2
- [2.01.02.04-3] Option 3
- [2.01.02.04-4] Option 4
- [2.01.02.04-5] Option 5
- [2.01.02.04-6] Option 6

Drag items from this list to the rules on the right. Drop on an existing group to add to the group or at the bottom to create a new group.

**Requires** Goes With Incompatible Add If

If you add [2.01.02.01-3] Option 3 to the vehicle, then you must add the part(s) below.

- [2.01.02.04-2] Option 2
- or
- [2.01.02.04-6] Option 6
- and

Drag here to create a new group.

# Upgrades to FACT to Support ACV Team



- Improved Monte Carlo run management capabilities
  - Provide list of parts to consider in study
  - Track status of Monte Carlo runs
  - Export data into CSV or generate static plots

The screenshot shows the FACT: DOE Manager interface. At the top, there is a navigation bar with tabs: System Manager, Requirements, QFD, SysML, Point Solution, Tradespace, DOE Manager, Sensitivity, Compare, and About. The user is logged in as 'dbrowne'. The main window title is 'FACT: DOE Manager'. Below the title bar, there are tabs for 'New' and 'Status/Export'. The main content area displays a table of simulation runs and a configuration panel.

Run Name	Value	Start Time	End Time	Completion Time	User
TS09	1000.0	July 24, 2013, 7:14 p.m.	July 24, 2013, 7:14 p.m.	July 24, 2013, 7:47 p.m.	sbalestrini
TS09 ALL Optimized	6000.0	Sept. 24, 2013, 5:59 a.m.	Sept. 24, 2013, 5:59 a.m.	Sept. 24, 2013, 5:59 a.m.	dbrowne
TS09 FINAL RERUN	20000.0	Aug. 6, 2013, 4:58 p.m.	Aug. 6, 2013, 4:58 p.m.	Sept. 29, 2013, 2:51 p.m.	ahansen
TS09 OPTIMIZER	1000.0	Aug. 12, 2013, 9:46 p.m.	Aug. 12, 2013, 9:46 p.m.	Aug. 12, 2013, 11:44 p.m.	dbrowne
TS09 OPTIMIZER	2500.0	Aug. 14, 2013, 7:08 a.m.	Aug. 14, 2013, 7:08 a.m.	Aug. 14, 2013, 11:07 a.m.	dbrowne
TS09 OPTIMIZER	2500.0	Aug. 18, 2013, 8:58 p.m.	Aug. 18, 2013, 8:58 p.m.	Aug. 19, 2013, 2:51 p.m.	dbrowne
TS09 RERUN	20000.0	Aug. 6, 2013, 4:58 p.m.	Aug. 6, 2013, 4:58 p.m.	Aug. 8, 2013, 11:36 a.m.	ahansen

The configuration panel below the table includes:

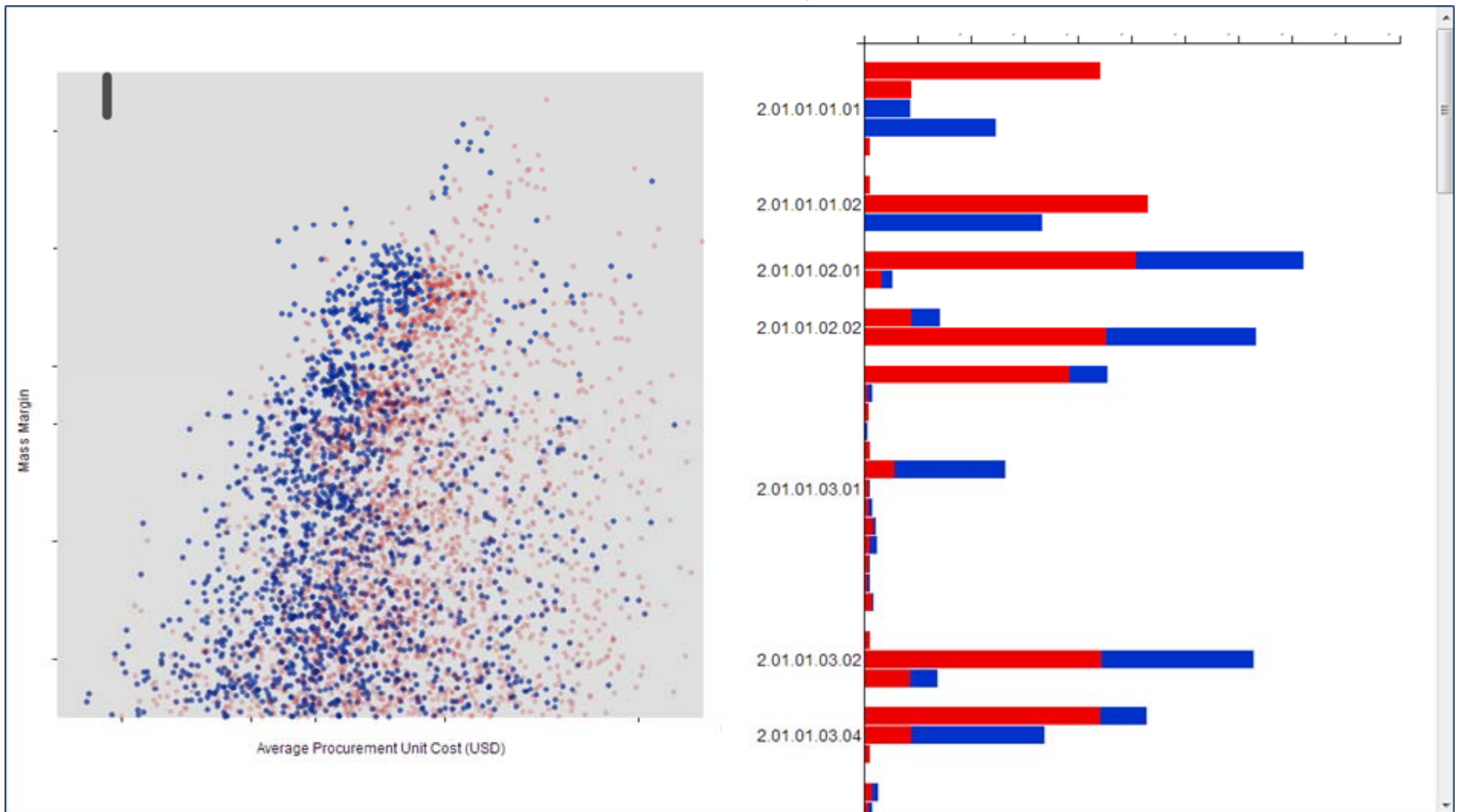
- WBS:** A tree view showing the hierarchy: [2] ACV Domain > [2.01] ACV > [2.02] Environment > [2.03] ACV O&S (selected) > [2.04] Transportability > [2.04.01] Rail > [2.04.02] Air > [2.04.03] Sea.
- Attributes:** A list of attributes with a filter set to '(mid)'. The list includes: APUC (mid), AUMC (mid), Development Cost (mid), LCCE (mid), O&S Cost (mid), and Procurement Cost (mid).
- Selected Fields:** A list of fields to be included in the export, including: BOM Cost, Empty Mass, Gross Mass (Fuel Req), Mass Margin, and APUC (mid).

Buttons for 'Preview' and 'Export' are located at the bottom right of the configuration panel.



# Upgrades to FACT to Support ACV Team

- Integrated scatterplot and part-select histogram
  - Improved inspection capability of Monte Carlo runs



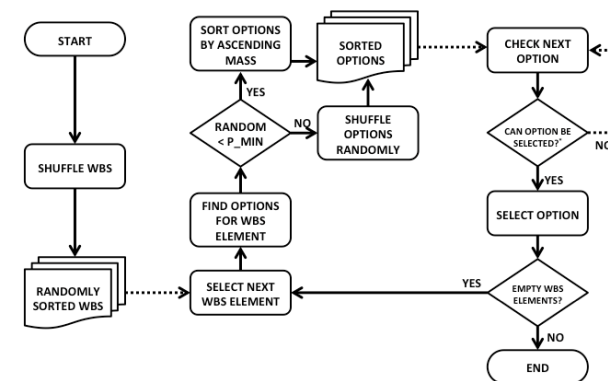
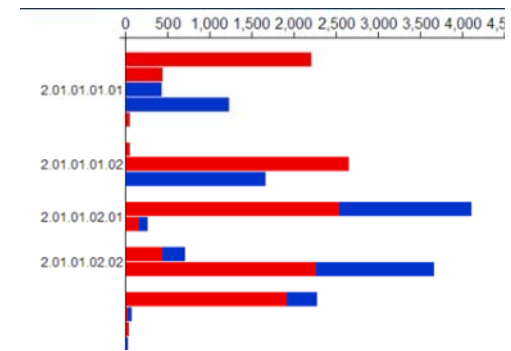
# Example Study

- Generated 20,000 configurations randomly, ensuring each configuration provide the same portfolio of capabilities
- Analyzed the cost of the configurations vs. the capabilities portfolio
- Some capabilities have a maximum allowable mass
- To better understand how to achieve a certain portfolio of capabilities, the region of lighter configurations needed to be explored more intentionally

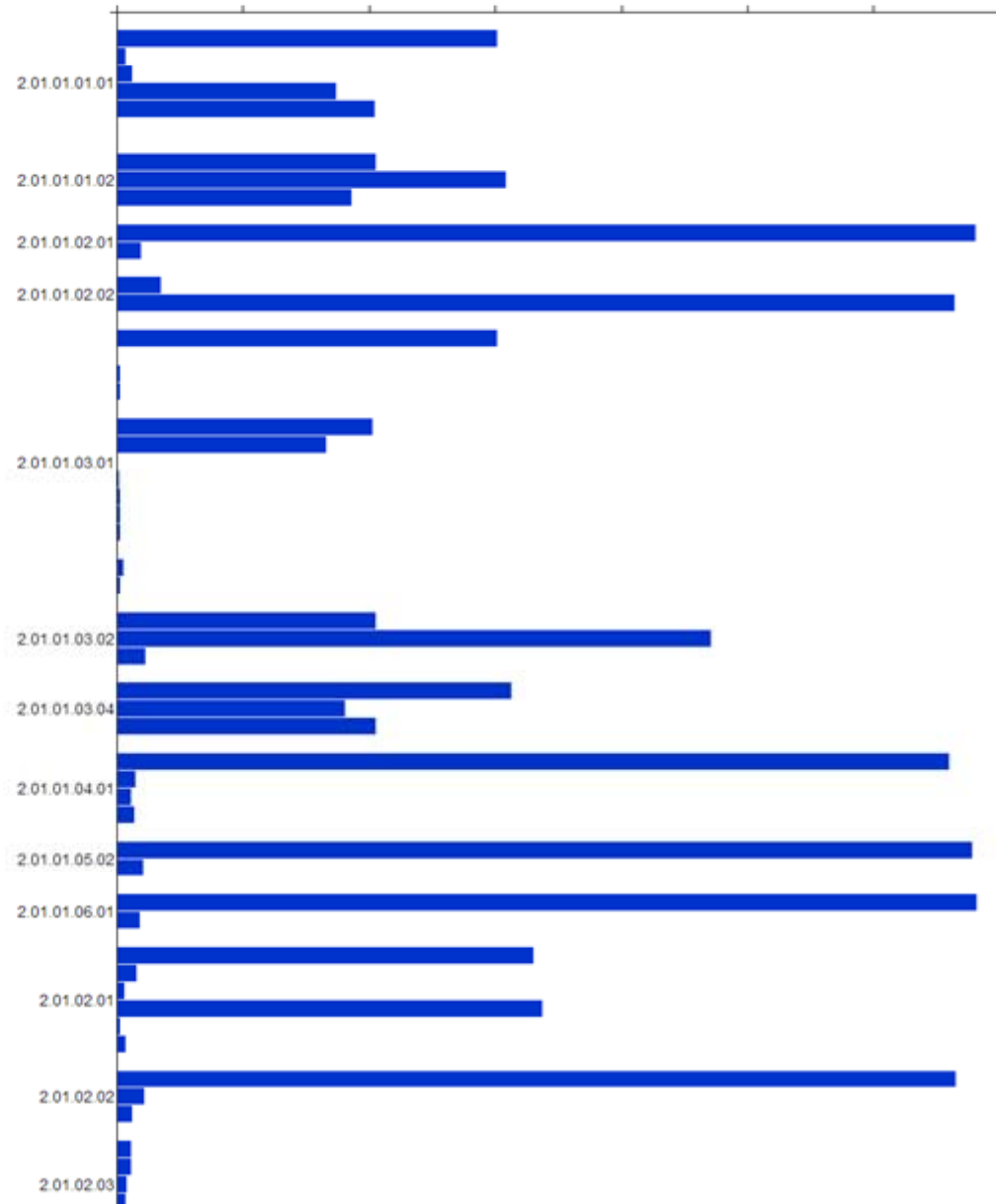
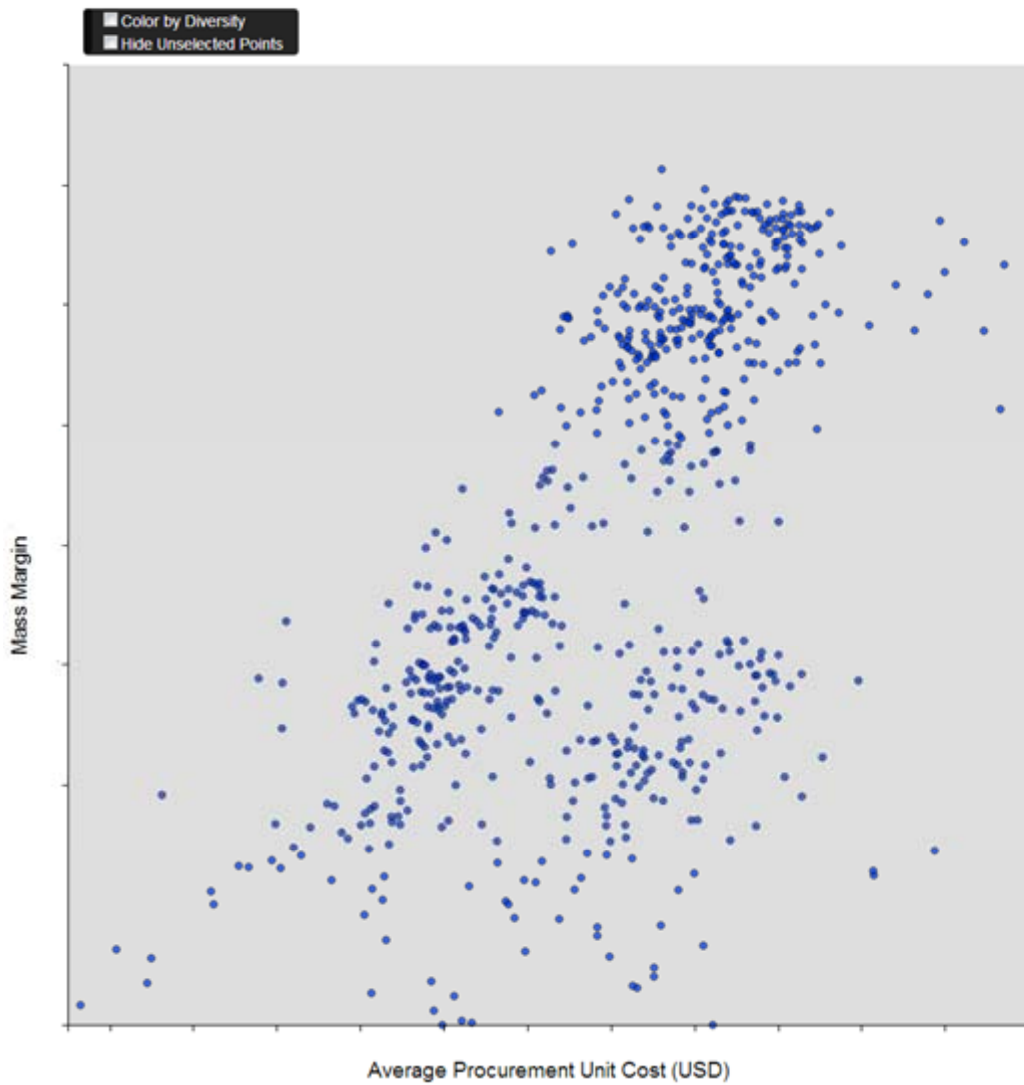
# Mass Minimization Heuristic

- Implemented **mass minimization heuristic** within vehicle configuration generation logic
- Developed an **interactive design space exploration** tool for concurrently analyzing cost, mass margin, composition (which parts are selected) and diversity
- Capability added on top of FACT's initial scatterplot to be geared towards **part-based** (as opposed to part attribute-based) **design exploration**

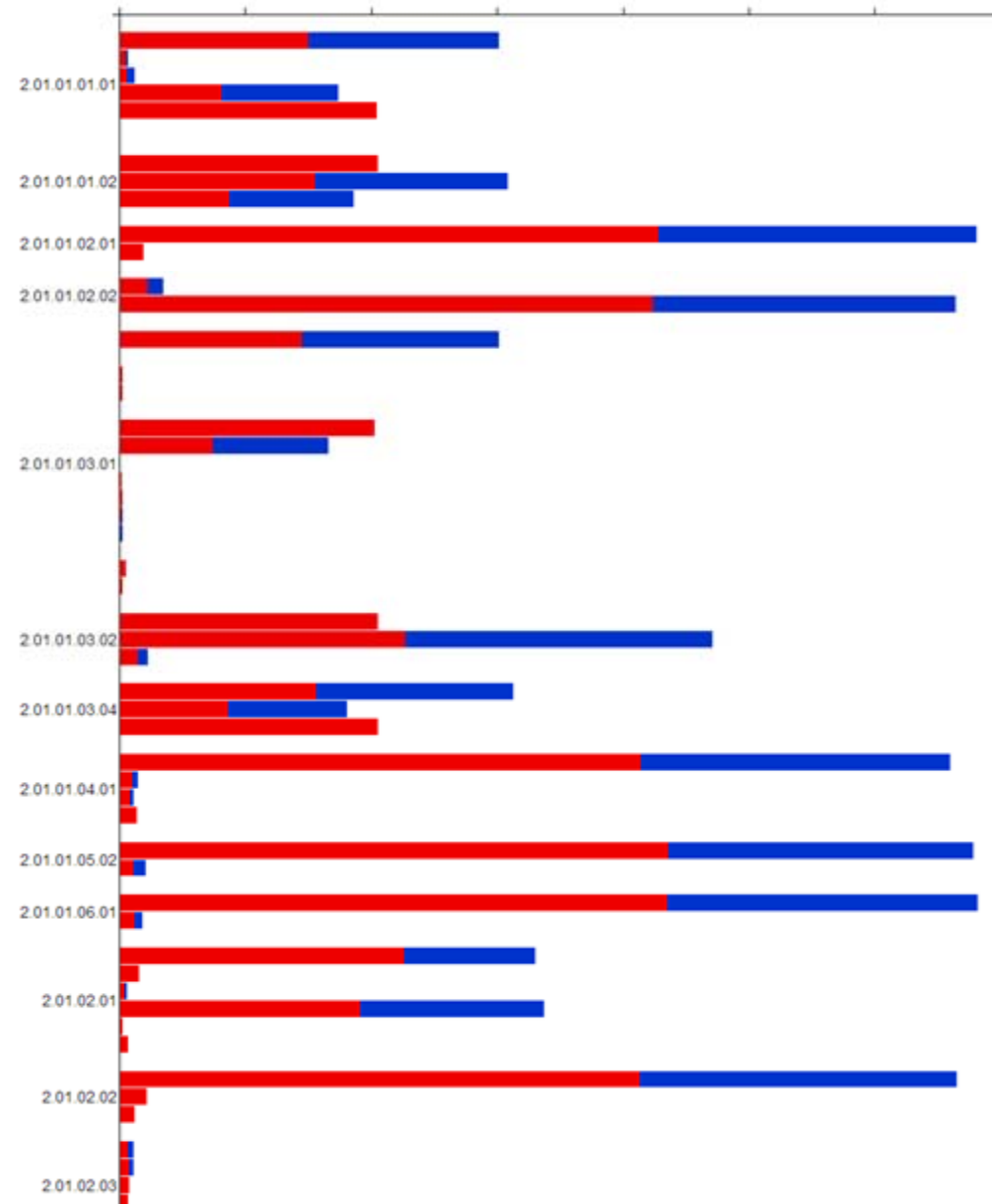
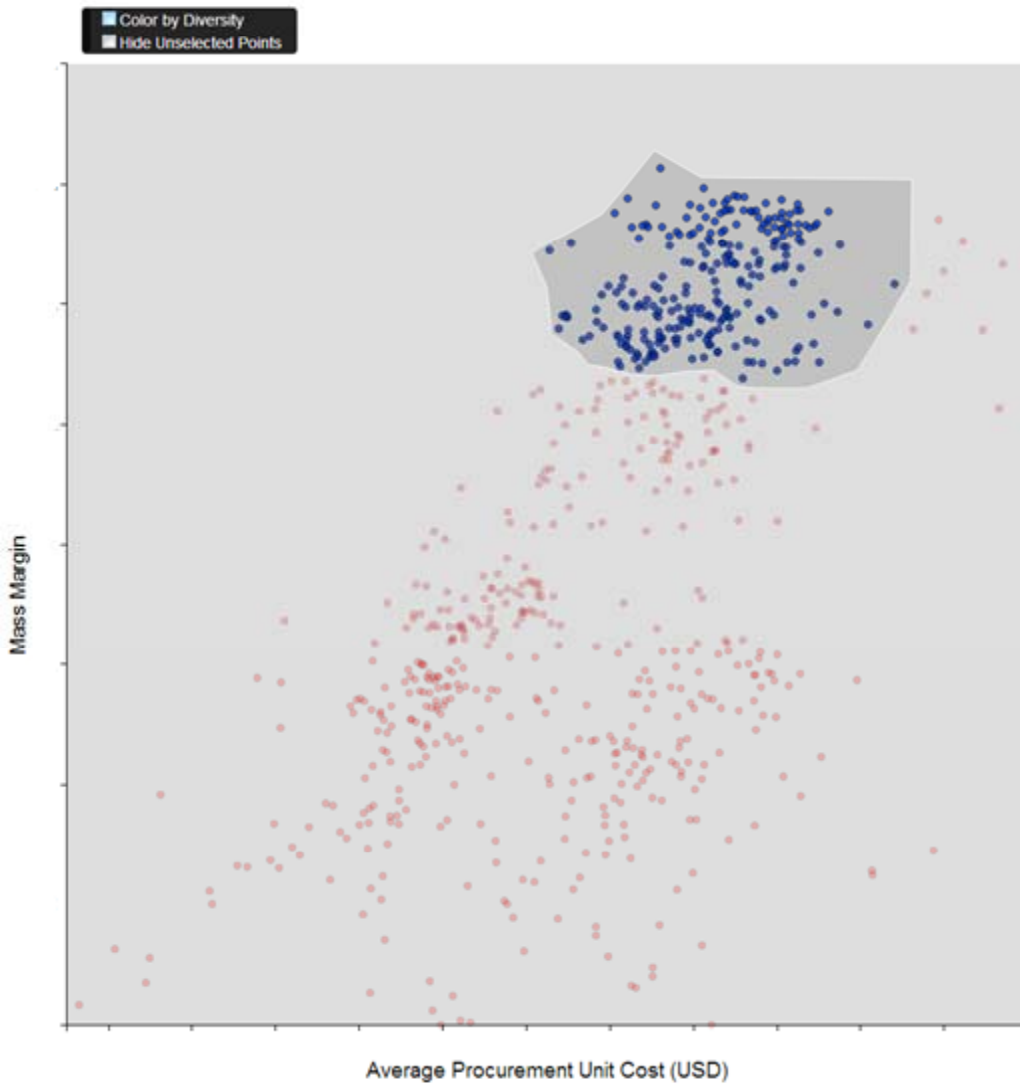
*Populated lower mass space with thousands of solutions*



# Design Space Exploration Tool

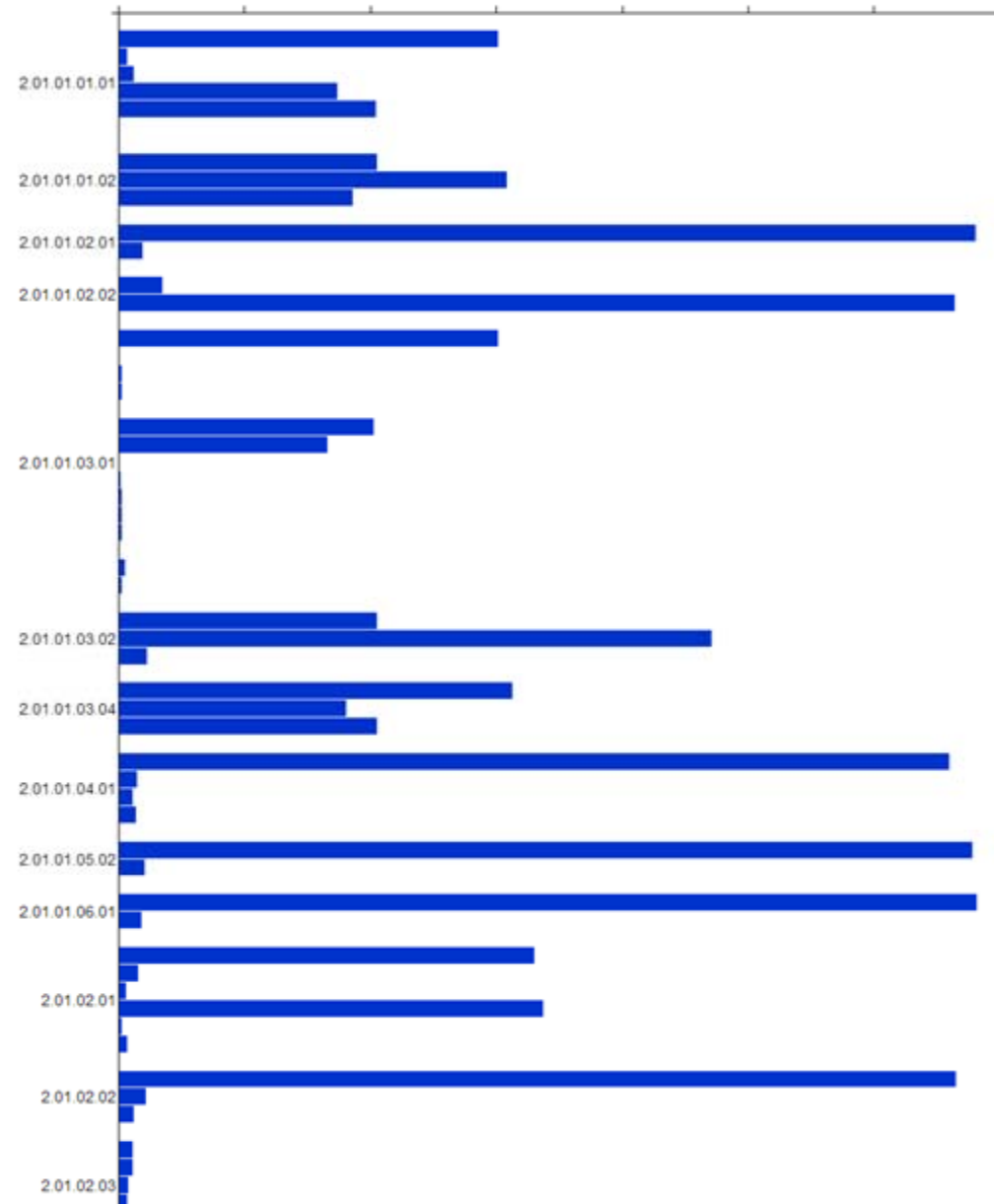
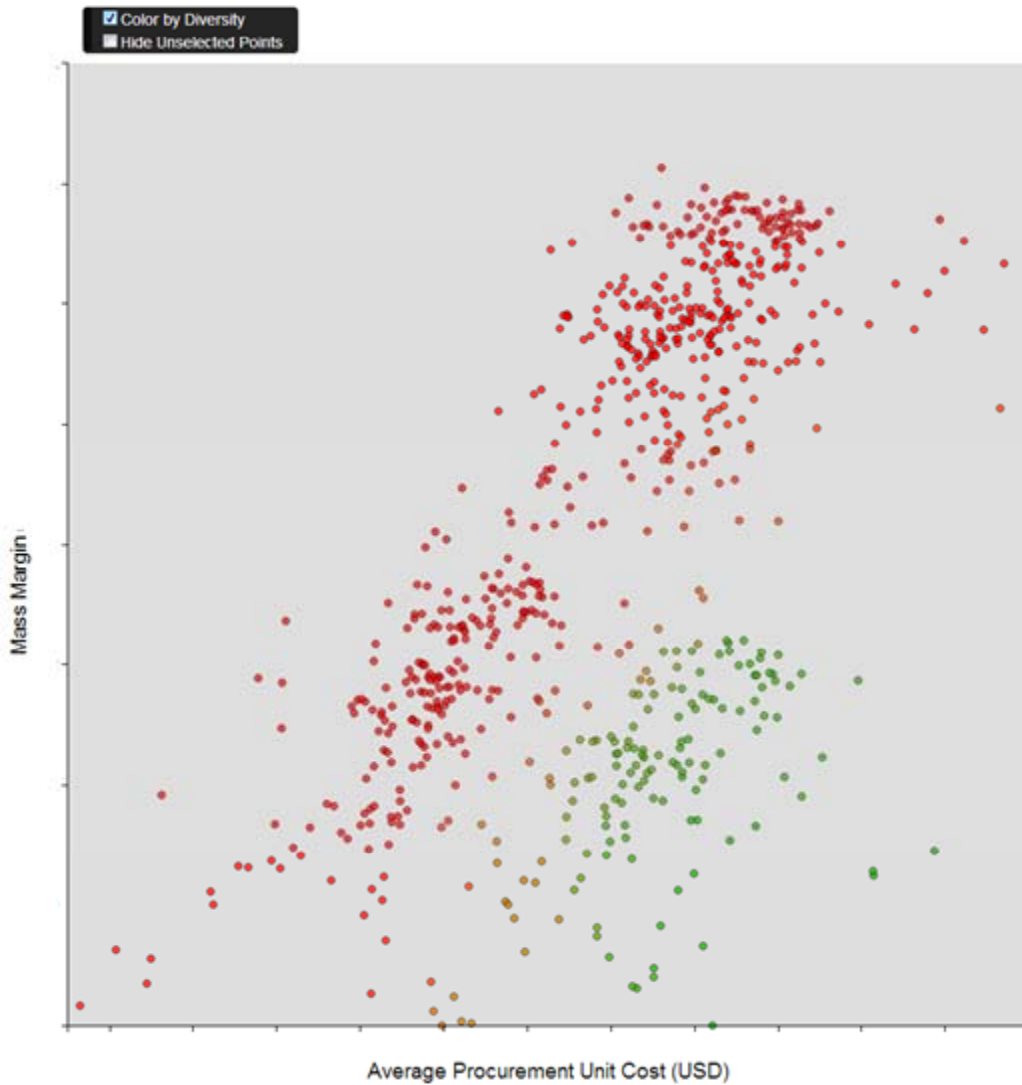


# Design Space Exploration Tool *Cloud Selection*



- What is the risk associated with setting the cost limit too low and/or the mass margin too high?
- Score a sub-region on the scatterplot based on the number of alternative options for each component in relation to the entire design space
  - The more alternative options available, the less likely any single component could impede successful realization of the integrated system
- Assumptions:
  - All part options have the same infeasibility likelihood
  - Diversity is only valid as a relative metric
  - The configuration space has been sufficiently sampled for the results to be statistically accurate

# Design Space Exploration Tool *Diversity Metric*



Utilizing FACT by the ACV Team has enabled:

- Exploration of **hundreds of thousands**, as opposed to dozens, of solution configurations
- **Standardization** of method and data for capturing component interactions (e.g. incompatibilities)
- Integration of various models ensuring that mass, cost and fuel estimates **updated automatically** based on updates to the Market Research Database
- **Improved understanding** of the design space through interpreting the Monte Carlo results using interactive visualizations



# Contact



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“This is not a huddle for six months and then show up on stage and say, 'here's what we find, decide, '...This is a deliberate process from where we are today to where we are going to be at the end of this phase of the effort that people are going to be engaged and people are going to have an opportunity to comment, to understand and to think through these problems.”

Dr. John Burrow,  
Executive Director, Marine Corps Systems  
Command & Director, USMC ACV Team

Interview with *Inside the Navy*, 25 March 2013



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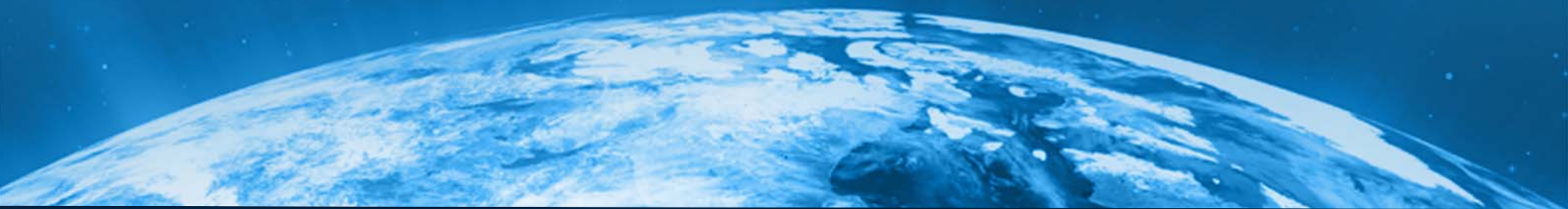
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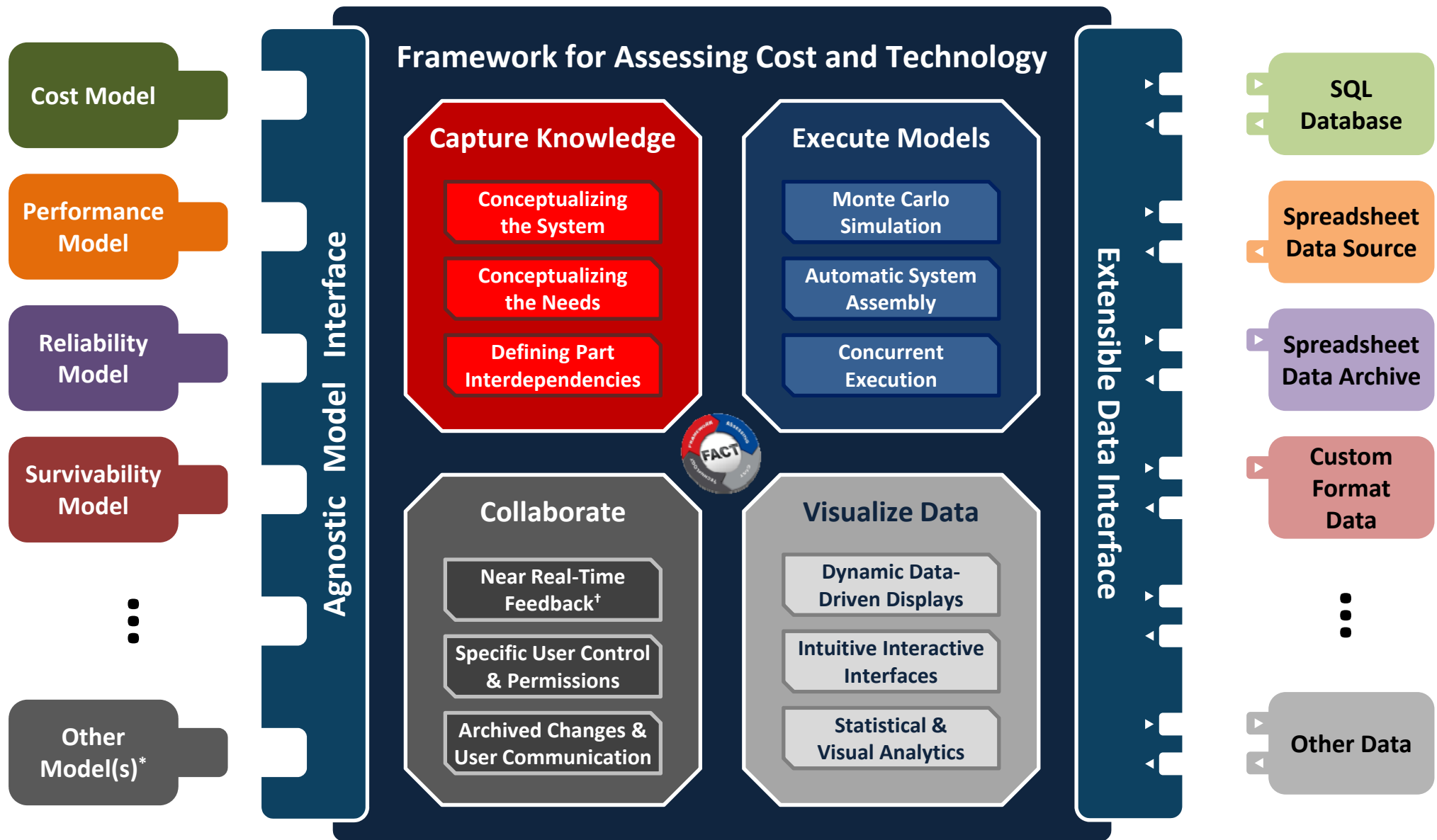
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# BACKUP



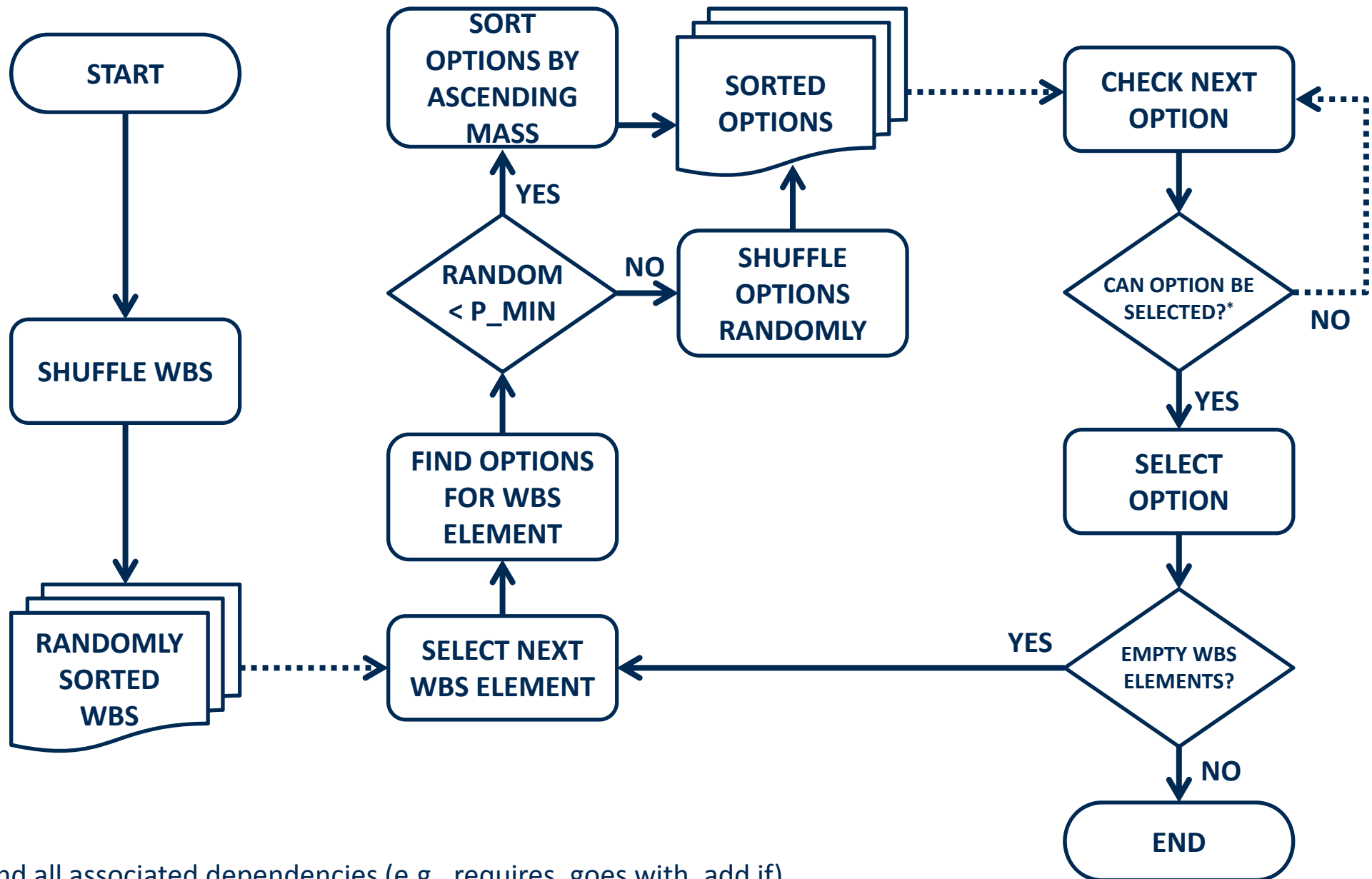
# FACT Capability Overview



\* There can be multiple models within these generic categories, e.g., cost models for both the life cycle and acquisition, each being its own "peg"

<sup>†</sup> Requires integrated models to be executable in near real-time

# Mass Minimization Heuristic



\* and all associated dependencies (e.g., requires, goes with, add if)