Conference briefing

Applying Cost Capability Curves

Lessons learned from US Air Force Analysis of Alternatives

San Diego, CA
09 June 2015

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What is a Department of Defense (DoD) Analysis of Alternatives (AoA)?

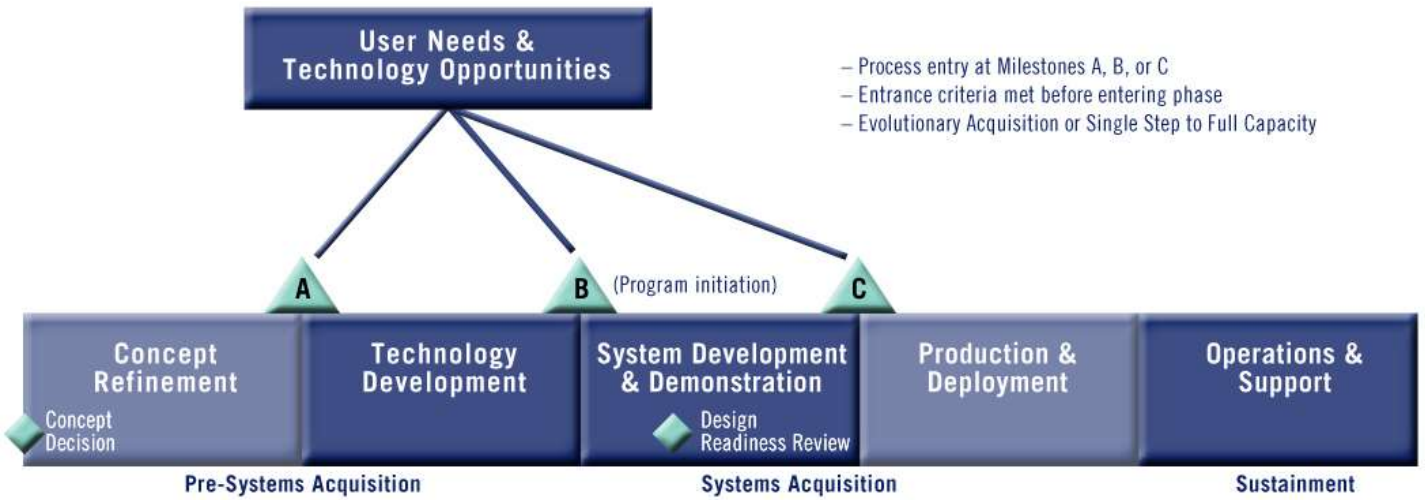
- An AoA is one of several inputs required to initiate a new weapon systems program
- Requirement for an AoA is regulatory and governed by the DoD acquisition process
- For Major Defense Acquisition Programs (MDAP) refer to 10 USC § 2366a&b: Milestone Certifications to Congress
- For IT systems refer to 40 USC § 1401 et seq.: Clinger-Cohen Act (CCA) of 1996 and PL 107-248 § 8808: CCA Compliance & Major Automated Information System (MAIS) funding
- MDAP defined as a program expected to have development cost more than $365M in Base Year 2000 dollars (BY00$)

While all the services conduct AoAs, Booz Allen primarily works with the Air Force (USAF)

- The Army uses its Training and Doctrine Command (TRADOC) Analysis Center (TRAC) to conduct AoAs
  - Booz Allen did support, however, Joint Cooperative Target Identification-Ground, a JFCOM AoA in 2011, where the Army was the lead service
- Navy AoAs tend to be conducted by the Federally Funded Research and Development Centers (FFRDC) like MITRE, for example
  - The last major Navy AoA engagement by Booz Allen was in 2009-2010 when the firm led the study on replacements for the Navy's Intelligence, Surveillance and Reconnaissance (ISR) EP-3 platform
- This briefing is focused on Air Force AoA, since it was the Air Force that implemented Cost Capability Curve analysis as part of its AoA process
  - While actual experience on Air Force AoA is drawn upon no reference will be made to a specific AoA and all data is notional
  - This is not a USAF-sponsored briefing
  - The opinions expressed herein are strictly those of the briefer

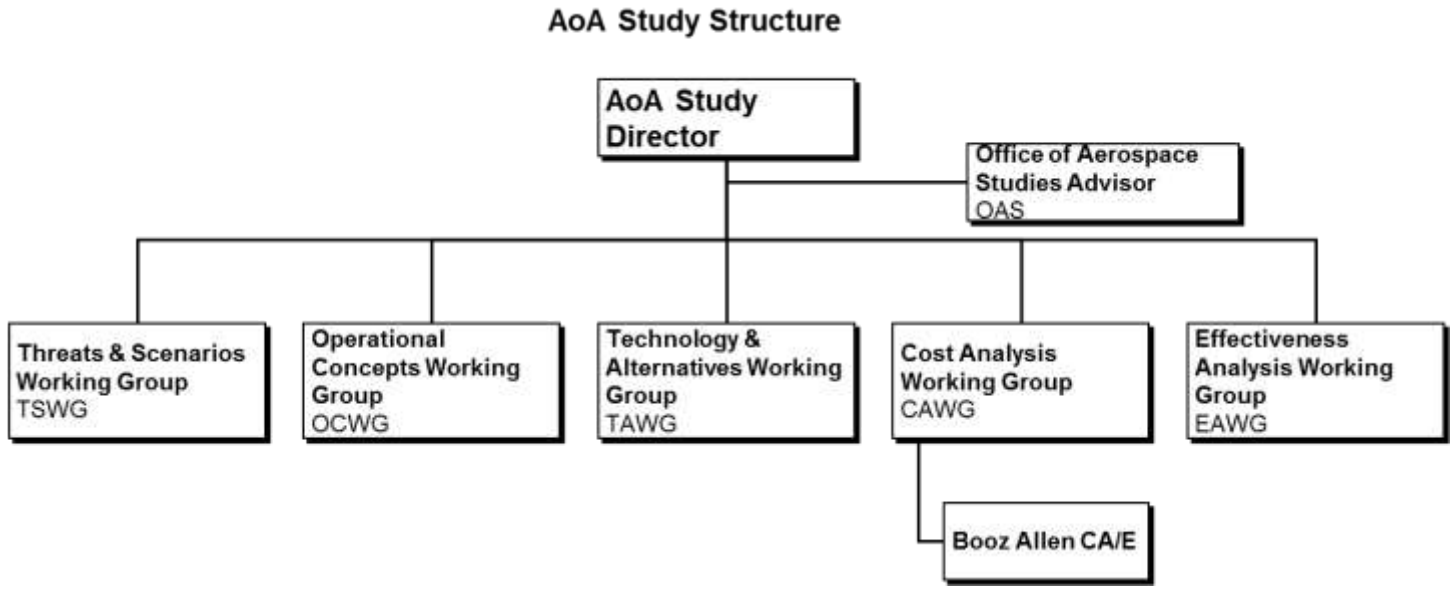
AoAs assess the operational effectiveness, costs and risks of alternative weapon system solutions

- The Defense Acquisition Management Framework utilizes a designated Milestone Decision Authority (MDA) to determine if a system can be initiated, continued, revised or cancelled
- AoAs provide MDAs critical information to help formulate their decisions, which are documented in an Acquisition Decision Memorandum (ADM)



For the purpose of this briefing we focus on the Cost Analysis (CAWG) and Effectiveness Analysis (EAWG) Working Groups

- The Study Director is usually uniformed military (O-5 is typical) from the responsible Major Command (MAJCOM)
- Booz Allen may have facilitators for each of the working groups and/or staff identifying the study scenarios, determining the alternatives for assessment, developing the employment concepts, and conducting effectiveness analysis or cost analysis



The CAWG develops the estimating methodology in accordance with study guidance,

- The CAWG gathers technical inputs from the Concept Characterization and Technical Descriptions (CCTD) documents produced by the TAWG for each alternative, and develops Life Cycle Cost Estimates (LCCE) by Alternative

- For space-based AoA Booz Allen often has to rely on parametric tools developed by Tecolote
  - Accredited tools for Air Force Space Command
  - Examples include Automated Cost Estimating Integrated Tools (ACEIT), Launch Vehicle Cost Model (LVCM), Unmanned Space Vehicle Cost Model (USCM)

- For non-space based AoA Booz Allen uses a Government Off The Shelf (GOTS) model, called the Aircraft Conceptual Design Cost model (ACDC) model, developed with RAND, the Institute for Defense Analyses (IDA), and the Air Force Cost Analysis Agency (AFCAA) cost estimating relationships (CER)
  - Accepted tool for Air Mobility Command (AMC) and Air Combat Command (ACC)

The EAWG conducts the effectiveness analysis for the AoA

- The effectiveness analysis is built on a rigorous hierarchy of:
  - System performance as defined by mission tasks (MTs) derived from the mission needs (e.g., kill tanks)
  - Measures of Effectiveness (MOEs) indicating how well the mission task are performed (i.e., battlespace effectiveness as defined by measures such as weapons expended for each tank kill)
  - Measures of Performance (MOPs) describing fundamental mission capabilities (e.g., weapon delivery error)

The EAWG conducts modeling and simulation with a variety of tools

- Tools of Choice
  - BRAWLER/MIL-AASPEM (air-to-air, 1v1 to few vs few)

    Provides air-to-air combat outcomes
  - SUPPRESSOR is a general-purpose digital simulation designed to simulate a multisided conflict; specifically designed to address the class of penetrator/air defense problems, with highly detailed interactions, characterized by large joint attack missions
  - Enhanced Surface to Air Missile Simulation (ESAMS) Engagement Model models interaction between a single airborne target and a specified Surface to Air Missile (SAM) fired from a designated location

    Provides probability of kill (Pk) data for RF air defense systems
  - Vulnerability & Endgame Analysis Determines how a threat projectile damages aircraft systems using FASTGEN and COVART models

CAWG estimates have always been combined with the EAWG effectiveness results to compare the alternatives

- Before cost capability curves came into being the results were known colloquially as the 'Chiclet chart' and summarized as a table shown below to the right

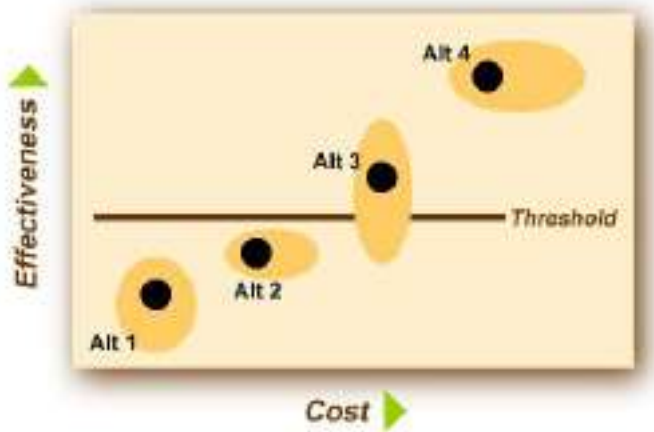
Effectiveness Results

	MT 1			MT 2			MT 3		
	MoE 1-1	MoE 1-2	MoE 1-3	MoE 2-1	MoE 2-2	MoE 2-3	MoE 3-1	MoE 3-2	MoE 3-3
Alternative 1									
Alternative 2									
Alternative 3									

LCCE Results

	R&D	Investment	O&S	Disposal	Total LCC
Alt 1					
Alt 2					
Alt 3					
...					
Alt *n*					

Cost Effectiveness Comparison



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Innovation of Cost Capability Curves in Air Force Studies began in 2011

- CORONA Fall 2011 Tasker-9 directed AF/A3/5 and SAF/AQ to conduct “Contractual and Requirements Sufficiency”
- Aug 2012 AFMC/A5R selected six pilot programs for the implementation of cost capability curves
- Nov 2012 new direction from Air Force leadership (Memorandum for implementation of contractual and requirements sufficiency) established a requirement for the presentation of life cycle cost versus capability tradeoff analysis for all AoA final reports
- AF/A3/5 directed A5R to establish the Air Force Requirements Review Group (AFRRG)
  - AFRRG replaced the Requirements Strategy Review (RSR) and Air Force Requirements Oversight Council (AFROC) Red Team
- 2013 AoA cost capability curves pilot projects briefed to the AFROC
  - The AoA the briefer worked on was held up by the chair of the AFROC as the ‘gold standard’ and cost capability curve results were briefed up to the Vice Chair of the Air Force
  - Other pilot projects attempts to implement the analysis were not as successful

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Imagine the USAF has a front line fighter with a subsystem that requires updating

- Suppose the F-4 Phantom fighter-bomber has an electronic warfare (EW) system that requires an update

- The options are either:
  - Alt 0 - additional maintenance at greater cost over time
  - Alt 1 - an enhanced baseline capability that addresses parts obsolescence, or
  - Alt 2 - new system with

    Radar Warning Receiver

    Radar jammer

    Counter Measures Dispenser

- For Alt 2 several additional capabilities will be studied:
  - Ability to provide location information on ground-based threats (Advanced Geolocation)
  - Missile Warning System (MWS)
  - millimeter Wave detection (mmW)
  - Fiber Optic Towed Decoy (FOTD)

Each possible combinations of four capabilities were examined

Alternative 2-1 • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS	**Alternative 2-2** • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • **Fiber Optic Towed Decoy (FOTD)**
Alternative 2-3 • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • **Millimeter Wave detection (mmW)**	**Alternative 2-4** • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • **mmW** • **FOTD**
Alternative 2-5 • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • **Missile Warning System (MWS)**	**Alternative 2-6** • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • **MWS** • **FOTD**

The possible permutations available to Alt 2 result in 16 versions

Alternative 2-7 • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • MWS • **mmW**	**Alternative 2-8** • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • MWS • mmW • **FOTD**
Alternative 2-9 • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • **Advanced Geolocation**	**Alternative 2-10** • **Description:** New internal EW system • **Characteristics:** • RWR, ICS, and CMDS • Advanced Geolocation • **FOTD**
Alternative 2-11 • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • Advanced Geolocation • **mmW**	**Alternative 2-12** • **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • Advanced Geolocation • mmW • **FOTD**

Permits a stepwise increase in capability

Alternative 2-13	Alternative 2-14
• **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • Advanced Geolocation • **MWS**	• **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • Advanced Geolocation • MWS • **FOTD**
Alternative 2-15	**Alternative 2-16**
• **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • Advanced Geolocation • MWS • **mmW**	• **Description:** New internal EW system • **Characteristics:** • RWR, Jammer, and CMDS • Advanced Geolocation • MWS • mmW • **AFOTD**

AoA CAWG develops a life cycle cost estimate (LCCE) for each alternative/capability

- Costs were developed by Alternative and for Alternative 2 (new EW system) costs were developed by capability
- For example the cost for the RWR was estimated separate from the CMDS and separate from a Fiber Optic Towed Decoy (FOTD), etc.
- Sixteen possible combinations of capabilities were estimated
- Total risk adjusted LCCE was used for the Y-axis
- Effectiveness analysis was run by capability as well permitting a comparison of cost and effectiveness

The cost side of the cost capability curve is relatively simple; translating effectiveness is difficult

- Effectiveness analysis results (e.g. P_k) are not in a structure that easily translates to the X-axis on a chart to compare to cost
- Need to develop a subjective translation of Effectiveness working together with the end user community
- Actual effectiveness analysis results by any AoA candidate capability are classified
- What follows is strictly notional and not based on actual results

Develop a methodology to translate specific results to weighted utility

- Detect
  - How many threats can the RWR detect?
  - How many threats are left unambiguous?
  - How many threats can the system geolocate?
  - What is the missile warning system effectiveness?
- Deny/Deceive/Disrupt
  - How many threats can the jammer detect?
  - How many threats can the jammer burn through?
  - How much do countermeasures reduce lethality?
- Defeat
  - How much does the FOTD reduce lethality?
- Reliability

- The answers to these questions are the objective of the effectiveness analysis set up by the study plan

In interviews with end users determine the weighting of the effectiveness

- For example to the user Deny/Deceive/Disrupt is equally important as Defeat and twice as important as Reliability
- Detect is 2.5 times as important as Deny/Deceive/Disrupt

System Attribute	Value
1. Detect	0.5
2. Deny/Deceive/Disrupt	0.2
3. Defeat	0.2
4. Reliability	0.1
Total	**1.0**

For the example of Detection each architecture was scored by summing total effectiveness and dividing by 7 (notional results)

- Multiply the results by 0.5 (notional example) because the user had determined half of his utility came from the ability to detect a threat

	EFFECTIVENESS							
	Detect							0.5
		0.4	0.2	0.1	0.05			0.75
Architectures	% of all threats detected	% of priority 1 threats detected	% of priority 2 threats detected	% of priority 3 threats detected	% of priority 4 threats detected	% of threats left Unambiguous	% Geolocated Threats	Utility
Alt 0	15%	5%	3%	6%	60%	4%	0%	0.133
Alt 1	85%	40%	80%	100%	100%	80%	0%	0.693
Alt 2	95%	98%	100%	100%	100%	98%	85%	0.966
Alt 2+FOTD	95%	98%	100%	100%	100%	98%	85%	0.966
Alt 2+mmW	96%	99%	100%	100%	100%	98%	85%	0.969
Alt 2+mmW+FOTD	96%	99%	100%	100%	100%	98%	85%	0.969
Alt 2+MWS	95%	98%	100%	100%	100%	98%	85%	0.966
Alt 2+MWS+FOTD	95%	98%	100%	100%	100%	98%	85%	0.966
Alt 2+MWS+mmW	96%	99%	100%	100%	100%	98%	85%	0.969
Alt 2+MWS+mmW+FOTD	96%	99%	100%	100%	100%	98%	85%	0.969
Alt 2+Advanced Geo	95%	98%	100%	100%	100%	98%	95%	0.980
Alt 2+Advanced Geo+FOTD	95%	98%	100%	100%	100%	98%	95%	0.980
Alt 2+Advanced Geo+mmW	96%	99%	100%	100%	100%	98%	95%	0.983
Alt 2+Advanced Geo+mmW+FOTD	96%	99%	100%	100%	100%	98%	95%	0.983
Alt 2+Advanced Geo+MWS	95%	98%	100%	100%	100%	98%	95%	0.980
Alt 2+Advanced Geo+MWS+FOTD	95%	98%	100%	100%	100%	98%	95%	0.980
Alt 2+Advanced Geo+MWS+mmW	96%	99%	100%	100%	100%	98%	95%	0.983
Alt 2+Advanced Geo+MWS+mmW+FOTD	96%	99%	100%	100%	100%	98%	95%	0.983

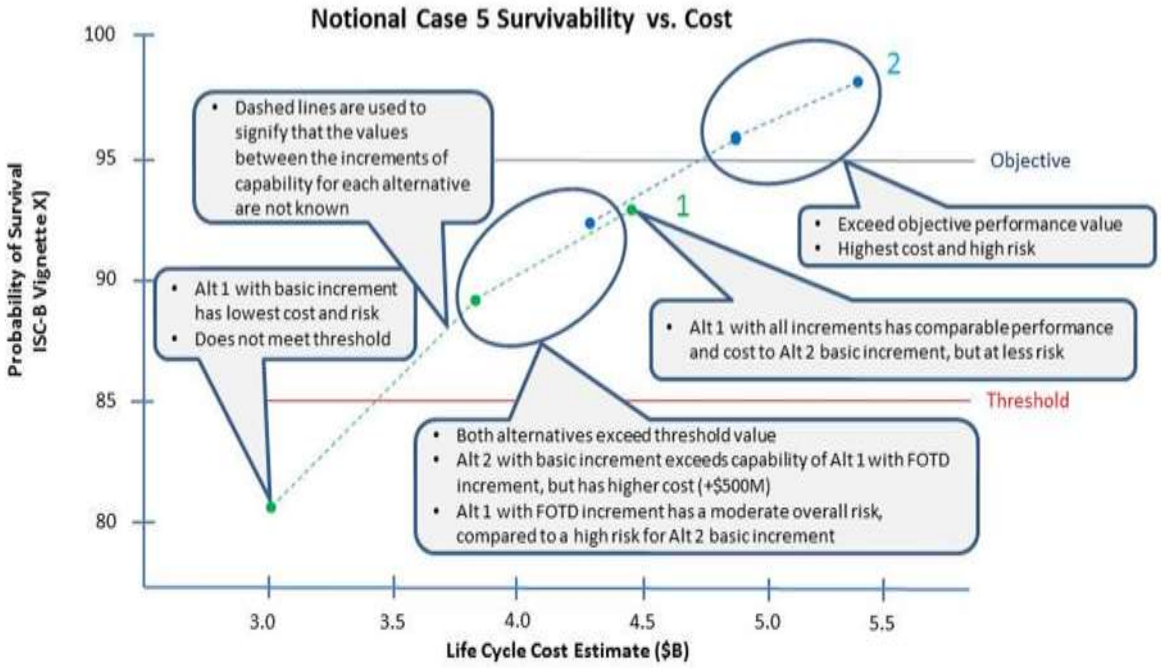
Completely notional

Completely notional

This process was repeated for each category and then summed to arrive at a total utility score for each architecture

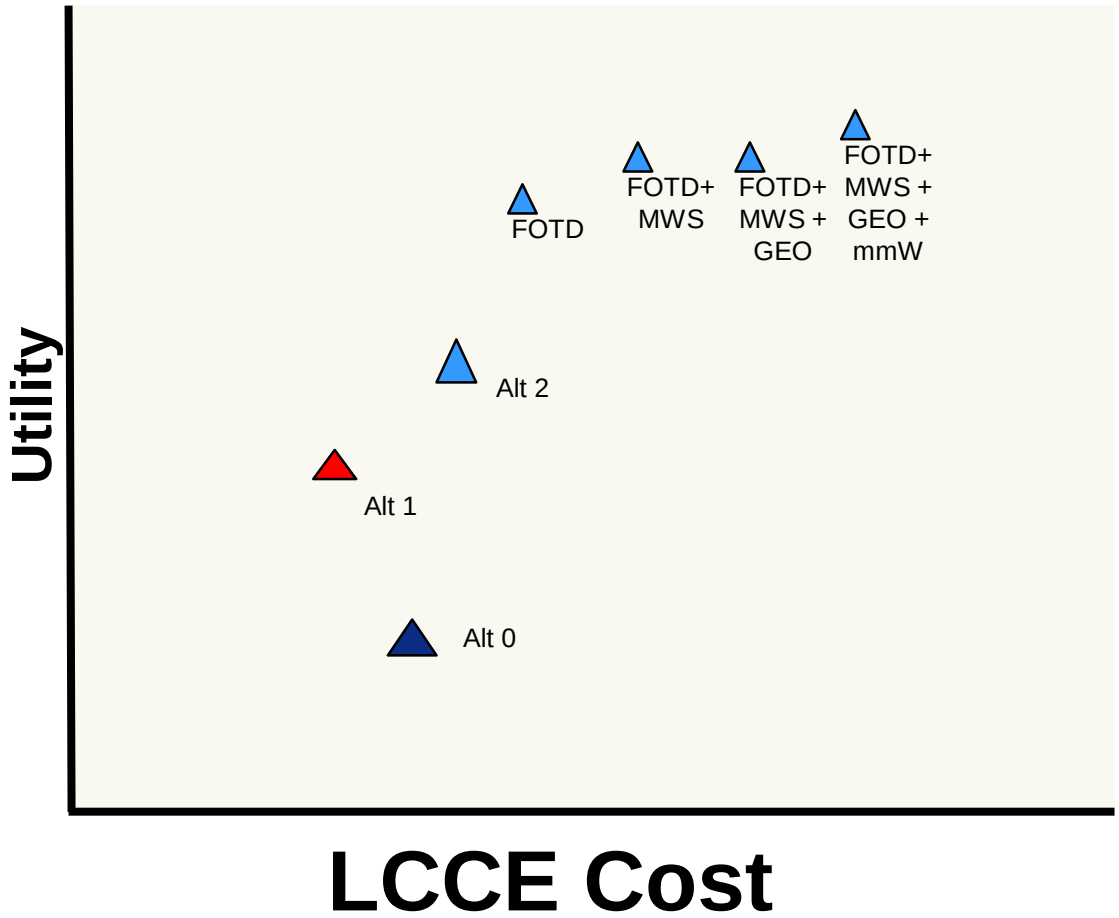
	EFFECTIVENESS																								
	Detect							0.5	Deny/Deceive/Disrupt										0.2	Defeat			0.2	Reliability	0.1	
	0.4		0.2		0.1	0.05		0.75																		
Architectures	% of all threats detected	% of priority 1 threats detected	% of priority 2 threats detected	% of priority 3 threats detected	% of priority 4 threats detected	% of threats left Unambiguous	% Geolocated Threats	Utility	% of all threats jammer detected	% of priority 1 threats jammer detected	% of priority 2 threats jammer detected	% of priority 3 threats jammer detected	% of priority 4 threats jammer detected	% of all threats burnthrough	% of priority 1 threats burnthrough	% of priority 2 threats burnthrough	% of priority 3 threats burnthrough	% of priority 4 threats burnthrough	Utility	CM RIL	FOTD RIL	MWS RIL	Utility		Utility	Total Utility
Alt 0	15%	5%	3%	6%	60%	4%	0%	0.133	50%	60%	80%	80%	90%	45%	40%	50%	50%	50%	0.595	70%	0%	0%	0.233			0.2321
Alt 1	85%	40%	80%	100%	100%	80%	0%	0.693	94%	90%	90%	100%	100%	55%	50%	60%	60%	60%	0.759	75%	0%	0%	0.250			0.5482
Alt 2	95%	98%	100%	100%	100%	98%	85%	0.966	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	0%	0.267			0.7306
Alt 2+FOTD	95%	98%	100%	100%	100%	98%	85%	0.966	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	0%	0.450			0.7673
Alt 2+mmW	96%	99%	100%	100%	100%	98%	85%	0.969	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	0%	0.267			0.7320
Alt 2+mmW+FOTD	96%	99%	100%	100%	100%	98%	85%	0.969	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	0%	0.450			0.7687
Alt 2+MWS	95%	98%	100%	100%	100%	98%	85%	0.966	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	60%	0.467			0.7706
Alt 2+MWS+FOTD	95%	98%	100%	100%	100%	98%	85%	0.966	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	60%	0.650			0.8073
Alt 2+MWS+mmW	96%	99%	100%	100%	100%	98%	85%	0.969	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	60%	0.467			0.7720
Alt 2+MWS+mmW+FOTD	96%	99%	100%	100%	100%	98%	85%	0.969	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	60%	0.650			0.8087
Alt 2+Advanced Geo	95%	98%	100%	100%	100%	98%	95%	0.980	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	0%	0.267			0.7377
Alt 2+Advanced Geo+FOTD	95%	98%	100%	100%	100%	98%	95%	0.980	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	0%	0.450			0.7744
Alt 2+Advanced Geo+mmW	96%	99%	100%	100%	100%	98%	95%	0.983	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	0%	0.267			0.7392
Alt 2+Advanced Geo+mmW+FOTD	96%	99%	100%	100%	100%	98%	95%	0.983	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	0%	0.450			0.7758
Alt 2+Advanced Geo+MWS	95%	98%	100%	100%	100%	98%	95%	0.980	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	60%	0.467			0.7777
Alt 2+Advanced Geo+MWS+FOTD	95%	98%	100%	100%	100%	98%	95%	0.980	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	60%	0.650			0.8144
Alt 2+Advanced Geo+MWS+mmW	96%	99%	100%	100%	100%	98%	95%	0.983	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	0%	60%	0.467			0.7792
Alt 2+Advanced Geo+MWS+mmW+FOTD	96%	99%	100%	100%	100%	98%	95%	0.983	98%	95%	98%	100%	100%	94%	92%	95%	100%	100%	0.972	80%	55%	60%	0.650			0.8158

Notional AoA Final Report Cost/Cape Presentation from Office of Aerospace Studies



Alt	Performance, Cost, and Risk	T	O	Increments		
				Basic	+ FOTD	+ MMW
1	Probability of Survival	.85	.95	.81	.89	.93
	LCCE ($B)			3.0	3.8	4.5
	Risk			Low	Moderate	Moderate
2	Probability of Survival	.85	.95	.92	.96	.98
	LCCE ($B)			4.3	4.9	5.4
	Risk			High	High	High

The final product is a graphical representation of utility and cost



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Consider a driver education program with an asset that is out dated

- The cars used for instruction are so old they are no longer representative of models on the road today
- Constant break downs interfere with availability for instruction
- Cost of maintenance is growing
- Decision is made to conduct an AoA for a replacement vehicle

When considering new vehicles the school decides to buy an existing vehicle

- Desire is to minimize development cost by making acquisition of “off-the-shelf” product
  - Will still require signage and perhaps modification for a braking system on the passenger side
- Requirements are well known and understood
- Decision is made to look at a Chevrolet Cruze, Toyota Corolla, Honda Civic, Dodge Dart
- For the purpose of the study, maintaining the current vehicle is Alt 0
- Alt 1 - Cruze
- Alt 2 – Corolla
- Alt 3 - Civic
- Alt 4 - Dart

Cost estimates are performed only for modifications

- Each vehicle has a Manufacturer's Suggested Retail Price (MSRP) which sets the base cost for each alternative
- The user community requirements may, however, mean that there has to be a modification to standard vehicle features available from the manufacturer
- For example, the user community desires the ability to practice on automatic park assist
- The 2014 Corolla does not come with a park assist feature
- Estimate the cost of adding park assist to the MSRP of a Corolla
- Conduct similar analysis for any alternative (vehicle) missing a desired capability

Cost capability curve analysis does not lend itself to the results of this study example

- (Alt 1) Chevy Cruze 2014 MSRP includes the park assist feature
- The study estimate for the (Alt 2) Toyota Corolla adds an estimated cost of adding park assist to the MSRP
- There is no way of saying what the incremental cost of additional capability (park assist) is
- Furthermore although the vehicles are identified as “Alt 2” or “Alt 3” in briefings of results, an easy translation back to the make and model exists
- This means the results are too much like a sourcing of actual possible vendor offers and mimics a source selection
  - Not the purpose of an AoA

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Primary lessons learned identified by HQ AFMC/A2/5

- Most beneficial when analysis performed pre-MS A
  - *The level of technical data to inform cost and effectiveness may not exist at this stage in the opinion of Booz Allen analyst*
- No one-size-fits-all formula
- Takes dedicated time and resources to do it right
- Requires specialized skill sets
- Requires close interactions among stakeholders
- Affordability decisions are better informed when adequate time and resources are dedicated to cost capability analysis