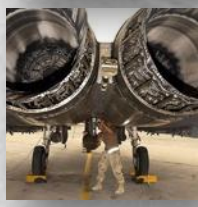
HIGH PERFORMANCE TECHNOLOGIES GROUP

15th ANNUAL SYSTEMS ENGINEERING CONFERENCE







"Turning Data in to the Tradeoff Analyses needed by Decision Makers"

October 24, 2012

Large company practices. Small company responsiveness. Working for YOU.

Author: Richard Swanson
rswanson@drc.com

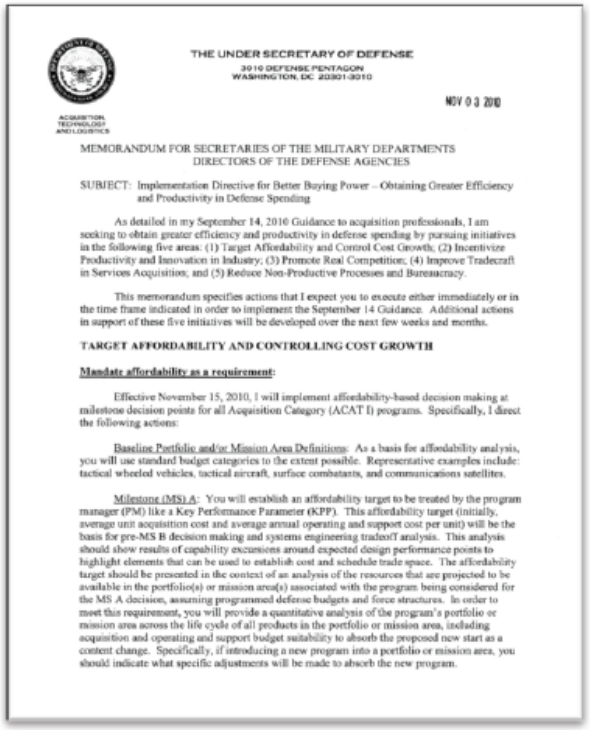
Acknowledgements

- **Co-Presenter: Clifford Marini**
  - U.S. Army Armament Research, Development, and Engineering Center
- **Task Lead: Mathew Cilli**
  - U.S. Army Armament Research, Development, and Engineering Center
- **Thought Leadership: Dr. Greg Parnell**
  - Professor of Systems Engineering, Department of Systems Engineering, United States Military Academy at West Point

Outline

- Need for Tradeoff Analysis and a Robust Tool
- Genesis of a Solution
- Realization of a Tool
- Path Forward

DoD Guidance places an emphasis on Tradeoff Analysis…



THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

NOV 0 3 2010

ACQUISITION, TECHNOLOGY AND LOGISTICS

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
DIRECTORS OF THE DEFENSE AGENCIES

SUBJECT: Implementation Directive for Better Buying Power – Obtaining Greater Efficiency and Productivity in Defense Spending

As detailed in my September 14, 2010 Guidance to acquisition professionals, I am seeking to obtain greater efficiency and productivity in defense spending by pursuing initiatives in the following five areas: (1) Target Affordability and Control Cost Growth; (2) Incentivize Productivity and Innovation in Industry; (3) Promote Real Competition; (4) Improve Tradecraft in Services Acquisition; and (5) Reduce Non-Productive Processes and Bureaucracy.

This memorandum specifies actions that I expect you to execute either immediately or in the time frame indicated in order to implement the September 14 Guidance. Additional actions in support of these five initiatives will be developed over the next few weeks and months.

TARGET AFFORDABILITY AND CONTROLLING COST GROWTH

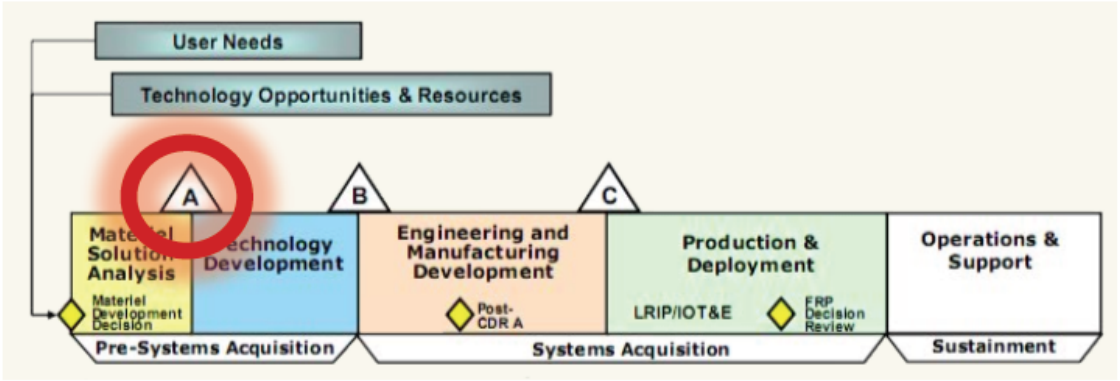
Mandate affordability as a requirement:

Effective November 15, 2010, I will implement affordability-based decision making at milestone decision points for all Acquisition Category (ACAT I) programs. Specifically, I direct the following actions:

Baseline Portfolio and/or Mission Area Definitions: As a basis for affordability analysis, you will use standard budget categories to the extent possible. Representative examples include: tactical wheeled vehicles, tactical aircraft, surface combatants, and communications satellites.

Milestone (MS) A: You will establish an affordability target to be treated by the program manager (PM) like a Key Performance Parameter (KPP). This affordability target (initially, average unit acquisition cost and average annual operating and support cost per unit) will be the basis for pre-MS B decision making and systems engineering tradeoff analysis. This analysis should show results of capability excursions around expected design performance points to highlight elements that can be used to establish cost and schedule trade space. The affordability target should be presented in the context of an analysis of the resources that are projected to be available in the portfolio(s) or mission area(s) associated with the program being considered for the MS A decision, assuming programmed defense budgets and force structures. In order to meet this requirement, you will provide a quantitative analysis of the program's portfolio or mission area across the life cycle of all products in the portfolio or mission area, including acquisition and operating and support budget suitability to absorb the proposed new start as a content change. Specifically, if introducing a new program into a portfolio or mission area, you should indicate what specific adjustments will be made to absorb the new program.

Directive for Better Buying Power – Obtaining Greater Efficiency and Productivity in Defense Spending. NOV 3, 2010. Under Secretary of Defense for Acquisition, Technology, and Logistics, Dr. Ashton Carter



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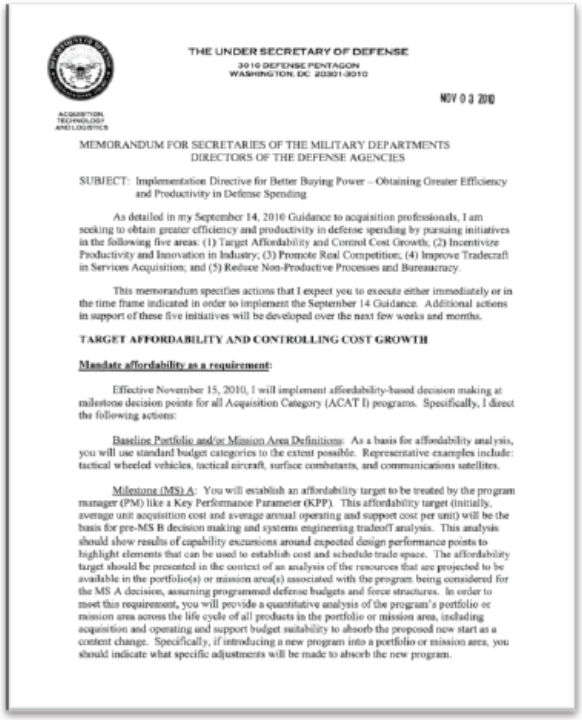
Twice in the seven page Directive



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NOV 03 2010

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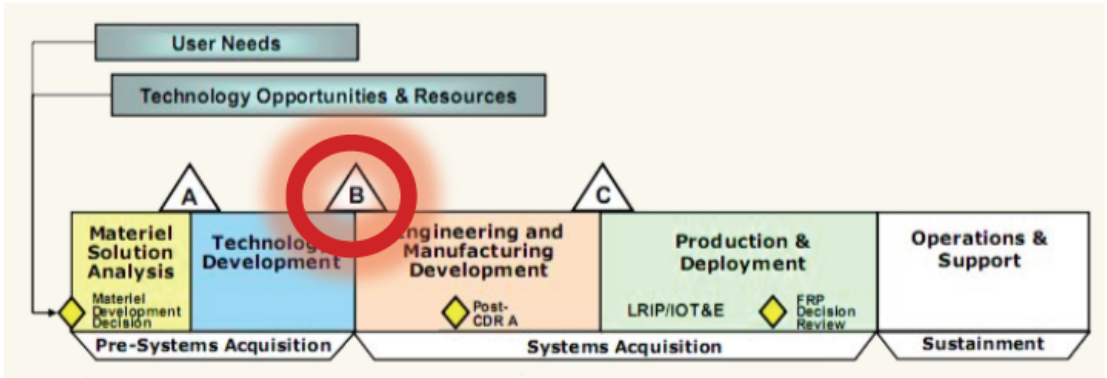
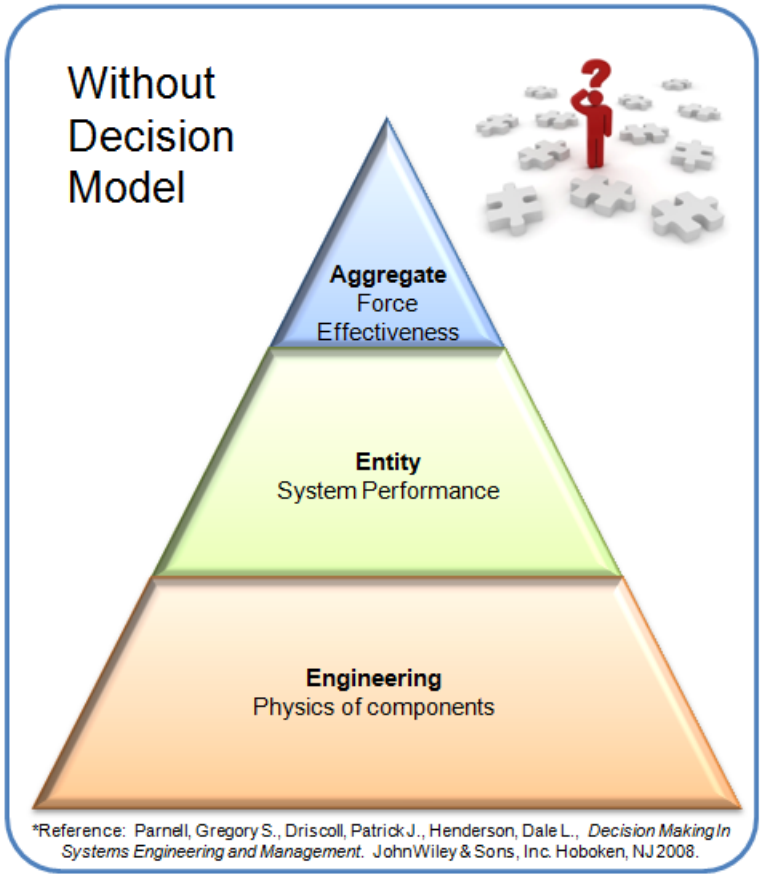
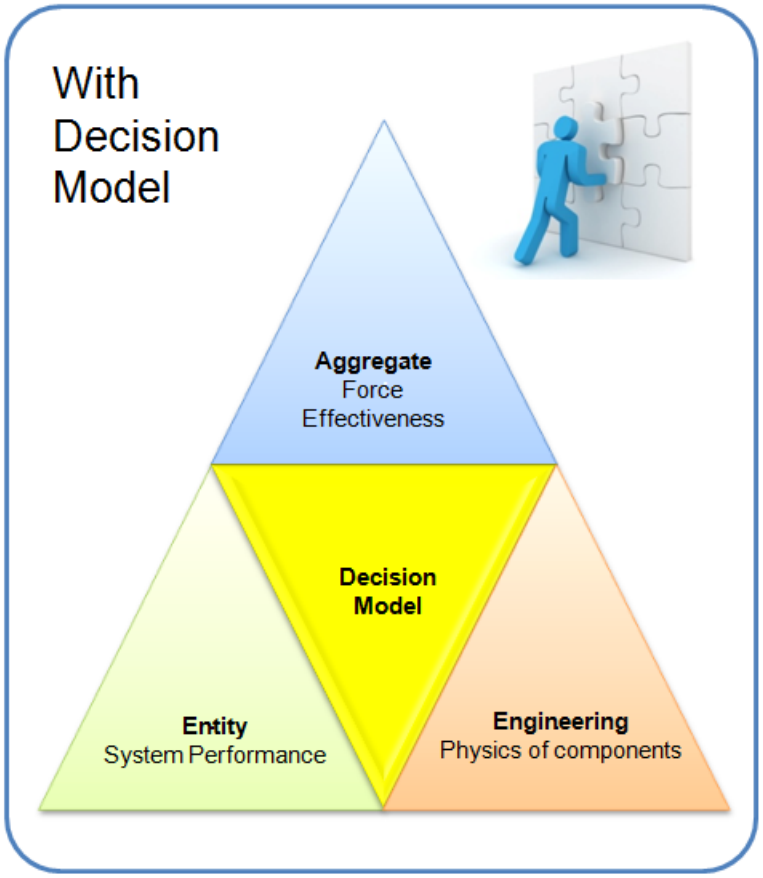


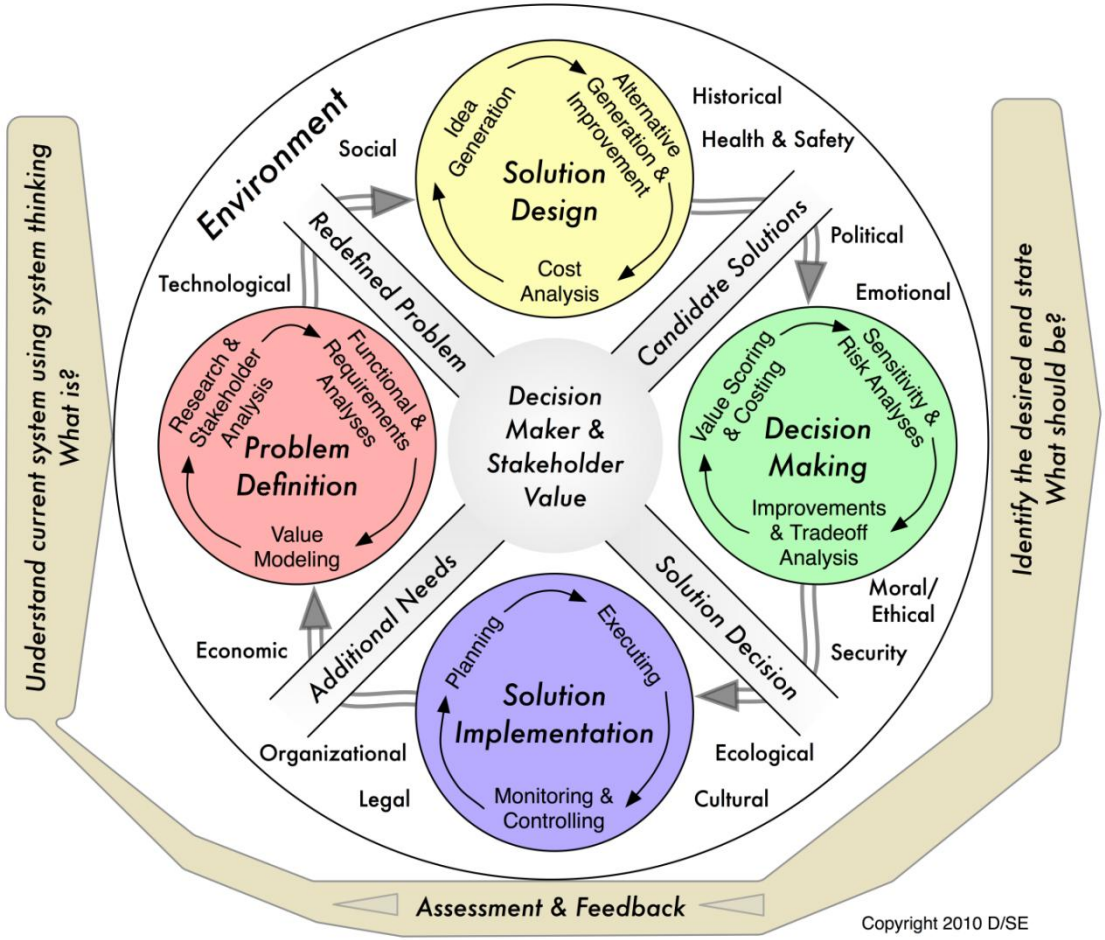
"Milestone B: You will present a **systems engineering tradeoff analysis** showing how cost varies as the major design parameters and time to complete are traded off against each other. The analysis will pay due attention to spiral upgrades. You will recommend for my approval to establish and document, in the Acquisition Decision Memorandum (ADM) and in the program baseline, an 'Affordability Requirement' for acquisition cost and for operating and support cost. This requirement will be the functional equivalent of Key Performance Parameters (KPPs) for baseline establishment and monitoring. You will provide cost tradeoff curves or trade space around major affordability drivers (including KPPs when they are major cost drivers) to show how the program has established a cost-effective design point for these affordability drivers."

Decision Model facilitates these analyses





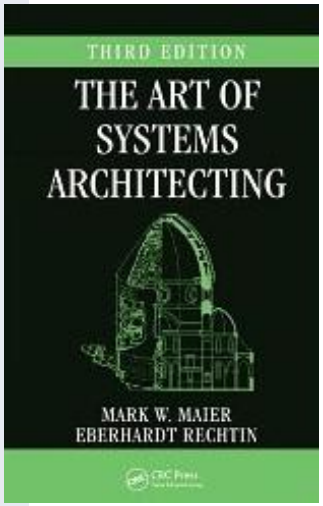
The System Decision Process



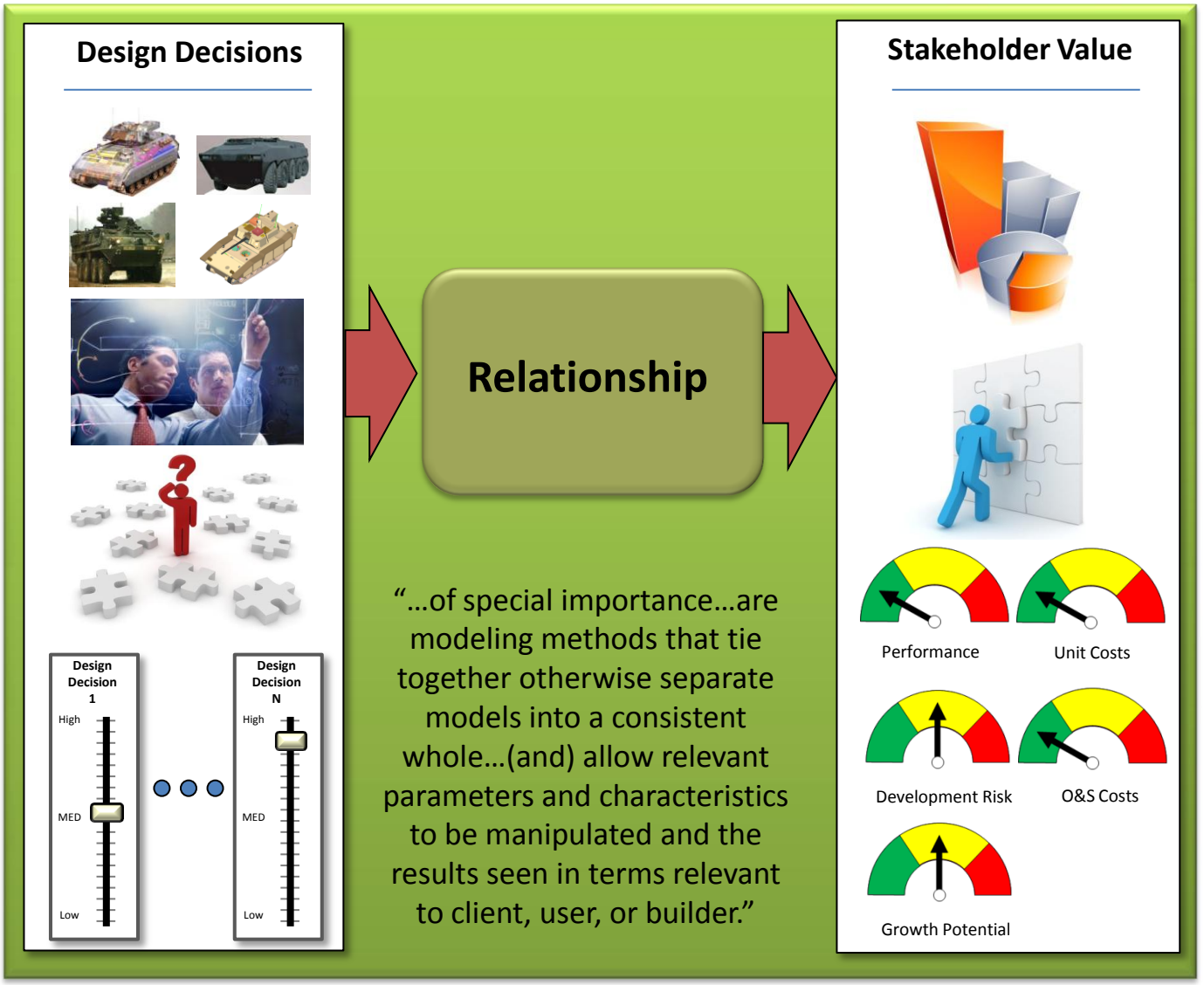
The mathematical foundation of the SDP is Multiple Objective Decision Analysis and Life Cycle Cost Analysis.

Parnell, G. S., Driscoll, P. J., and Henderson D. L., Editors, **Decision Making for Systems Engineering and Management**, 2nd Edition, Wiley Series in Systems Engineering, Wiley & Sons Inc., 2011

Model the Relationship Between Design Decisions & Stakeholder Value



Reference: Mark W. Maier, Eberhardt Rechtin, *The Art of System Architecting*. CRC Press, Boca Raton, FL, 2009. Page 222.



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Challenges from our past…

- Previous analysis done ad-hoc
- Minimal flexibility in existing software solutions
- Limited output options
- Lack of scalability to handle different types of analysis
- Not based on a decision model
- Lack of centralization and data management

The Vision…

Paper #1569263584

Vision for Multiple Objectives Decision Support Tool for Assessing Initial Business Cases of Military Technology Investments

By

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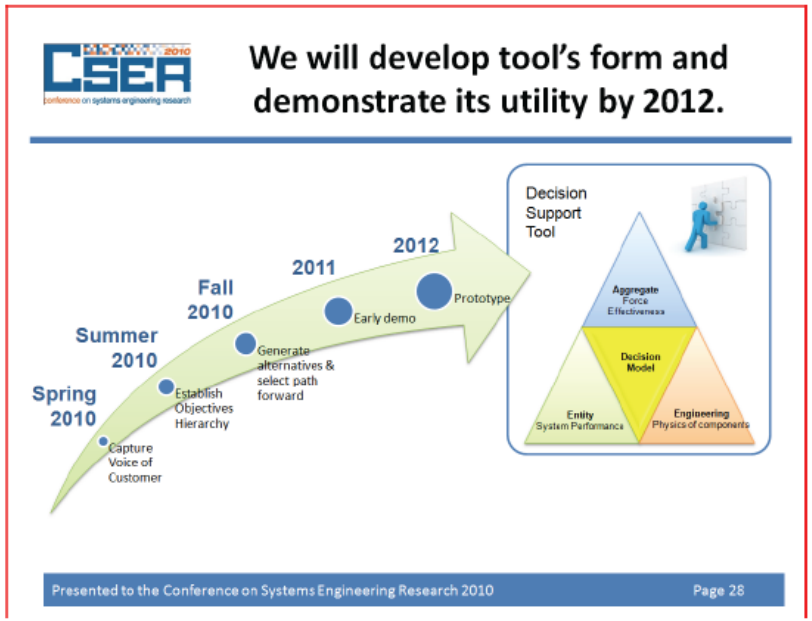
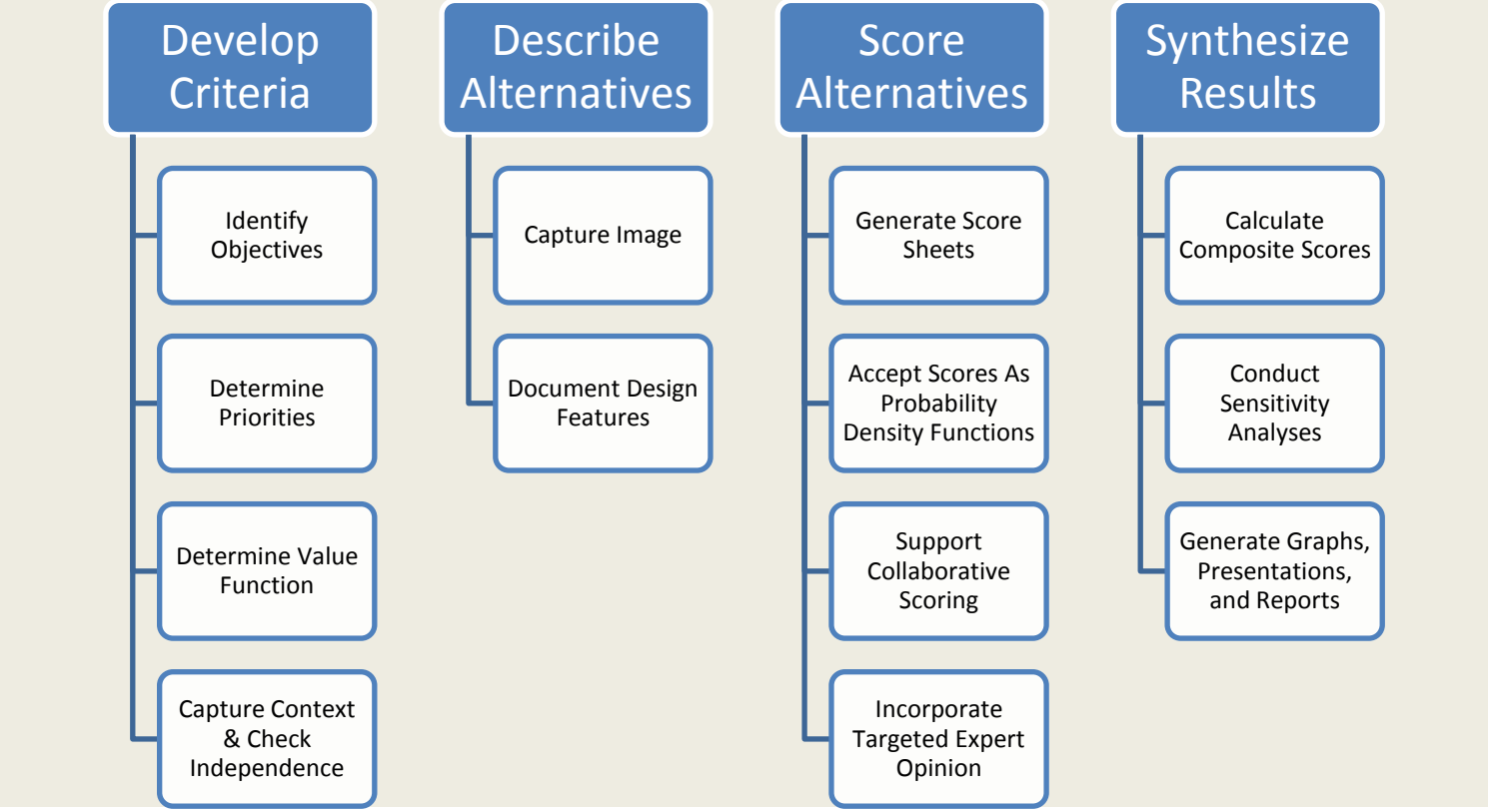
Dr. Gregory S. Parnell
Professor of Systems Engineering, Department of Systems Engineering United States Military Academy, West Point, NY 10996-1779 Gregory.Parnell@usma.edu and Innovative Decisions Inc. gparnell@innovativedecisions.com



- In the Spring of 2010, Dr. Parnell and Mr. Cilli provided a vision for a decision support tool suitable for initial business case assessments of military technology investments. This is the prototype.

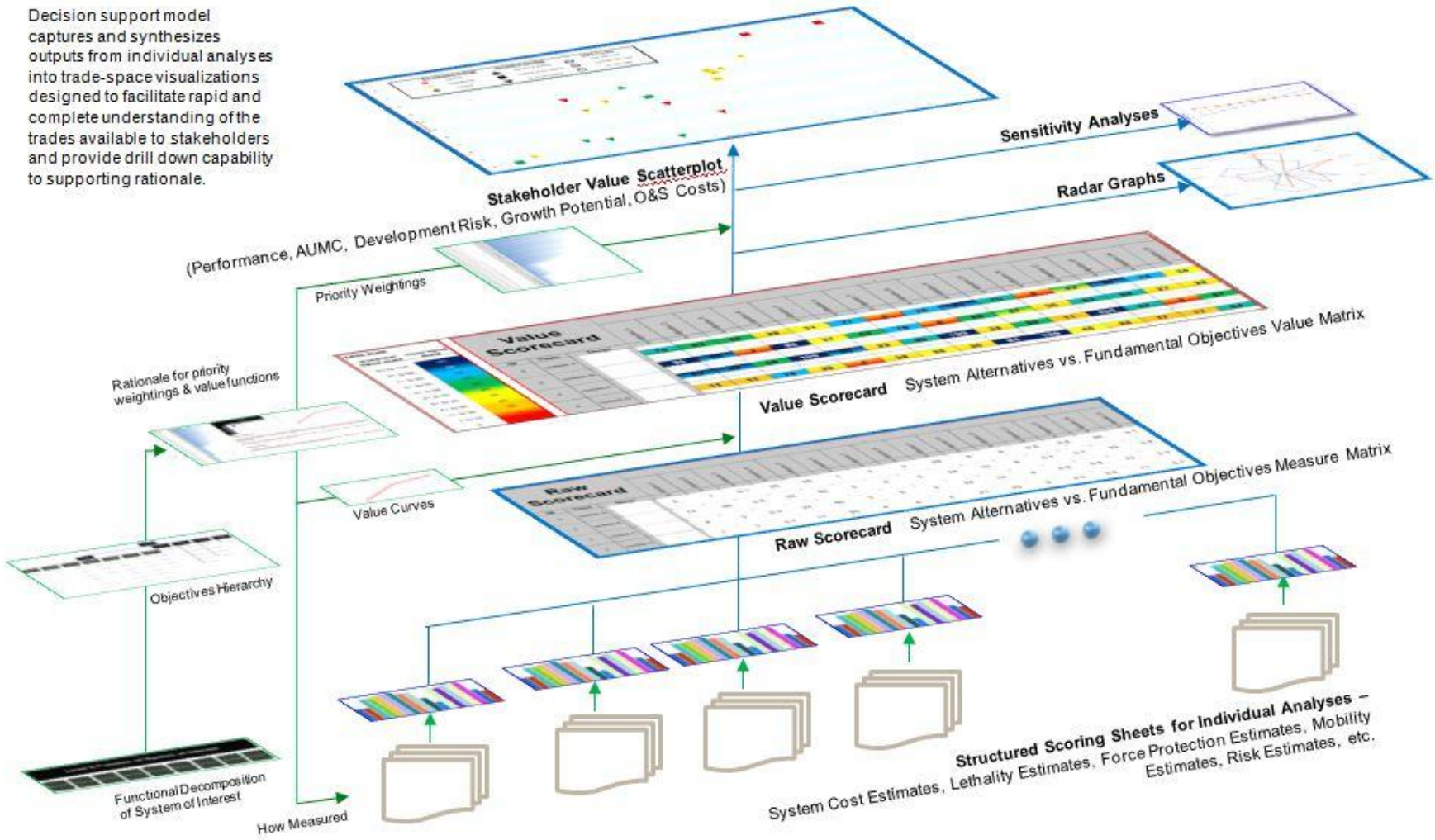
Our Goal..

To be most valuable**, a decision support tool must aid the decision maker** through every step of the **formal decision process**… to transform a broadly stated decision opportunity into a **traceable**, **defendable**, and **actionable** decision.



Decision Support Model Realized

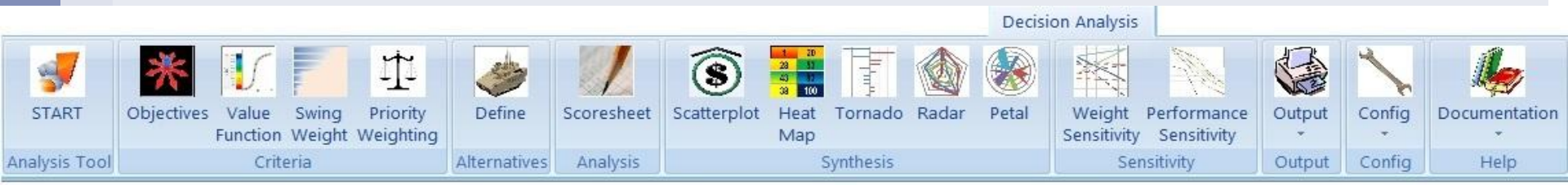
Decision support model captures and synthesizes outputs from individual analyses into trade-space visualizations designed to facilitate rapid and complete understanding of the trades available to stakeholders and provide drill down capability to supporting rationale.

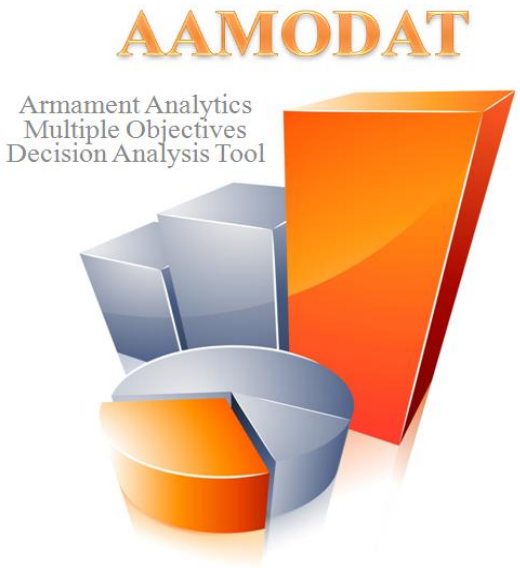


In a product that is…

- Designed to solve our challenges
- Highly scalable
  - supports diverse types of analysis
  - can link to external applications, such as Palisade's DecisionTools Suite
- Intuitive and user friendly
  - minimizes the need for user knowledge of Excel and VBA – no formula manipulation or code editing
  - ribbon Menu guides the user through the decision model process
  - allows the User to focus on the tradeoffs

Armament Analytics Multiple Objectives Decision Analysis Tool





AAMODAT is a Government Developed, MS Excel based applications that automates decision theory computations, data management, trade-space visualizations, and report generation thereby increasing decision efficiency and effectiveness.

Key Features

- Enables Efficient Creation of Value Functions
- Automates Swing Weight Matrix Calculations To Generate Priority Weightings
- Captures Key Design Features Of Considered Alternatives
- Creates Structured Score Sheets To Capture Voice of the SME
  - Captures Rational for assessment
  - Automatically maps performance score to value space using value functions
  - Allows scores to be entered as probability density functions to account for uncertainty
- Generates Compelling Tradespace Visualizations
  - 5 dimensional scatterplots
  - Decision heatmap
  - Radar graphs
  - Tornado graphs
- Conducts one-click sensitivity analyses

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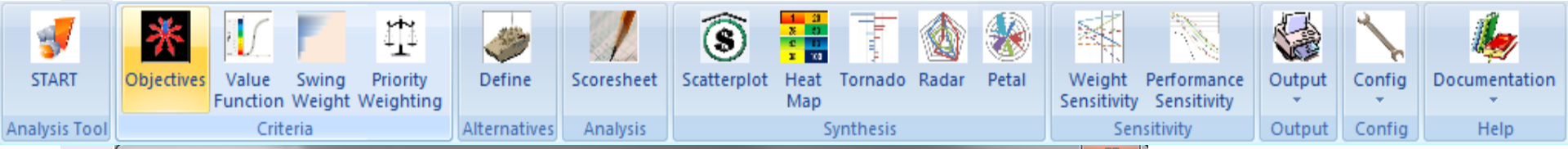
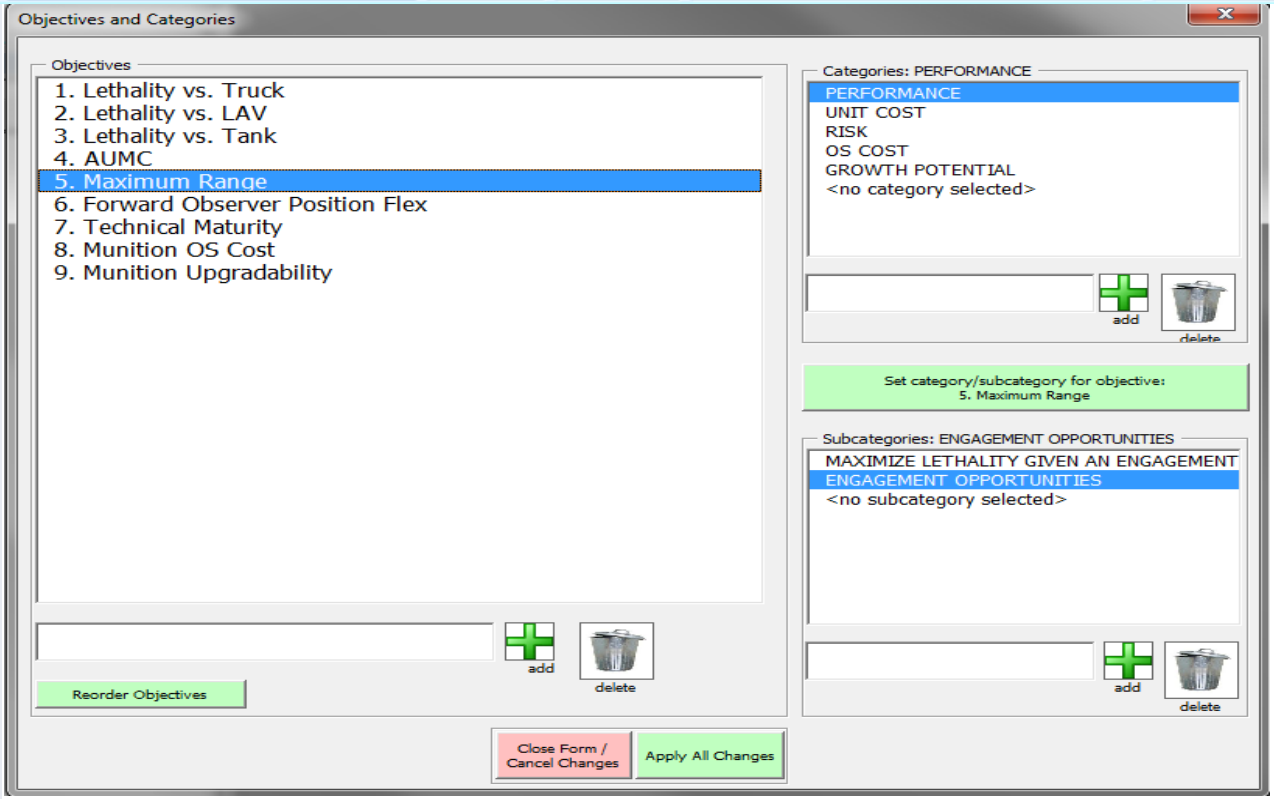
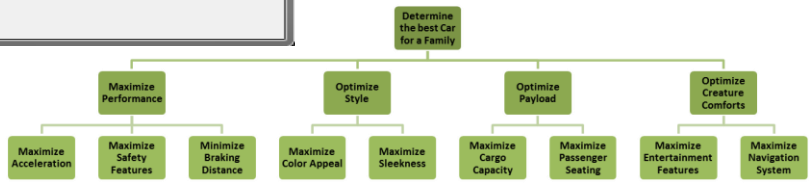
Establish Criteria for Evaluation / Identify Objectives







- Identify possible evaluation criteria
  - Should be traceable to program documents and must be measurable
- Confirm that all participants share a common understanding and commitment

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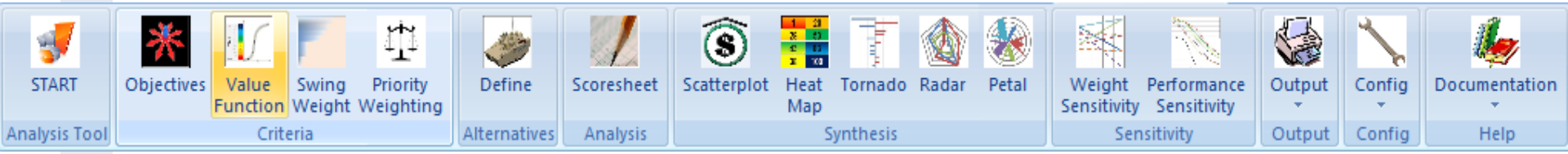
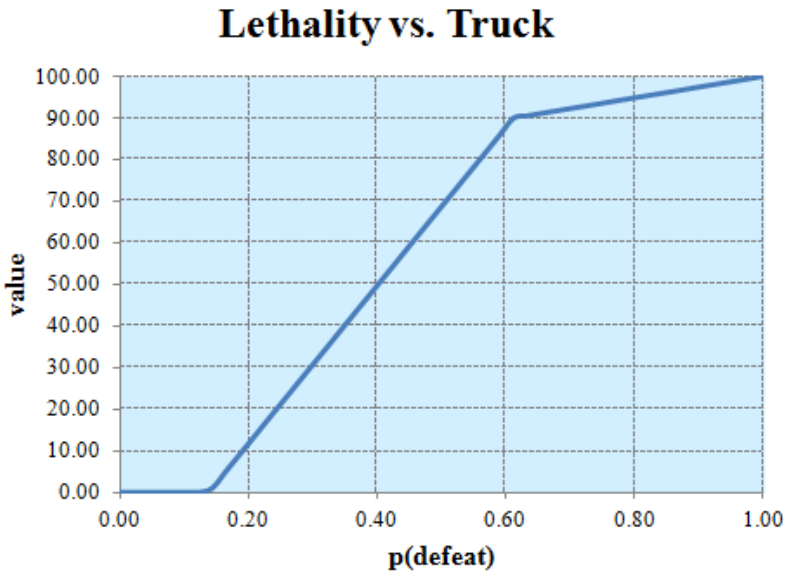
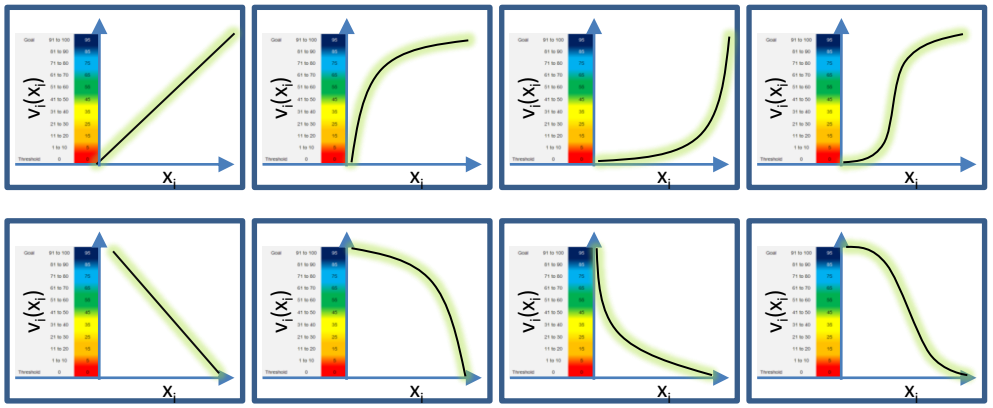
Criteria – Value Functions







*Reference: Parnell, Gregory S., Driscoll, Patrick J., Henderson, Dale L., *Decision Making In Systems Engineering and Management*. John Wiley & Sons, Inc. Hoboken, NJ 2008.

- The raw scores for each Functional Objective must be converted a standard Value Space. (return to scale)
- This mapping can be linear or more complex

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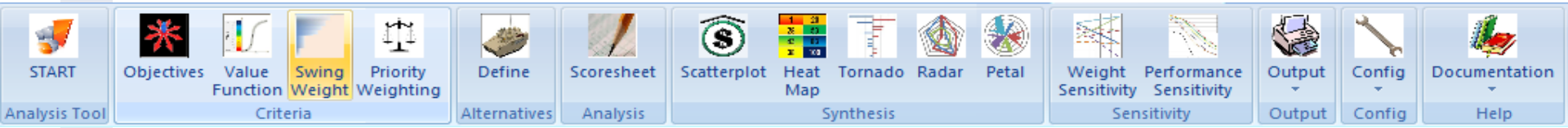
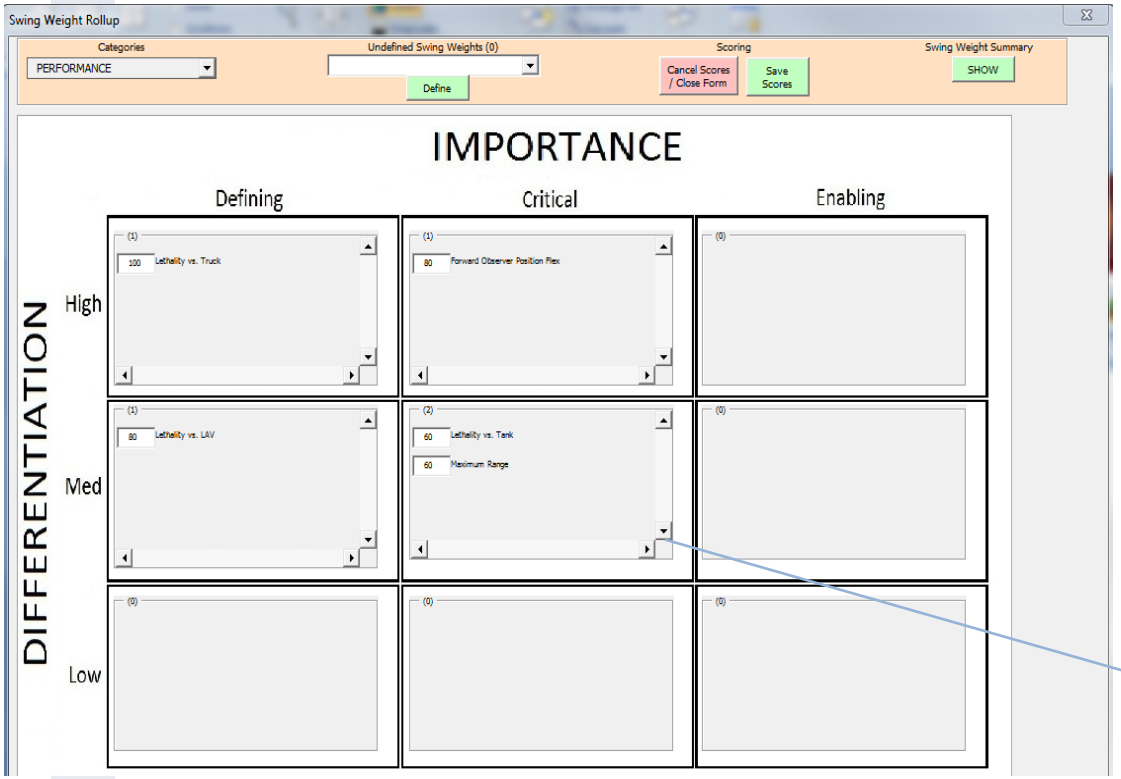
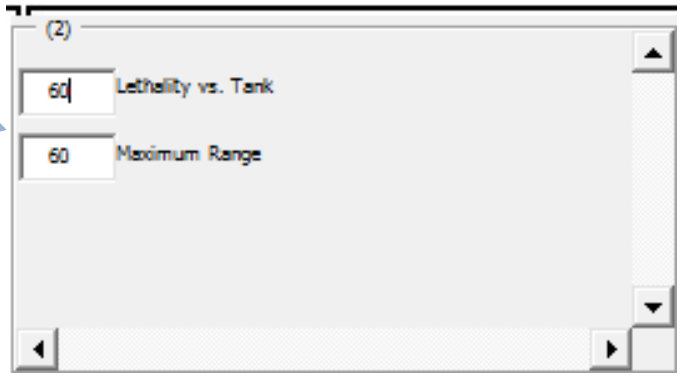
Criteria – Swing Weight





Swing Weight Matrix		Level of Importance of Value Measure		
		Mission Critical	Mission Effectiveness	Mission Efficiency
Variation in measure ranges	Dramatic improvement over today's capability	**Accuracy (100)**	**Range (50)**	
	Significant improvement over today's capability	**Speed (85)**	**Thrust (45)**	**Grade (5)**
	Small improvement over today's capability	**Number of Payloads (60)**	**Number of People (20)**	



- Define swing weights to measure variation of prioritization

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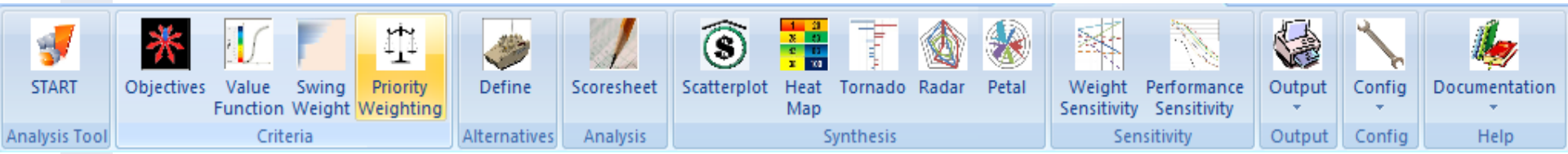
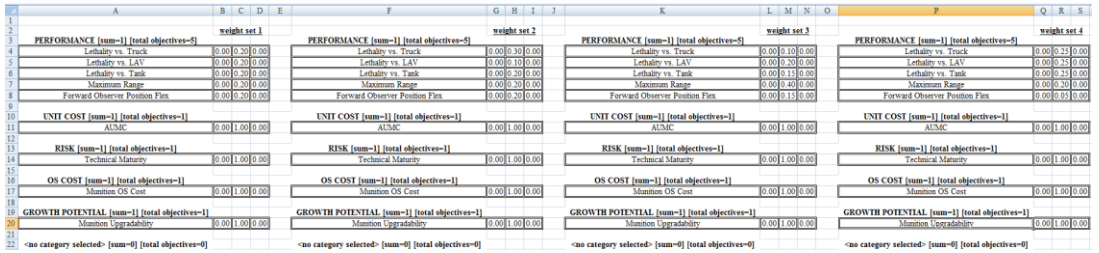
Criteria – Priority Weighting





		weight set 2		
PERFORMANCE [sum=1] [total objectives=5]				
Lethality vs. Truck	0.00	0.30	0.00
Lethality vs. LAV	0.00	0.10	0.00
Lethality vs. Tank	0.00	0.20	0.00
Maximum Range	0.00	0.20	0.00
Forward Observer Position Flex	0.00	0.20	0.00
UNIT COST [sum=1] [total objectives=1]				
AUMC	0.00	1.00	0.00
RISK [sum=1] [total objectives=1]				
Technical Maturity	0.00	1.00	0.00
OS COST [sum=1] [total objectives=1]				
Munition OS Cost	0.00	1.00	0.00
GROWTH POTENTIAL [sum=1] [total objectives=1]				
Munition Upgradability	0.00	1.00	0.00
<no category selected> [sum=0] [total objectives=0]				

- Or assign weight manually to each objective
  - Allows sensitivity analysis against differing stakeholder opinions

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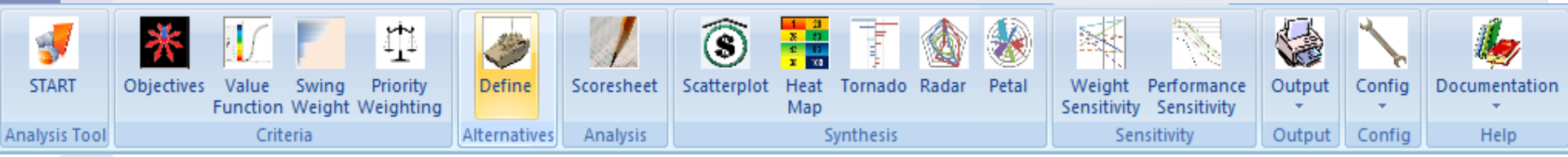
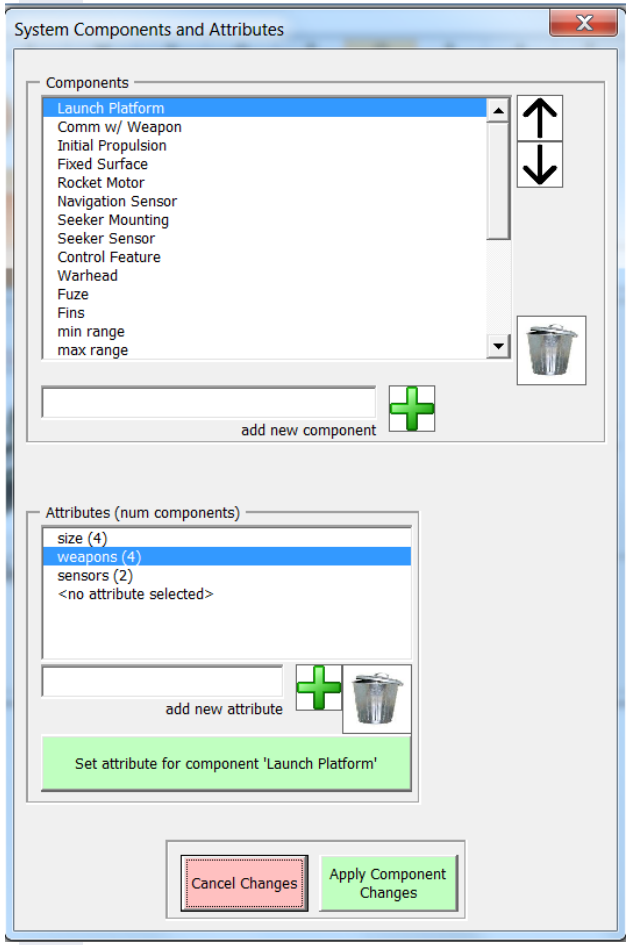
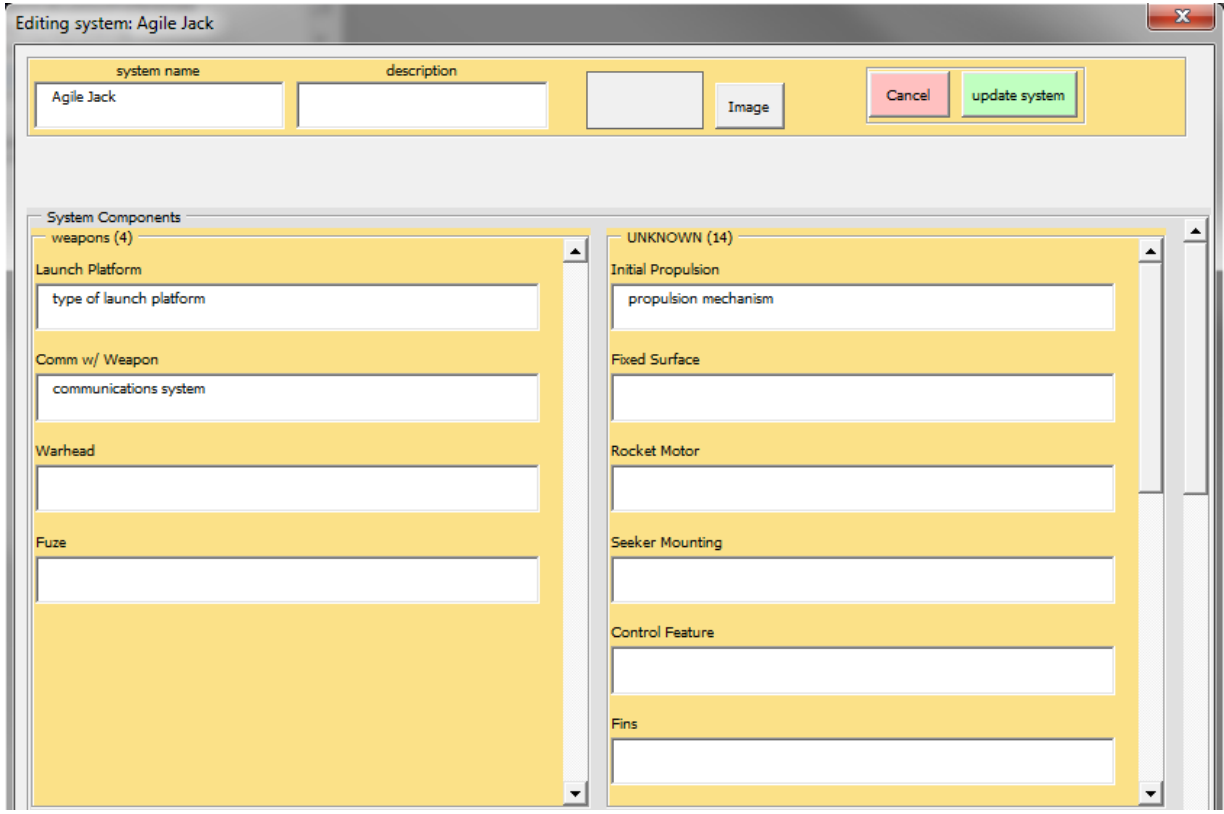
Configuration – System Components, Attributes & Alternatives





- Summarize key design features for each alternative
- Logically group into categories



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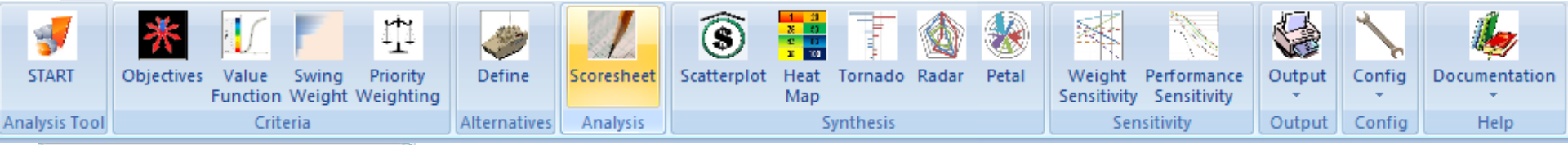
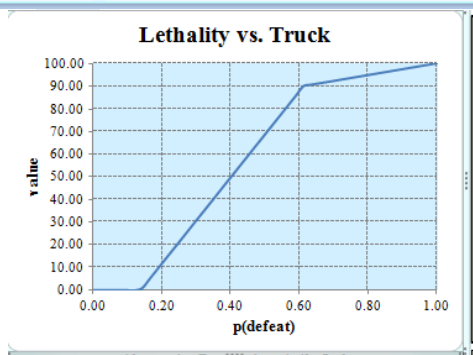
Analysis - Scoresheet





Explanation of Performance Metric and Value Mapping

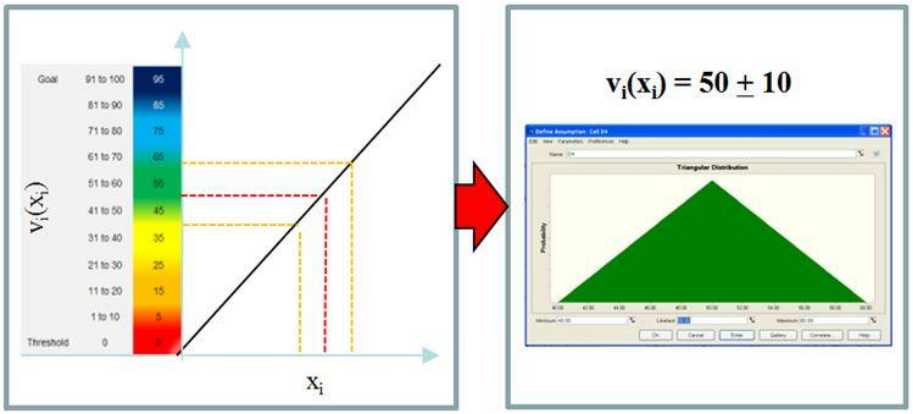
Alternative Description: Agile Jack

System Component	Value
Launch Platform	type of launch platform
Comm w/ Weapon	communications system
Initial Propulsion	propulsion mechanism
Fixed Surface	
Rocket Motor	
Navigation Sensor	
Seeker Mounting	
Seeker Sensor	

Upper Bound	1.00	100.00
Expected	0.90	97.42
Lower Bound	0.80	94.84
scored on:	09/19/2012 10:11	
person scored		

Assessment Rationale

- Capture voice of the subject matter expert and results from other models / analyses
- Document supporting rationale
- Express scores as probability density functions to capture uncertainty



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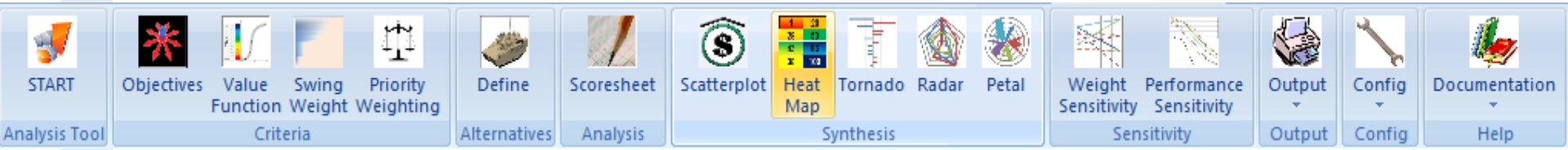
Synthesis – Heat Map

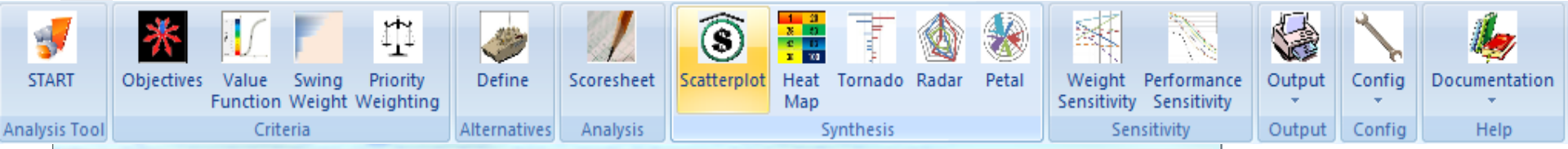


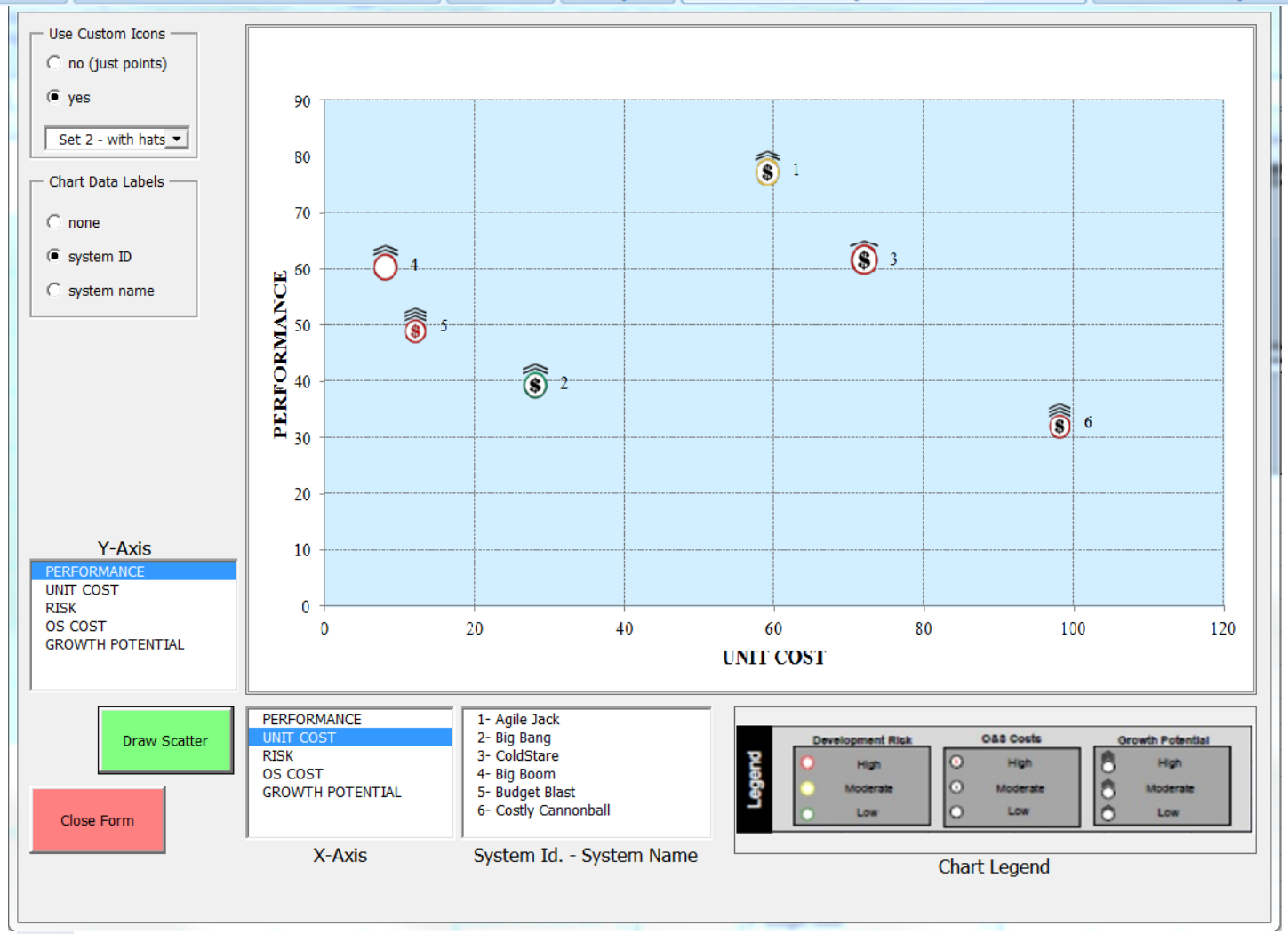
End-State Attractiveness Assessment Matrix			Maximize Lethality Given an Engagement			Engagement Opportunities		Unit Cost	Risk	OS Cost	Growth Potential
			Lethality vs. Truck	Lethality vs. LAV	Lethality vs. Tank	Maximum Range	Forward Observer Position Flex	AUMC	Technical Maturity	Munition OS Cost	Munition Upgradability
ID	Name	Image	0.07	0.02	0.05	0.06	0.02	0.02	0.01	0.01	0.01
1	Agile Jack		75	100	42	91	80	59	43	59	54
2	Big Bang		94	11	42	26	25	28	100	36	37
3	ColdStare		91	13	96	57	54	72	11	23	59
4	Big Boom		95	4	51	61	96	8	13	49	68
5	Budget Blast		0	48	49	58	95	12	29	68	26
6	Costly Cannonball		18	55	18	31	46	98	8	74	47

- Graphically display scored values
- Allows user to rapidly assess areas of strength and weakness
- Additionally can provide insight in to program requirements and their achievability

HIGH PERFORMANCE TECHNOLOGIES GROUP

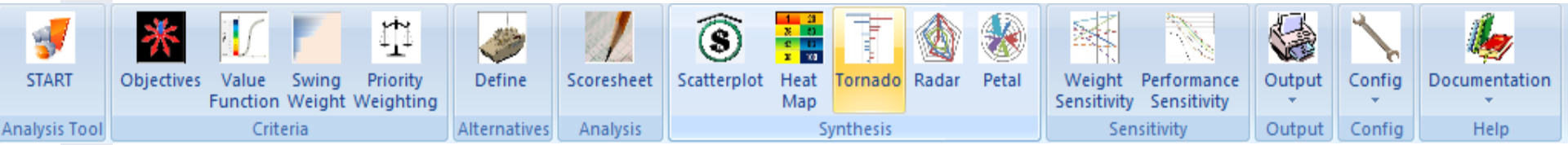
Synthesis – Scatterplot

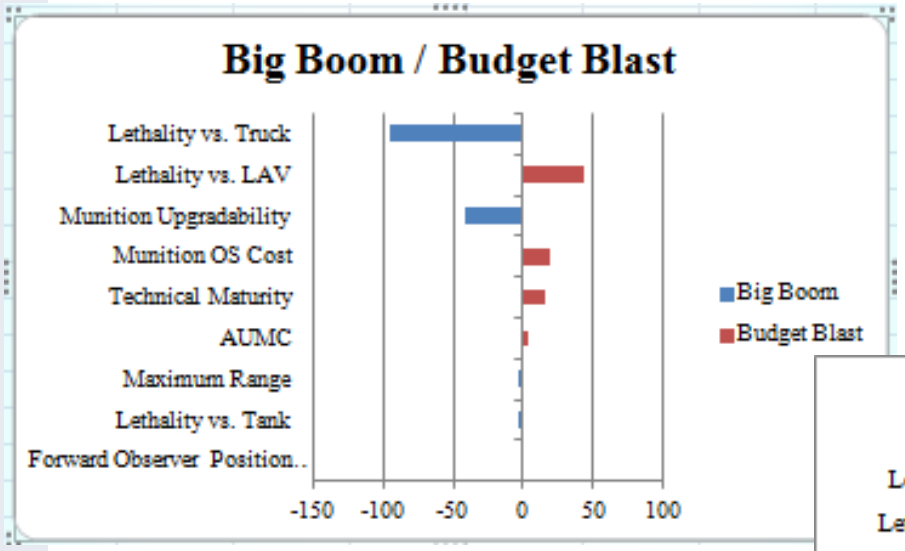


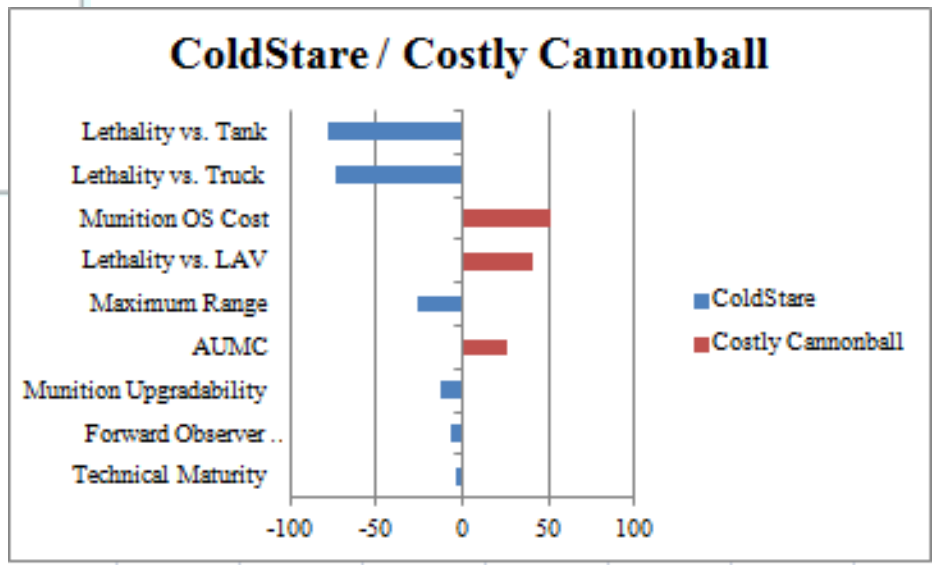


- Custom icons allow for up to five dimensions of information

Synthesis – Tornado Plot







- Highlights differences between two alternatives
- Can show variation on 0-100 scale per objective or can take in to account priority weighting

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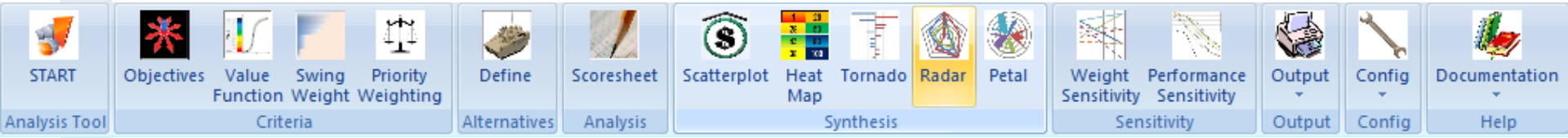
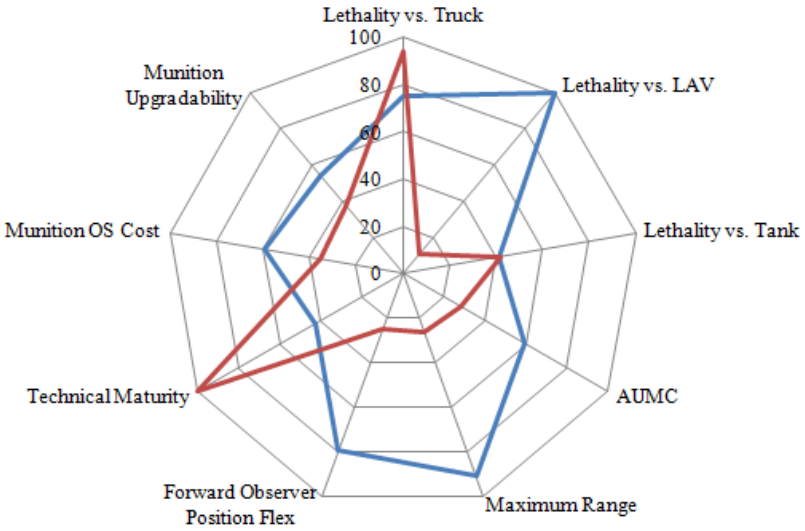
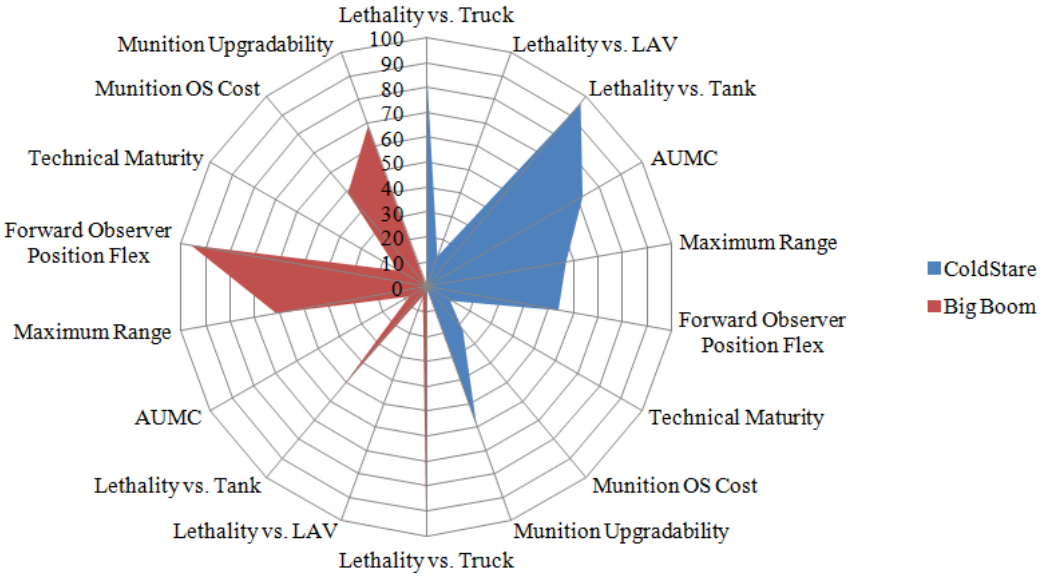
Synthesis – Radar and Petal Charts

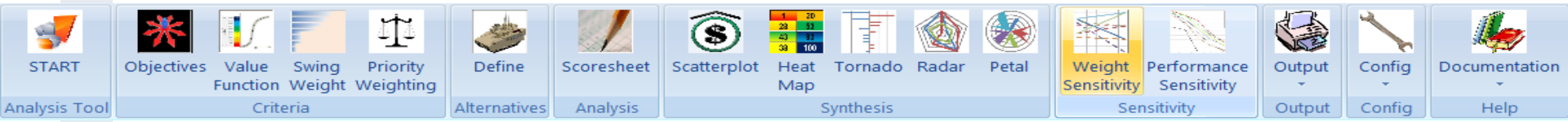


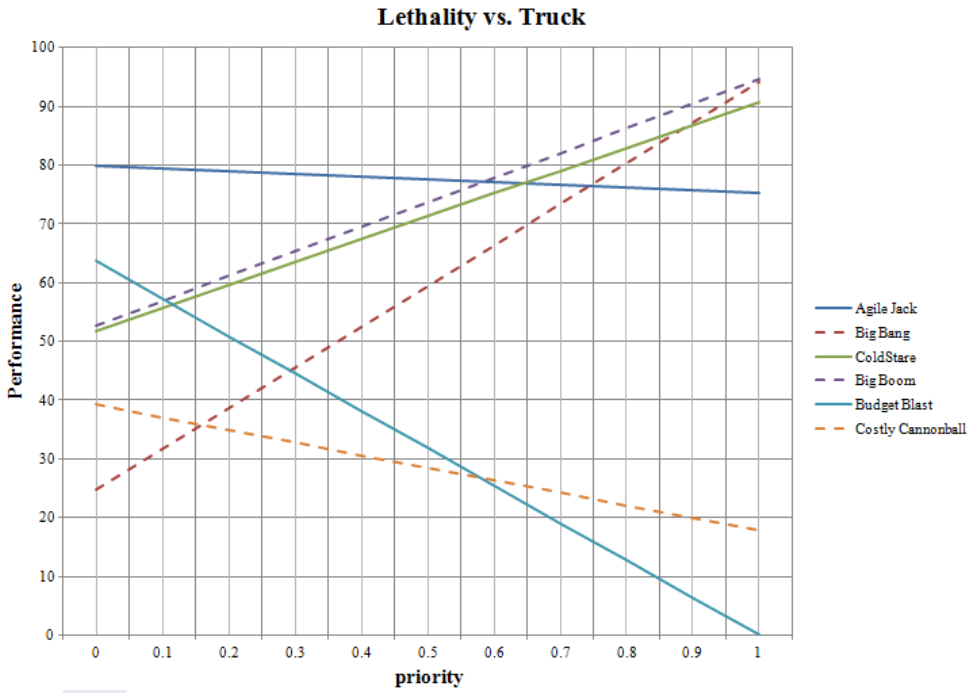




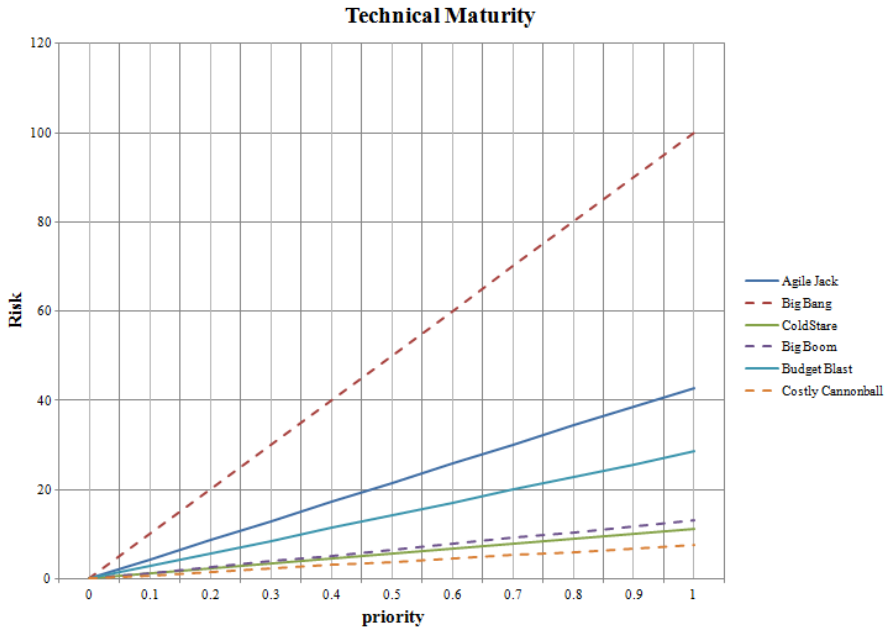
HIGH PERFORMANCE TECHNOLOGIES GROUP

Sensitivity - Weight





- Show sensitivity of overall value to priority weighting of an individual objective
- Also can generate all previous analyses for multiple sets of stakeholder priorities and compare results



- We are researching ways to use genetic algorithms, and "solvers" to analyze trade space results given uncertainty bounds around all priority weightings.

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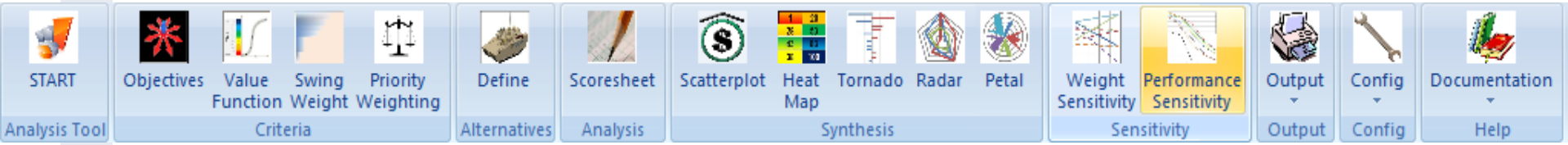
Sensitivity - Performance



- Utilizes Palisade's @Risk analysis software, the Probability Density Functions defined on the scoresheets and Monte Carlo analysis

	Lethality vs. Truck	Lethality vs. LAV	Lethality vs. Tank	AUMC	Maximum Range	Forward Observer Position Flex	Technical Maturity	Munition OS Cost	Munition Upgradability				Decion Robustness. % chance from montecarlo that this alternative "wins"
	0	0	0	1	0	0	1	1	1				
Agile Jack	1	1	1	111667	11	14	6	10466667	41				
	97	60	54	63	28	5	70	65	42	292	58	0	**31.6%**
Big Bang	1	1	1	161111	23	13	7	20666667	77				
	92	81	81	47	58	5	79	32	78	300	60	1	**35.9%**
ColdStare	1	1	1	50000	18	13	4	20000000	60				
	88	80	82	84	45	5	42	34	61	282	56	0	**0.6%**
Big Boom	1	1	1	88000	22	256	5	10633333	25				
	90	82	80	71	56	71	49	65	26	288	58	0	**13.5%**
Budget Blast	0	1	0	10000	6	13	8	11083333	7				
	51	53	41	97	16	5	90	63	8	293	59	0	**18.4%**
Costly Cannonball	1	1	1	228333	40	250	5	25000000	65				
	90	80	92	25	100	70	58	18	66	251	50	0	**0.0%**

- Further views of this data are being developed to allow users to easily review the results within this uncertainty analysis.

DRC HIGH PERFORMANCE TECHNOLOGIES GROUP

The Future

- AAMODAT prototype being tested by Cadets and Professors at the USMA at West Point during the 2012 – 2013 Academic year
- AAMODAT being used for internal efforts at ARDEC
- AAMODAT will be refined based on early user feedback
- Decisions will be made regarding future availability of this tool to the DoD community

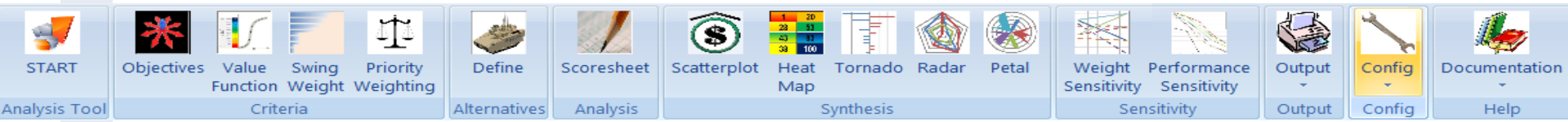
Questions & Suggestions

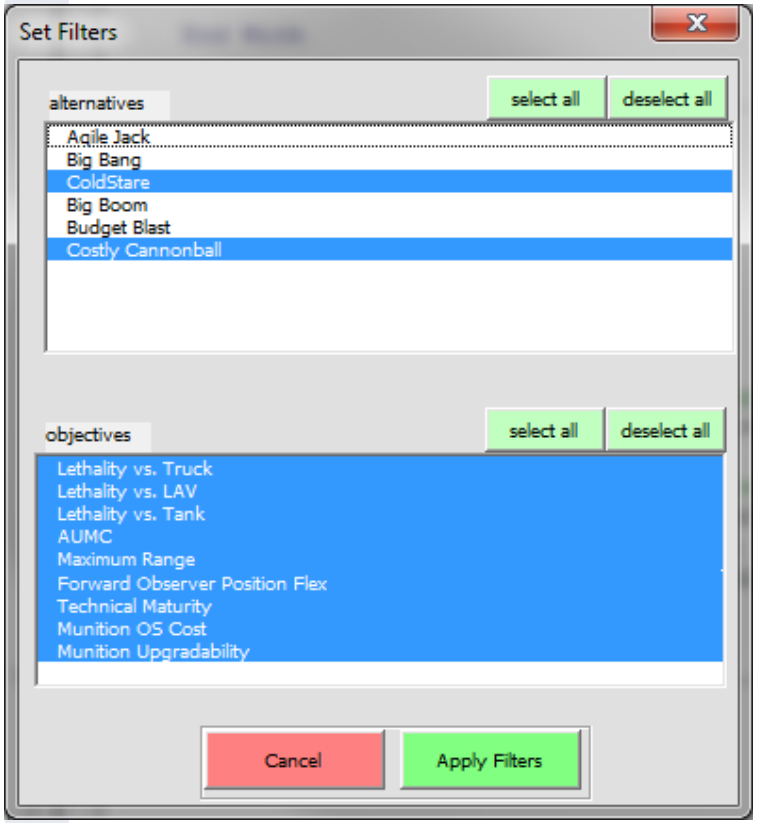
- What have we missed and should we add?
- Is there another tool available to all that does this better?
- What should we read re. novel approaches for analyzing and reporting on uncertainty/sensitivity?

- Email: rswanson@drc.com

Backup

Set Filters





- Allow for more focused output

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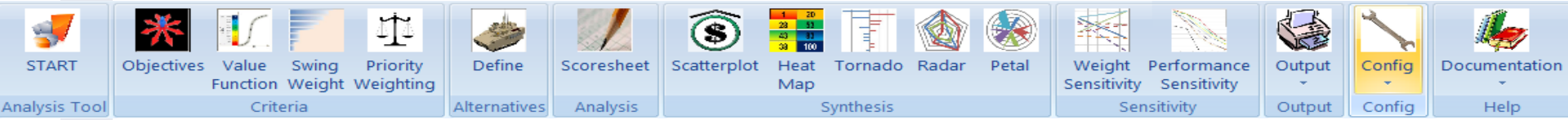
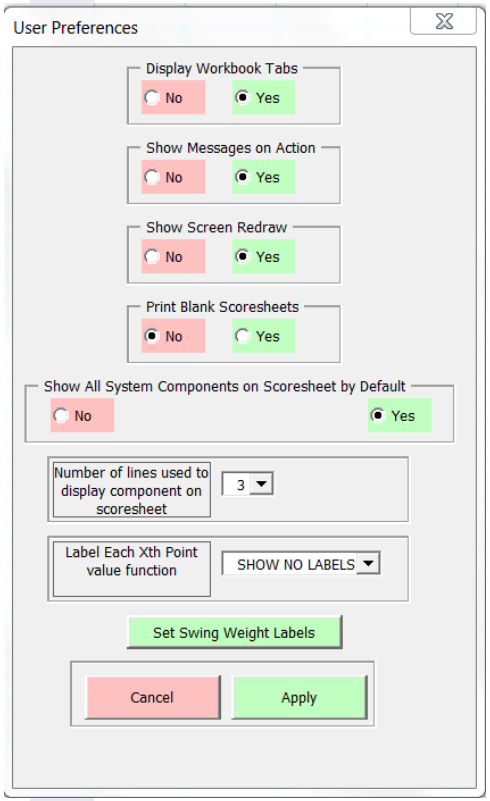
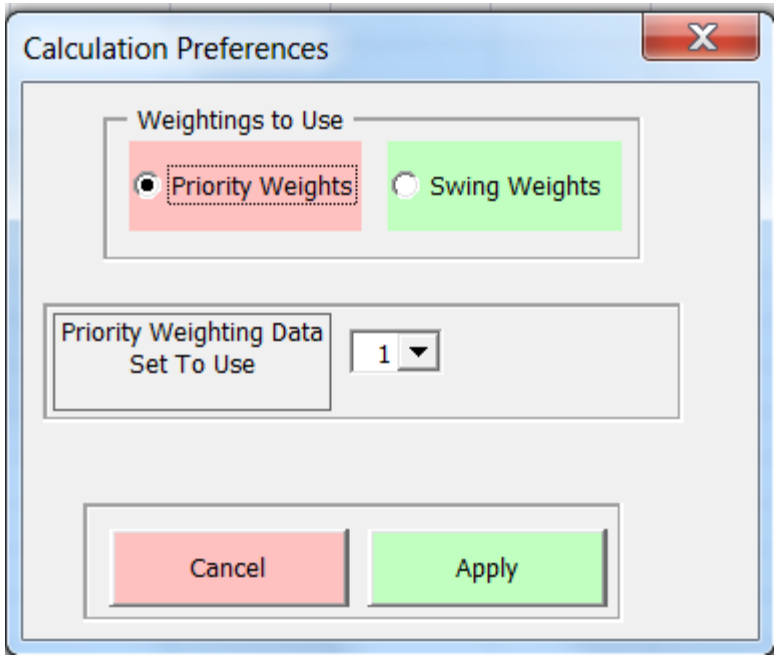
User and calculation preferences







- Set display options
- Specify priority or swing weight
- Identify data set to use

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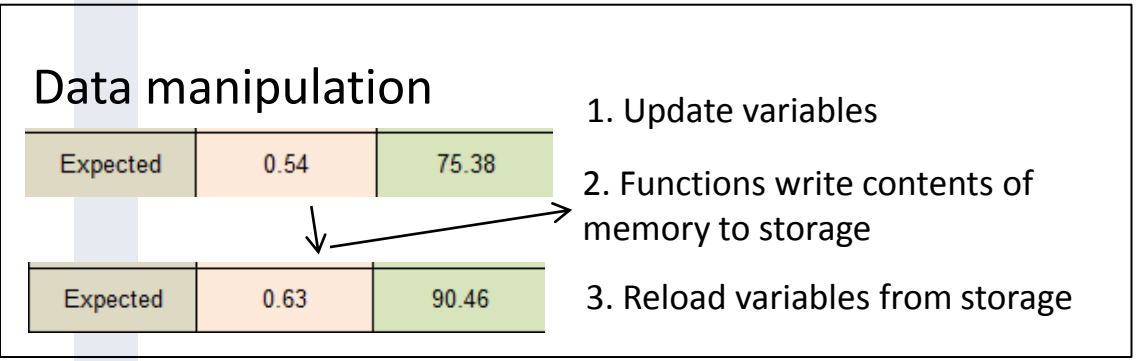
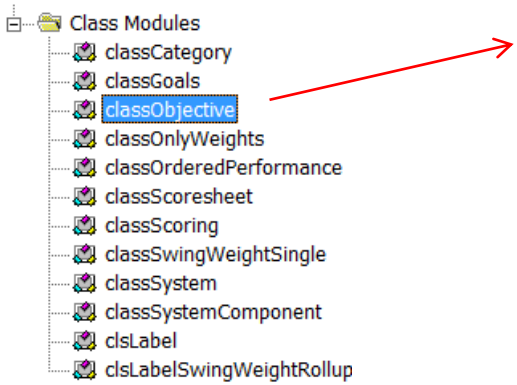
VBA Class Structure

- Edited data updated variables, which are then routed through various functions to update all relevant worksheets in data storage






```
' class module: objective

Public name As String
Public id As String
Public priority As Collection
Public priorityLower As Collection
Public priorityUpper As Collection
Public tier As Integer
Public category As classCategory
Public subcategory As classCategory
Public assumptions As String

' hold the pk and value columns
Public valueMappingPkTitle As String
Public valueMappingPks As Collection
Public valueMappingPkNumDecimals As Integer
Public valueMappingValueTitle As String
Public valueMappingValues As Collection
Public valueMappingValueNumDecimals As Integer

' define swing weight data
Public swingWeight As classSwingWeightSingle
```

```
weightToUse = objectiveClass.priority(priorityWeightingDataSetNumToUse)
Sheets(sheetnamePriorityWeighting).Cells(rowStart, colStart) = objectiveClass.name
```

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Data Storage

- Scalability facilitated by use of centralized data storage
- Data used throughout multiple worksheets and used in complex calculations traced back to single source
- Tight coupling of decision analysis data is transparent to the user
- Modifications propagate throughout the program, ensuring accuracy and simplicity when altering data