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Using Value-Focused Thinking for Engineered Resilient Systems

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Abstract

The DoD needs their systems to be resilient in the face of an ever changing world. To increase resilience in future systems the DoD has created a program called Engineered Resilient Systems. Resilience can be broken down into two parts, mission and platform resilience. Mission resilience is the ability of a system to repel, resist, absorb, and recover from environments and threats that occur on planned missions. Platform resilience is the ability of a system platform to adapt to new missions and new threats.

The University of Arkansas department of Industrial Engineering is working for the ERS program researching resilience. After the fall of the Soviet Union, the DoD decided their acquisition decisions need to focus on capability based planning instead of threat based planning. A value-focused thinking multiple objective decision analysis model has been a useful tool for capabilities based assessments. If all performance objectives can be categorized as mission or platform resilience, this extra value above the threshold of the minimum performance can provide mission and platform resilience. This information can be displayed in a value component chart, a floating value component chart, and as a reliance value and opportunity chart. These graphs allow decision makers to consider resilience in the acquisition decision making process.

Contents

1. Introduction

"The mission of the United States Department of Defense (DoD) is to equip and deploy the military forces needed to deter war and assure national security". To do this, the DoD needs to have continual readiness. They deploy many complex and simple systems to maintain readiness. Because the DoD needs to continue to deploy its systems throughout the world for the foreseeable future, the systems it deploys need to be resilient. One of the DoD definitions of a resilient system is to be "trusted and effective out of the box in a wide range of contexts, easily adapted to many others through reconfiguration or replacement with graceful and detectable degradation of function." (Goerger, Madni, & Eslinger, 2014)

In recent years, the DoD has realized that military systems have short lifetimes. In the rapidly changing battlefield, the DoD systems that have not been able to adapt to new threats have lost their usefulness. As a result, the DoD community has increased interest in designing in resilience to current and future threats.

In response to this growing challenge, the DoD created a program called Engineered Resilient Systems (ERS). ERS focuses on the effective and efficient design and development of complex systems across their lifecycle. ERS argues that resilience is a vital part of system design. Without resilience, a system risks ineffectiveness or failure in a future use or new environment. However, a design change that makes a system more resilient may have important performance, cost, and schedule implications. DoD wants to make these trade-offs more visible.

Goerger et al. defines resilience in four components in *Figure 1*, the ability to repel, resist, or absorb threats, the ability to recover from threats, the ability to adapt to new threats, and broad utility. (Goerger, Madni, & Eslinger, 2014) These four components can be viewed as mission resilience and platform resilience. The ability to repel, resist, or absorb known threats and the ability to recover from these threats can be described as mission resilience. Platform resilience is the additional capability that enables the platform to be adapted to new missions and new threats beyond those currently planned for the system.

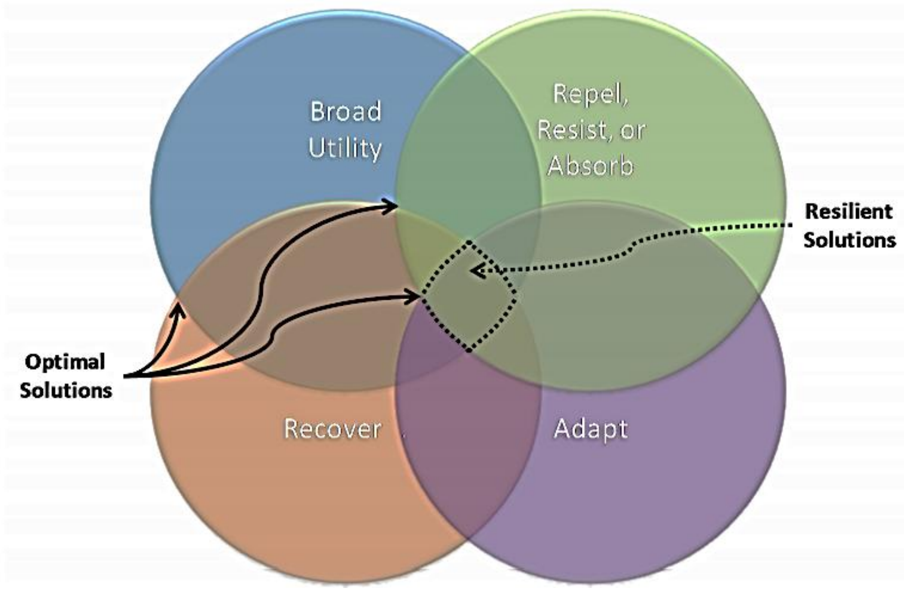

Figure 1- Properties of Resilient DoD Systems and System-of-Systems (Goerger, Madni, & Eslinger, 2014)

The ERS program is researching different ways the DoD can evaluate system resiliency and show the trade-offs to DoD decision makers. These approaches can include a single resilience metric, a set of metrics that can define resiliency, a framework to evaluate system resilience and platform resilience such as *Figure 2*, or other possible approaches. *Figure 2* is the way the team currently views resilience. It is shown as an influence diagram illustrating the relationship between design decisions and resilience response decision and the life cycle cost, value, and affordability. The design decision affects different uncertainties such as survivability, reliability, and others. These “ilities” along with resilience response decisions can affect the value, life cycle cost, and the affordability.

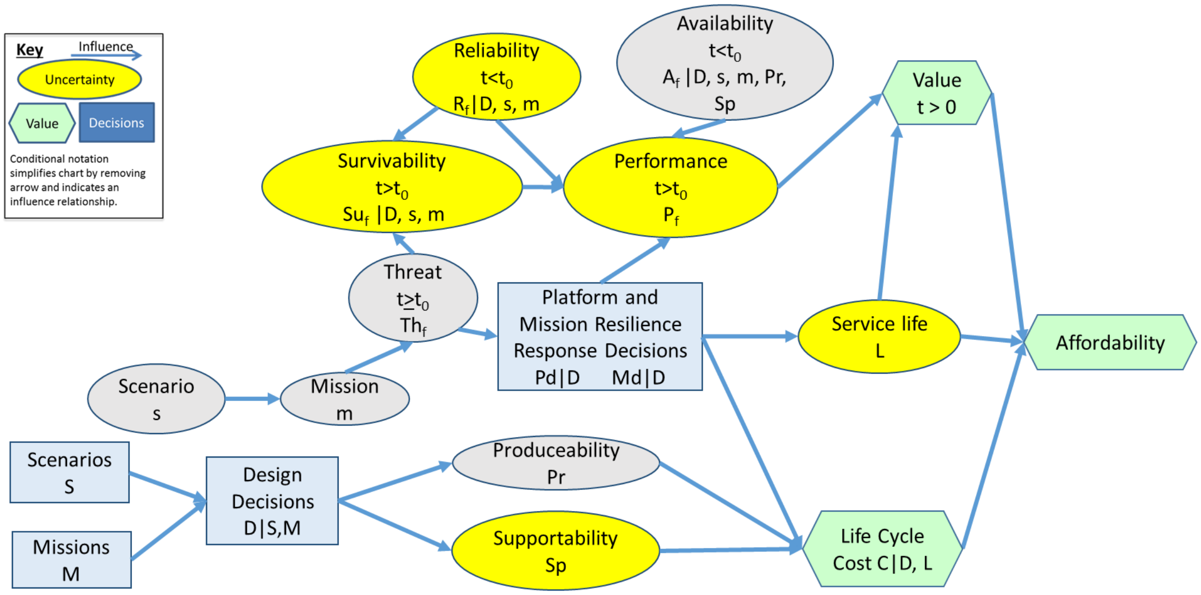

Figure 2-Current University of Arkansas research Framework.

In addition, the University of Arkansas ERS Project Team is also using a new definition of value to quantify resilience using existing systems performance measures and existing decision support tools. This method can consider many of the aspects of *Figure 2*. However, the example used does not consider the uncertainties in gray.

2. DoD Acquisition

During the Cold War, the DoD acquisition was based on threat-based assessment. The military developed and procured equipment to meet requirements to deter the Soviet Union and the Warsaw Pact. However, when the Soviet Union fell, the United States needed a new way to assess military requirements. In addition, new evolving threats and technologies led to an asymmetric warfare. The enemy comes in many different forms with multiple tactics all over the world. In this dynamic world, threat based assessment and acquisition is not appropriate.

In the 1990s, capability based planning and assessment planning was developed to remedy the problems with threat-based assessment. Capability based assessment involves functional area analysis, functional needs analysis, and functional solutions analysis "This analysis is meant to: define the mission, identify capabilities required, determine the attributes/standards of the capabilities, identify gaps, assess operational risk associated with the gaps, prioritize the gaps, identify and assess potential non-material solutions, and provide recommendations for addressing the gaps." (AcqNotes, n.d.) After this assessment, a system development is started using the process in *Figure 3*. We will use a UAV example to illustrate the approach we present.

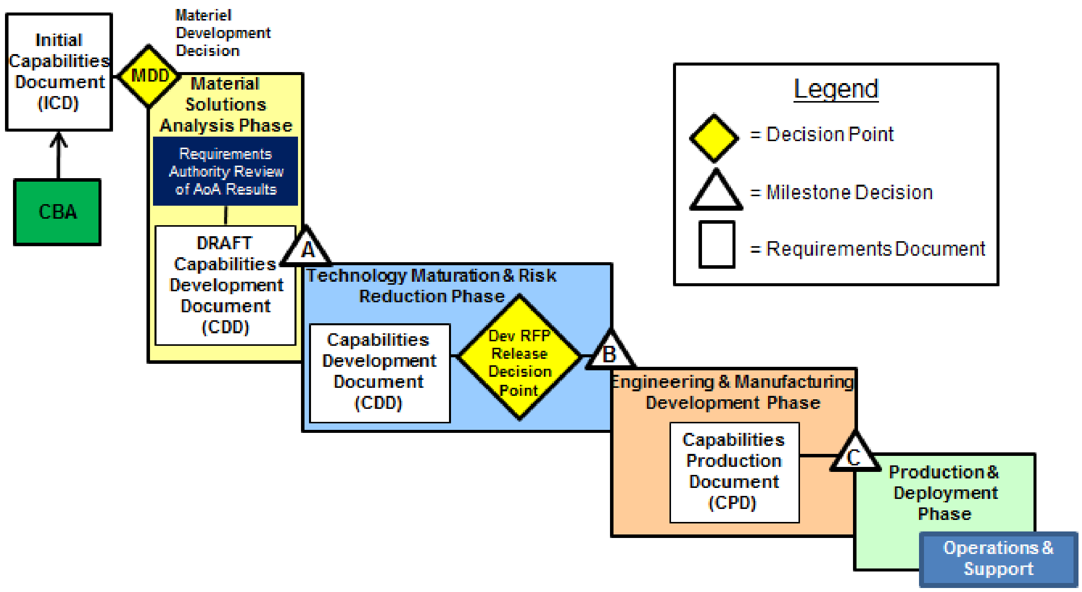

Figure 3- System Acquisition Process (AcqNotes, n.d.)

2.1 Requirements Analysis

One of the methods that the DoD uses to analyze different solutions is requirements analysis. In requirements analysis, key performance parameters (KPPs), the most important attributes of a system are identified. The important but not critical attributes are called key system attributes (KSAs). In each KPP and KSA, the threshold, or the point at which it cannot be below, and the objective are identified as in *Table 1*.

Measure (attribute)	*Threshold*	*Objective*
Availability	*80%*	*85%*
Probability of Detecting Objects	*88%*	*92%*
etc.		

Table 1- Illustrative Requirements

However, there are problems with requirements analysis. First, the two points are difficult to determine. Second, the two points do not give us the relative value of the threshold and objective or the value across the range of the attribute. The threshold value is the minimum acceptable value and the objective is the ideal value. This is shown in *Figure 4.* Note that there is no value added for levels above the objective. In addition, a second method of performing requirement view exists and is shown as a dotted line in *Figure 4*. In this method, the threshold earns the full value and no extra value is added as performance increases.

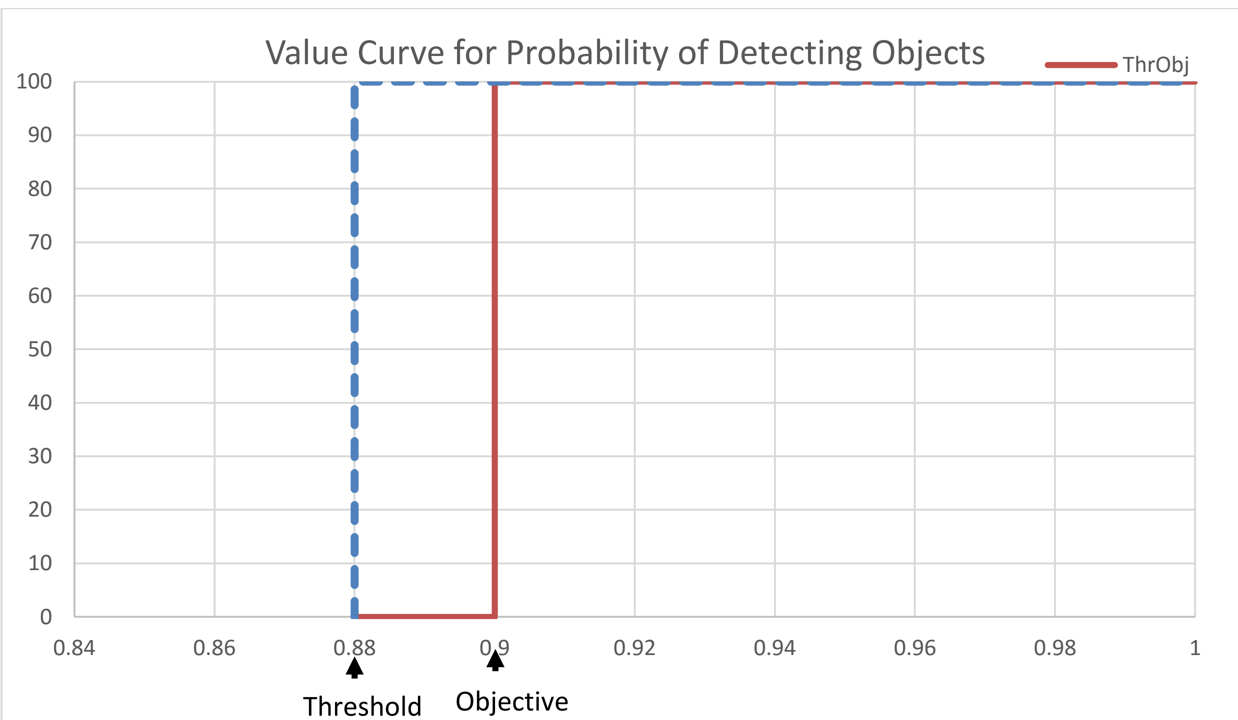

Figure 4-Requirements Value Curve

This is a large problem; it is unrealistic to have no change in value from threshold to the objective. Moreover, there may be added value after objective. For example, if the objective of payload for a bomber was at a certain level, but it was possible to reach much higher, should they not aim for much higher? In resilience terms, the additional capability above the threshold (and even the objective), may improve system resilience.

The second requirements problem is that point requirements to not enable a full exploration of the affordable tradespace. It only provides a long list of requirements, which does not give the best insight into value. Moreover, the technique assumes that all KPAs are equal and all KSAs are equal. This is a coarsening of information. For, even critical performance measures have different importance weights in real situations.

An example of the challenges with requirements view is the Army's Future Combat System (FCS). FCS was a large program intended to equip brigades with an advanced set of integrated systems. Requirements were still being defined when the program was cancelled in 2009. The program spent 6 years and 18 billion dollars before it was cancelled. The program began with seven KPPs, but as the KPPs evolved and expanded, the lower level requirements continued to grow. When the Army cancelled the project, they had over 50,000 lower level requirements.

2.2 Multiple Objective Decision Analysis

In 1976, Keeney and Raiffa created multiple objective decision analysis (MODA). (Keeney & Raiffa, Decisions with Multiple Objectives: Preference and Value Tradeoffs, 1976) Using the additive value model shown in *Figure 5*, MODA uses multiple measures with different weights and ranges of value for each measure to calculate the value.

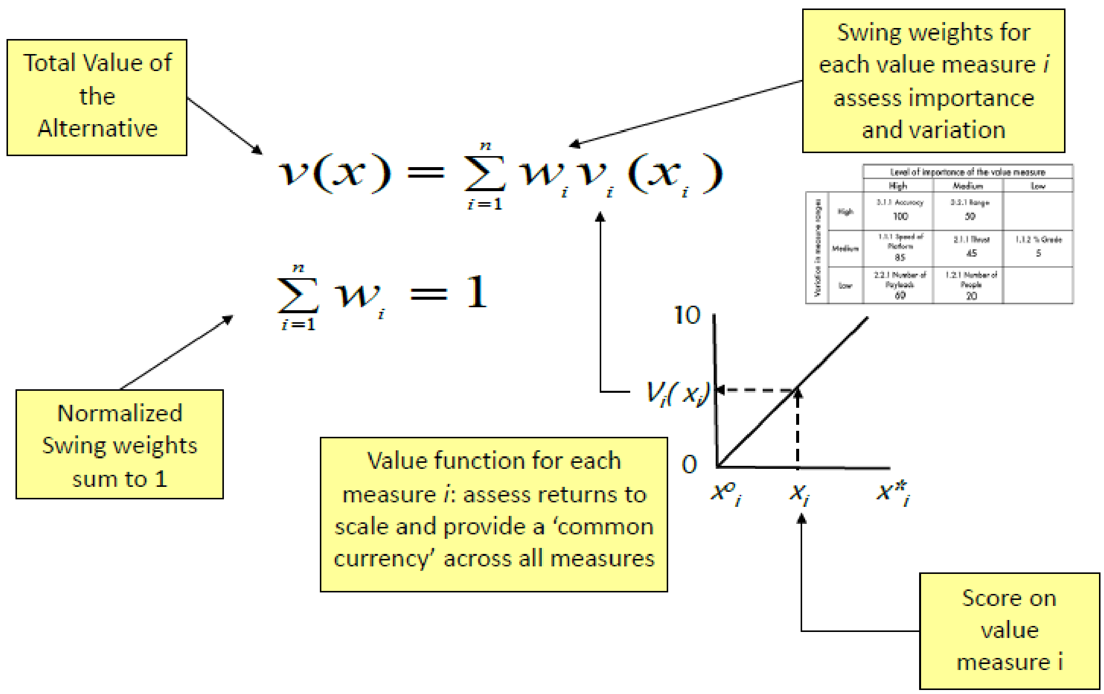

Figure 5- The Additive Value Model (Keeney & Raiffa, Decisions with Multiple Objectives: Preference and Value Tradeoffs, 1976)

2.3 Alternative-Focused Thinking

The first method DoD used to perform MODA was using alternative-focused thinking (AFT) also called *local* in the European decision analysis literature (Keeney & Raiffa, Decisions with Multiple Objectives: Preference and Value Tradeoffs, 1976). This method improves upon requirements analysis by adding value in between the threshold and the objective and after the objective, making it a value curve rather than two points. Often decision makers use the current system as the worst alternative with a value of zero. However, in MODA, a value of zero does not mean zero value but instead the minimum acceptable. The current system can be lower than the threshold. In this case, the threshold has a value. Using AFT, the highest value of 100 is typically given to the value of the best alternative in the measure. However, a second method exists that uses the objective as the full value instead of the best alternative. Overall, *Figure 6* provides a notional value curve using the above assumptions.

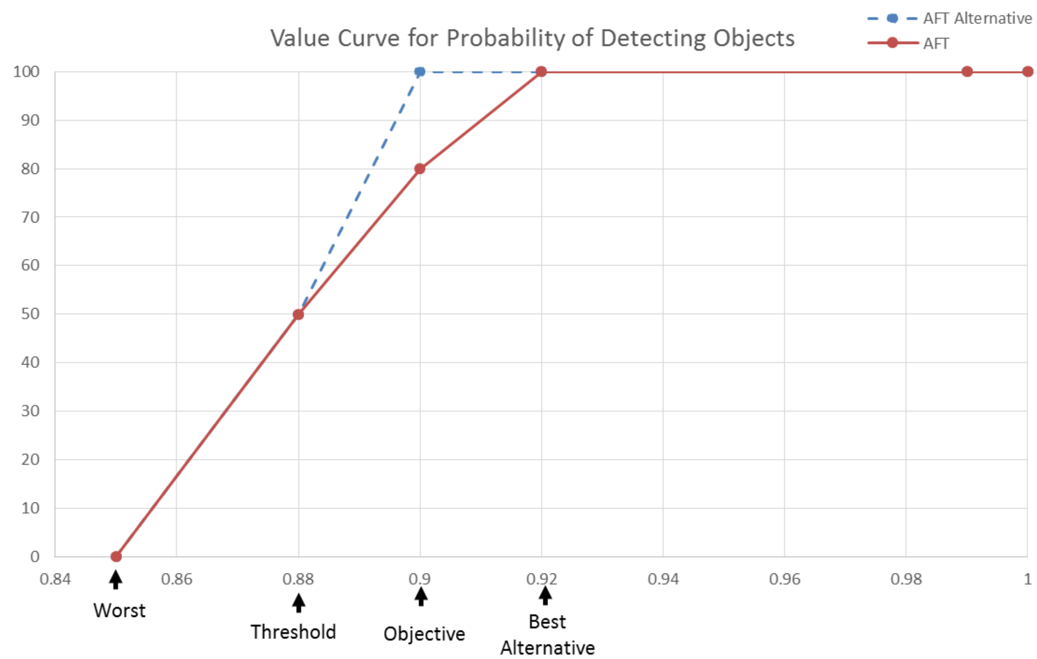

Figure 6- Alternative-Focused Thinking (Local) Value Curve

The first step is to develop an alternative focused thinking MODA model is to gather the data on the alternatives. The scores for each alternative are shown in *Table 2*.

Alternative Scores	UAS weight (lbs.)	UAV volume (ft3)	# of people to operate	Reliability	UAV range (km)	P[Detect Objects]	All weather capability	UAV endurance (hrs.)	P[UAV Recovery]
Cardinal	5	12	1	0.9	60	0.92	3	0.5	0.6
Buzzard	10	15	1	0.8	60	0.9	1	1	0.7
Crow	10	20	2	0.7	70	0.92	3	1	0.8
Pigeon	15	30	2	0.6	80	0.92	3	1.5	0.9
Robin	30	40	2	0.6	90	0.9	1	2	0.9
Hypothetical Best	5	12	1	0.9	90	0.92	3	2	0.9
Ideal	5	10	1	1	100	1	5	2.5	0.9

Table 2- Alternative Performance Scores

The next step in an alternative focused thinking is to develop a value table. In a value table, the scores on each measure and the value for the scores received are displayed. In alternative focused thinking, the highest value of 100 is given to the highest alternative. *Table 3* shows the value table for the UAV example.

UAS weight (lbs.)		UAV volume (ft3)		# of people to operate		Reliability		UAV range (km)		P[Detect Objects]		All weather capability		UAV endurance (hrs.)		P[UAV Recovery]	
X	V	X	V	X	V	X	V	X	V	X	V	X	V	X	V	X	V
5	100	12	100	1	100	0.6	0	50	0	0.85	0	1	0	0.5	0	0.5	0
10	86	20	75	2	50	0.7	25	60	20	0.9	50	2	25	1	60	0.6	47
20	58	30	50	3	0	0.8	80	80	60	0.92	100	3	100	1.5	80	0.7	77
30	29	40	25			0.9	100	90	100	0.99	100	4	100	2	100	0.8	90
40	0	50	0			1.0	100	100	100	1	100	5	100	2.5	100	0.9	100

Table 3- Value Curve Table

The swing weights for each measure are based on how important each measure is to the decision maker and how large the allowed range is for the values of the measure. They can be assessed using a swing weight matrix shown in *Figure 7.*

		Importance of the value measure to the decision		
		High*	Medium	Low
Impact of the value measure range variation	High	A	B_2	C_3
	Medium	B_1	C_2	D_2
	Low	C_1	D_1	E

Figure 7- Swing Weight Matrix (Parnell, Driscoll, & Henderson, Decision Making in Systems Engineering and Management, 2011)

Mathematically, these values are assessed by arbitrarily making the highest measure 100 or making the lowest value 1 and comparing the range of each measure with an already assessed measure. The resulting unnormalized weight must follow the 'down and right' relationships:

A > all other cells

B1 > C1, C2, D1, D2, E

B2 > C2, C3, D1, D2, E

C1 > D1, E

C2 > D1, D2, E

C3 > D2, E

D1 > E

D2 > E

To determine the normalized weights, the unnormalized weight for each measure is divided by the sum of all of the unnormalized weights.

A UAV example of a completed swing weight matrix that follows all rules is *Table 4*, which is the swing weight matrix for all of the examples throughout the paper. For the example the measures were placed in the appropriate rankings of importance and variance based on *Table 2*. Following the guidelines, the UAV endurance was given a weight, fi, of one hundred, and the number of people to operate was given a weight of one. All other boxes were filled using the down and right relationship. All normalized weights, wi, were calculated by divide each unnormalized weight by the total unnormalized weight.

	Mission Critical			Important			Useful		
	Measure	fi	wi	Measure	Fi	wi	Measure	fi	wi
High Capability Gap variation	UAV endurance (hrs.)	100	0.28	All weather capability	50	0.14	P[UAV Recovery]	10	0.03
Medium Capability Gap	Reliability	80	0.22	UAV range (km)	40	0.11	UAV volume (ft3)	5	0.01
Small Capability Gap	P[Detect Objects]	50	0.14	UAS weight (lbs.)	20	0.06	# of people to operate	1	0.00

Table 4- Swing Weight Matrix

Value tables such as in *Table 2*, are also used to create the value curves such as in *Figure 9* and are used to calculate the score for the alternatives on each measure.

Each measure in *Table 3* is graphed to develop a value curve in *Figure 8*. The order of the curves shown in *Figure 7* directly follows the order of the measures in *Table 3*. The shape, slope, and direction of the curves can vary in a value curve. For many measures such as weight, there is a downward slope as the score increases the value decreases. For others such as probability, there is s curve because of diminishing return as more value is earned between 60 and 80 percent, that between 80 and 100. Lastly, for others such as all-weather capability have an s curve. This is because there is little value with low scores but the most value is obtained in the middle ranges and once that score is reached, more value is earned, but the returns on value are less.

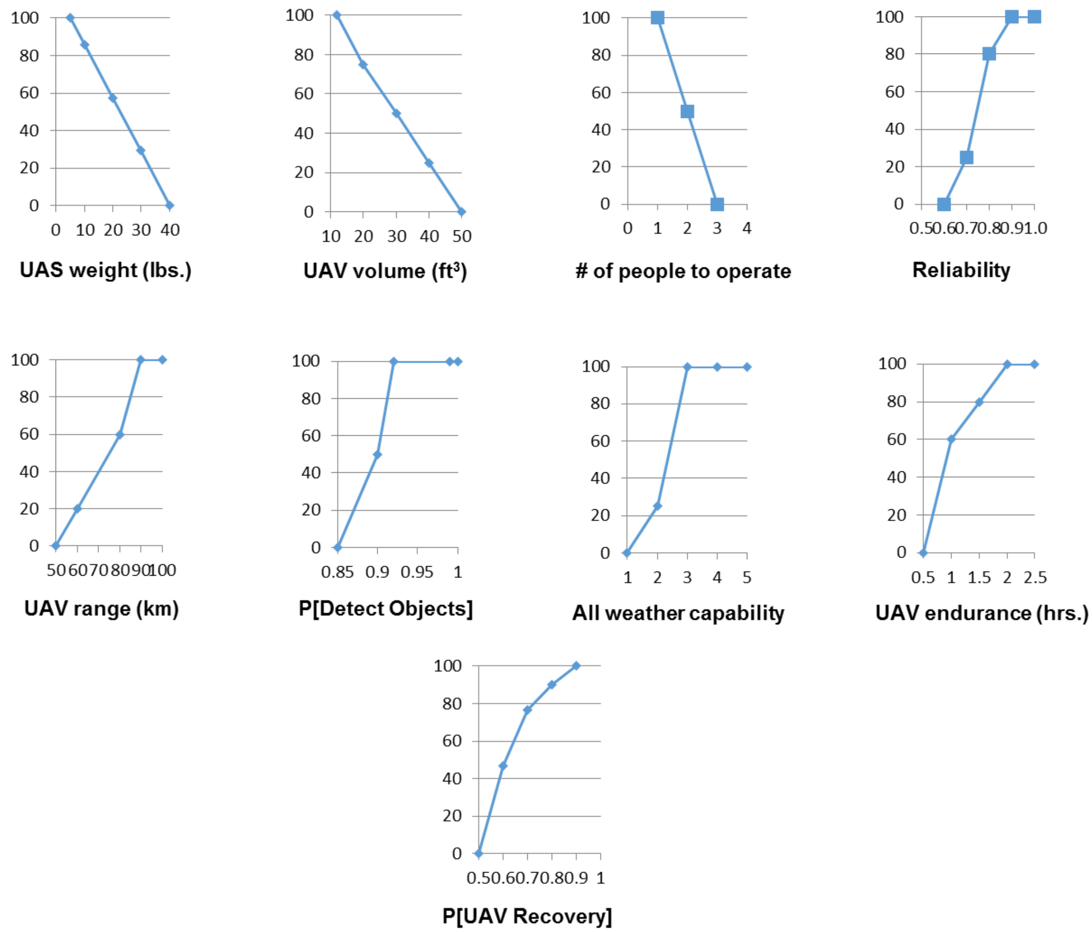

Figure 8- Example Value Curves

Using the performance data for the alternatives and the value curves from , we can calculate the alternative value on each measure. Using measures *Tables 2 and 3,* the value on each measure are a calculation of where they land on the value curve based on the data on the measure. The value for each alternative are shown in *Table 5.*

Alterative Value	UAS weight (lbs.)	UAV volume (ft3)	# of people to operate	Reliability	UAV range (km)	P[Detect Objects]	All weather capability	UAV endurance (hrs.)	P[UAV Recovery]
Cardinal	100	100	100	100	20	100	100	100	100
Buzzard	86	91	100	80	20	50	86	91	100
Crow	86	75	50	25	40	100	86	75	50
Pigeon	72	50	50	0	60	100	72	50	50
Robin	29	25	50	0	100	50	29	25	50
Hypothetical Best	100	100	100	100	100	100	100	100	100
Ideal	100	100	100	100	100	100	100	100	100

Table 5-Alternative Value on Each Measure

Swing Weights	UAS weight (lbs.)	UAV volume (ft3)	# of people to operate	Reliability	UAV range (km)	P[Detect Objects]	All weather capability	UAV endurance (hrs.)	P[UAV Recovery]
Normalized Swing Weight, wi	0.056	0.014	0.003	0.225	0.112	0.140	0.140	0.281	0.028

Table 6-Swing Weights

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wi * vi(xi)	UAS weight (lbs.)	UAV volume (ft3)	# of people to operate	Reliability	UAV range (km)	P[Detect Objects]	All weather capability	UAV endurance (hrs.)	P[UAV Recovery]
Cardinal	5.6	1.4	0.3	22.5	2.2	14.0	14.0	0.0	1.3
Buzzard	4.8	1.3	0.3	18.0	2.2	7.0	0.0	16.9	2.2
Crow	4.8	1.1	0.1	5.6	4.5	14.0	14.0	16.9	2.5
Pigeon	4.0	0.7	0.1	0.0	6.7	14.0	14.0	22.5	2.8
Robin	1.6	0.4	0.1	0.0	11.2	7.0	0.0	28.1	2.8
Hypothetical Best	5.6	1.4	0.3	22.5	11.2	14.0	14.0	28.1	2.8
Ideal	5.6	1.4	0.3	22.5	11.2	14.0	14.0	28.1	2.8

Table 7- Alternative Weighted Value on Each Measure

Multiplying each alternative's value on each measure by the swing weight for each measure in *Table 6*, which is a summarized version of *Table 4*, gives the value on each measure for each alternative in *Table 7*. This provides the value of each alternative for each measure, allowing a value component chart to be created. To discover the total value for each alternative the weighted values for each alternative are summed for all measures to create *Table 8*, the alternative value chart.

	Alterative Value
Cardinal	0
Buzzard	51
Crow	53
Pigeon	54
Robin	56
Hypothetical Best	48
Ideal	86

Table 8- Alternative Value

To break down the comparison of alternatives, the value for each measure is stacked in a bar chart called the value component chart shown in *Figure 9.* The hypothetical best alternative is the value of the best alternative for each measure. In AFT, the hypothetical best is the ideal alternative.

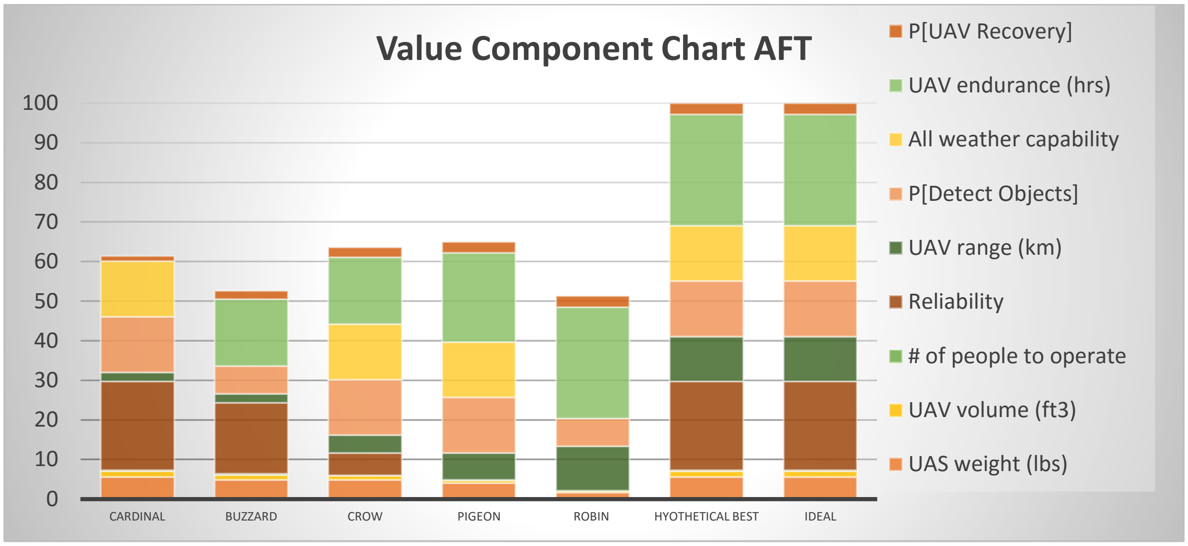

Figure 9-Alternative-Focused Thinking Value Component Chart

In this example, the best alternative is the hypothetical best, which is a combination of the highest value for each measure. This example is used throughout the paper; however, the value curves are different depending on the method being described.

This method improves upon requirements analysis. It quantitatively defines the tradespace using performance data, value curves and swing weights to prioritize measure. The value cures are relatively easy to construct and the swing weights can be assessed. In addition, sensitivity analysis can be performed. However, AFT does not evaluate the entire tradespace since it only considers known alternatives. AFT provides insight about a set of alternatives but does not assess future capability needs. Therefore, AFT is not well aligned with capability based planning.

2.4 Value-Focused Thinking

To solve the problems with alternative-focused thinking, value-focused thinking was developed in 1992 (Keeney, Value-Focused Thinking: A Path to Creative Thinking, 1992). Instead of focusing on alternatives and using the best on each measure for the "ideal", value-focused thinking focused on values, trying to find the ideal for each value measure. The best existing alternative on each measure can be compared to the ideal to identify the value gap.

Since VFT identifies the ideal for each value measure it aligns with capability based planning. *Figure 10* shows a notional VFT value curve.

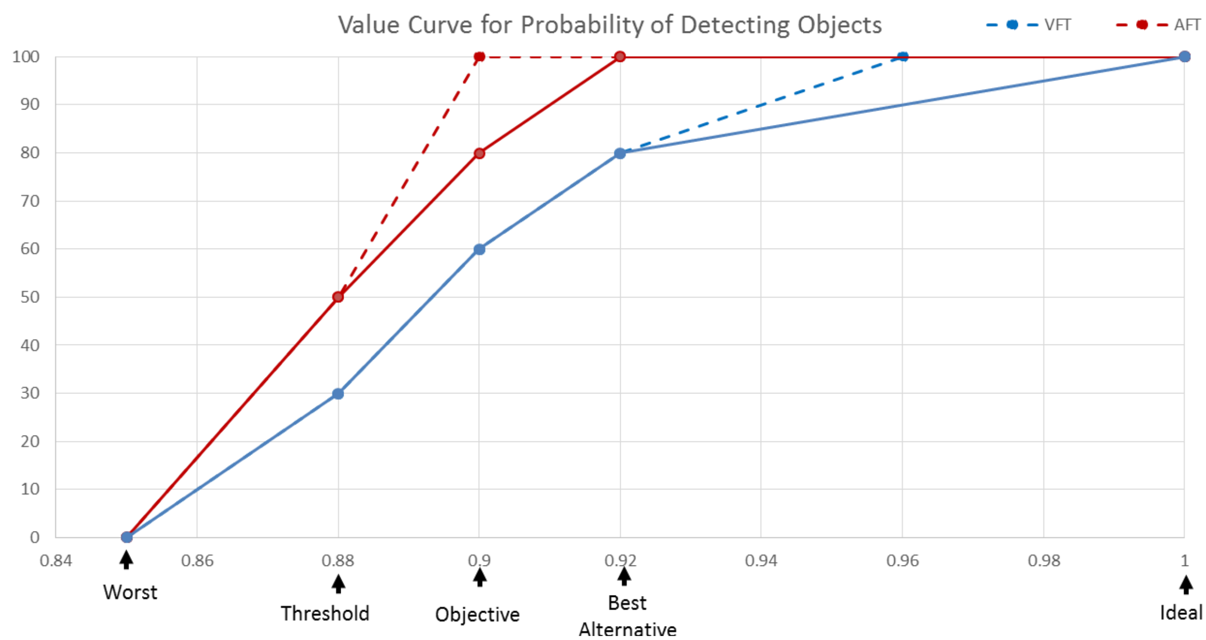

Figure 10- Value-Focused Thinking Value Curve

The VFT value curve increases the tradespace, allowing for more resilient alternatives. VFT identities larger value gaps than AFT. In the example the value table changed form *Table 4 to Table 9* by changing the ideal. However, for *Figure 10,* a second method exist that has the maximum value achieved at a lower performance level, because in this situation the ideal may not be achievable. Overall, using value focused thinking changed the value curves for the example to *Figure 11.*

UAS weight (lbs.)		UAV volume (ft3)		# of people to operate		Reliability		UAV range (km)		P[Detect Objects]		All weather capability		UAV endurance (hrs.)		P[UAV Recovery]	
X	V	X	V	X	V	X	V	X	V	X	V	X	V	X	V	X	V
5	100	10	100	1	100	0.6	0	50	0	0.85	0	1	0	0.5	0	0.5	0
10	86	20	75	2	50	0.7	25	60	20	0.9	50	2	25	1	60	0.6	47
20	58	30	50	3	0	0.8	80	80	60	0.95	85	3	70	1.5	80	0.7	77
30	29	40	25			0.9	95	90	80	0.99	99	4	90	2	95	0.8	90
40	0	50	0			1.0	100	100	100	1	100	5	100	2.5	100	0.9	100

Table 9- Value-Focused Thinking Value Table

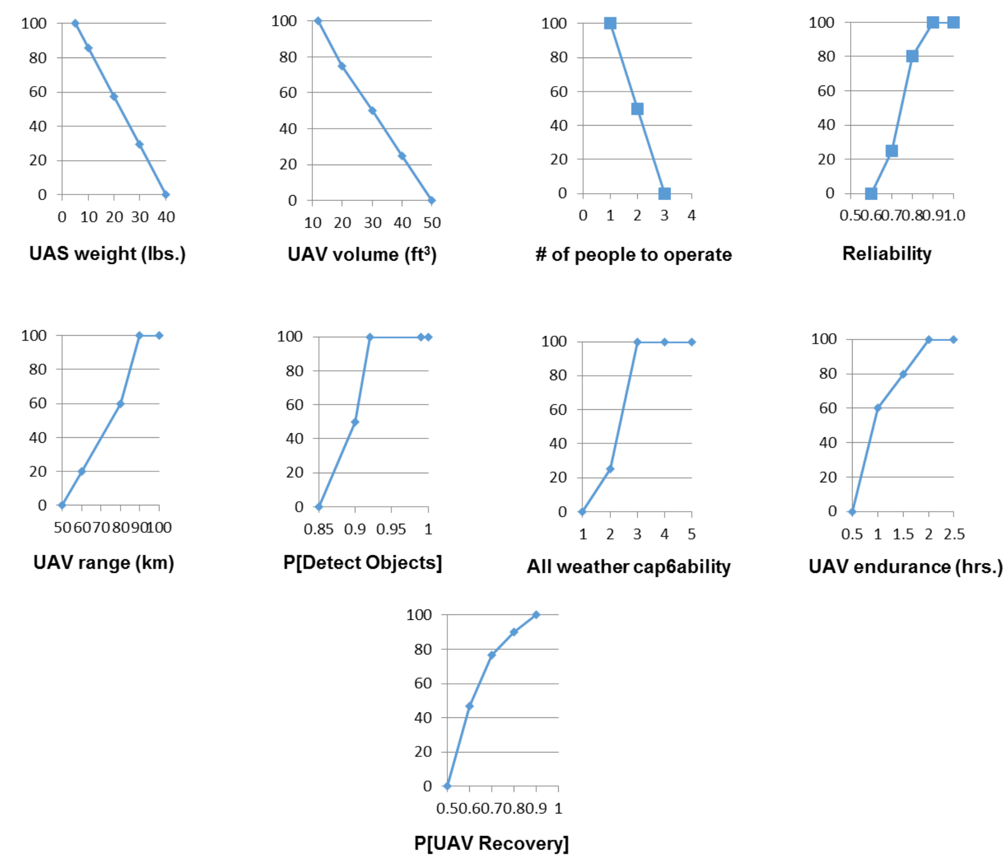

Figure 11- Value-Focused Thinking Value Curves

Just as in AFT, the value component chart is developed by stacking the value for each measure on top of each other. However, in the VFT value curve shown in *Figure 10*, the hypothetical best is the same as AFT, but the ideal is the best value that you can get on each measure.

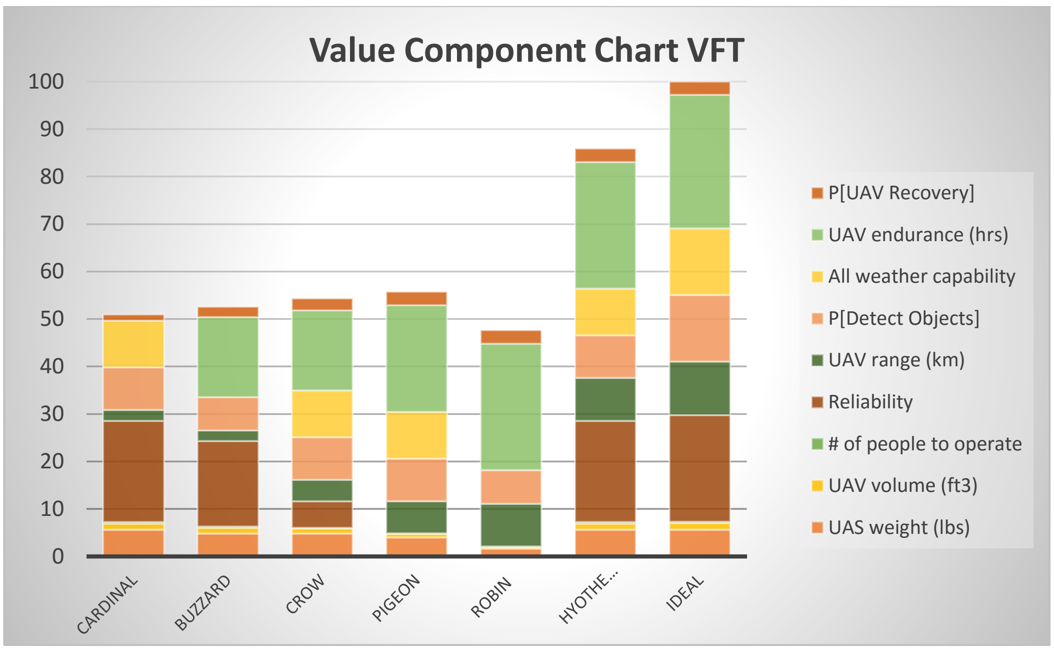

Figure 12- Value-Focused Thinking Value Component Chart

As the ideal for each measure will change, the value of each alternative on each measure will change, and the weights will change since weights depend on the range of each value measure. This means the ranking of the alternatives can change. For example, *Figure 12* has a different alternative ranking than *Figure 9*.

Overall, VFT aligns with capability based planning, quantitatively defines a larger tradespace, uses swing weights to prioritize measures (will be different than AFT), and it identifies value opportunities. However, it is more difficult to identify the ideal and construct the value curve. In addition, it may give value to a currently unachievable tradespace.

2.5 Alternative-Focused Thinking vs. Value-Focused Thinking

In summary, both AFT and VFT improve upon requirements analysis as they quantify the tradespace and provide a way to compare alternatives and allow for affordability analysis. Alternative-Focused Thinking identifies the highest value known alternative. Value-Focused Thinking aligns with capability based planning and expands the tradespace. However, Value-Focused thinking takes more effort to perform. In addition, using the same performance data but AFT and VFT value curves, the ranking of alternatives may be different as shown in *Figure 13*. VFT has been used more frequently for Capability Based Planning.

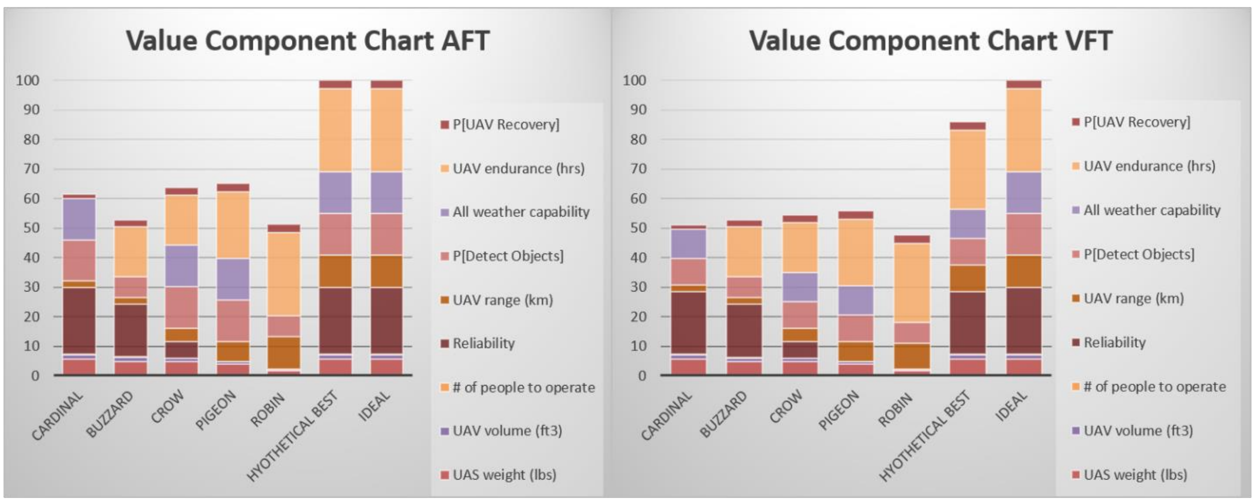

Figure 13- AFT vs. VFT Value Component Charts.

3. VFT and Resiliency

What does the extra tradespace in VFT actually identify? An increase in the reliability, all weather capability, probability of detecting object, and other measures would be an increase in resilience. Moreover, an increase in speed, payload weight, a decrease in volume, or extra value in many of the measures would be an increase in platform resilience. The measures already included in a MODA model can be an indirect measure for mission and platform resilience. The extra tradespace provides the capability to later adapt the platform to adapt to perform additional missions and the ability to better adapt to threats on current missions.

In the notional UAV decisions used in the earlier sections, all the measures can be divided into either mission resilience or platform resilience. Reliability, probability of detecting objects, all weather capability, and probability were classified as mission resilience. The weight, volume, number of people to operate, range, and endurance (hours) were classified as platform resilience. As these measures are increased, the UAV has increased platform resilience to perform other missions. On each measure, anything above the minimum acceptable is added platform resilience or mission resilience. In a visual manner, anything in the box is added mission resilience or platform resilience in *Figure 14.*

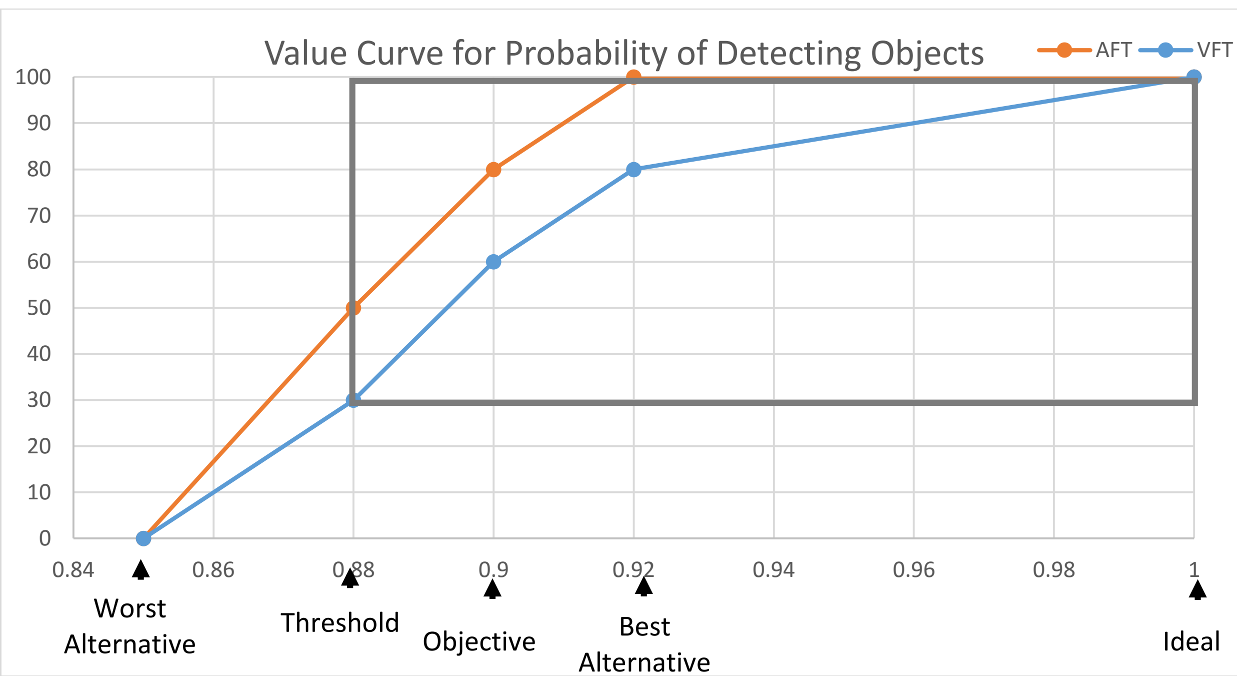

Figure 14- Resilience in VFT

Using VFT and partitioning the value measures into mission resilience and platform resilience allows the decision makers to see the capability space that would provide additional mission resilience and increase platform resilience. In this case, all measures can be put into two categories and added together to find the overall value for each alternative. Mathematically, a total value of 100 is equal to the value of each alternative plus the mission and platform resilience opportunity. The mission and platform opportunity is equal to the value of the ideal minus the value of the alternative. This is then multiplied by the weight of each mission and platform resilience measure to determine the weighted value of the opportunity. This is shown in *Figure 14.*

$$v(x_j) = \sum_{i=1}^{n} w_i v(x_{ij})$$

$$100 = v(x_j) + \sum_i^M w_i [v(x_{iI}) - v(x_{ij})] + \sum_i^P w_i [v(x_{iI}) - v(x_{ij})]$$

$$|M_i| + |P_i| = n$$

M= the set of all mission resilience measures
P= the set of all platform resilience measures
I = the set of ideals for each measure
n= the number of measures
t= threshold value

Figure 15- Mission resilience Platform resilience VFT Mathematics

This view of mission and platform resilience can provide benefits to decision makers: the current value of alternatives and the value and opportunities for mission and platform resilience.

Using *Figure 12* and categorizing it as either mission resilience or platform resilience creates the resilience opportunity graph in *Figure 16*. In *Figure 16,* the mission resilience is illustrated by the light green and platform resilience is shown as the light blue. This chart shows the value gaps according to their respective measure. It is known as a floating bar chart. When the chart is visualized in the light of mission and platform resilience, it shows where mission and platform resilience opportunities exist. If the gap on certain measures is large, it can signal to decision makers that they can add mission resilience or platform resilience.

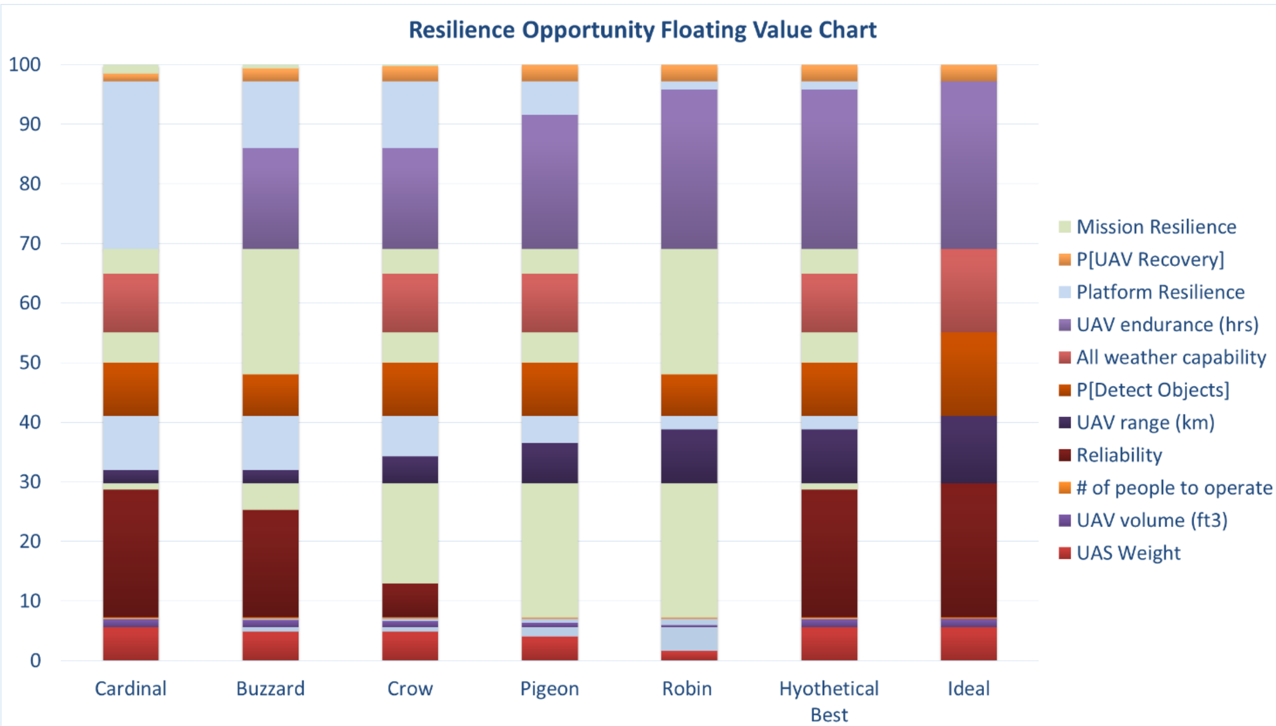

Figure 16-Mission Resiliency and Platform Resilience Opportunity Floating Value Chart

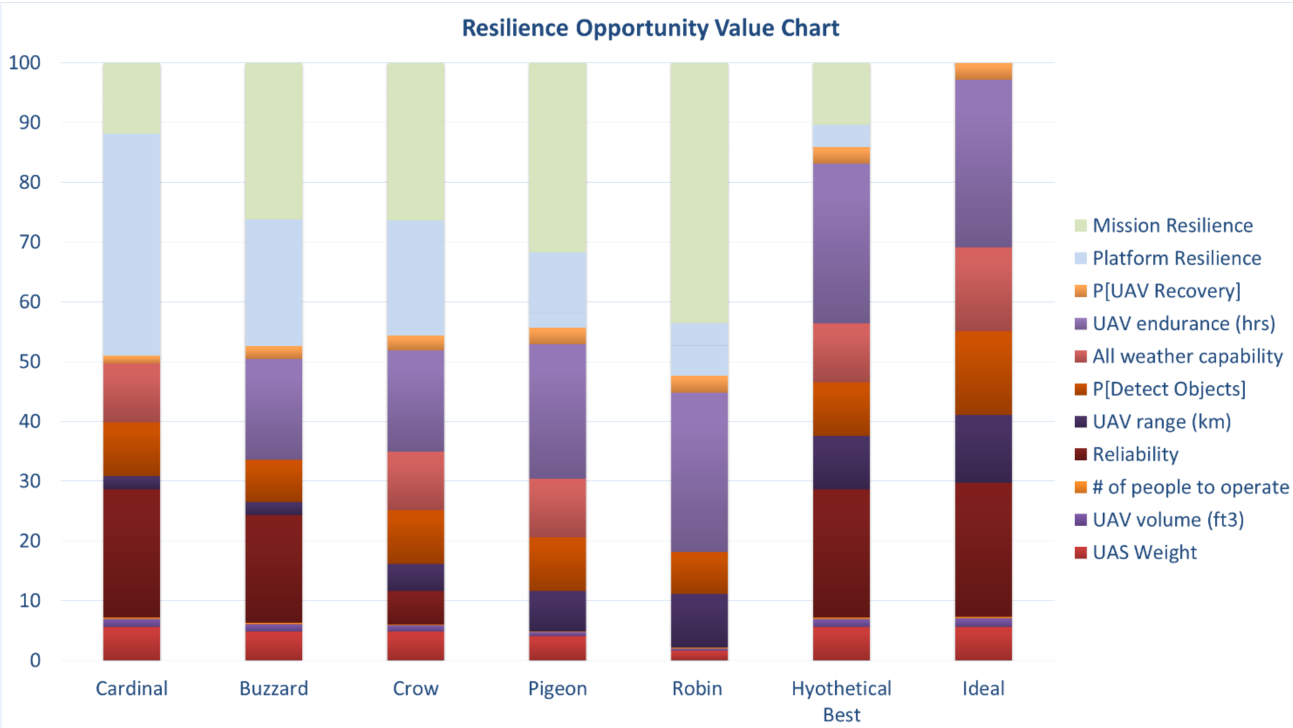

Figure 17- Resiliency and Platform resilience Opportunity Chart

Figure 17 illustrates a second way the data can be viewed by decision makers. Instead of showing the individual gaps for each measure, it shows the overall gap to show where each alternative has opportunities to improve resilience. One can visualize how much value it has and the weight for each measure while also showing the opportunity for mission and platform resilience.

The third and final way to show the value component chart is to show the value from mission resilience and platform resilience and the opportunities for mission and platform resilience improvements in *Figure 18*.

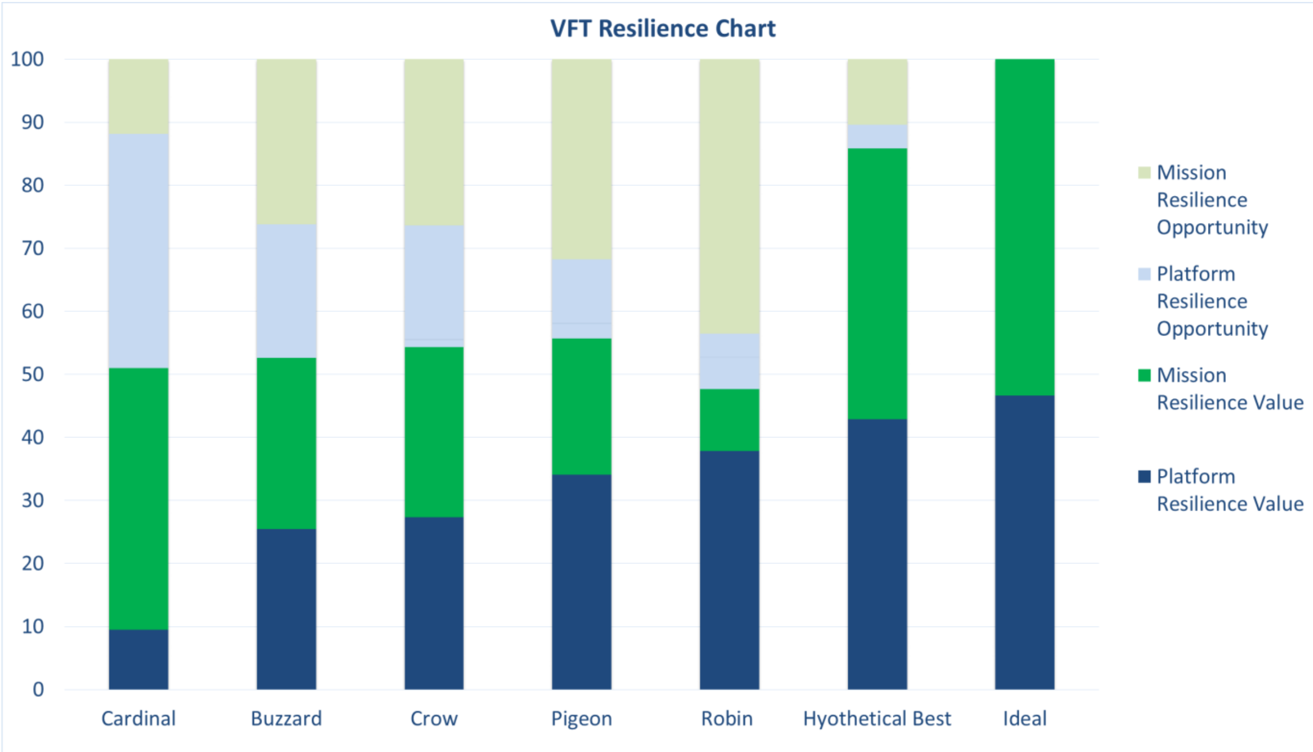

Figure 18- Resiliency Value and Opportunity

In addition, thinking of mission and platform resilience as the difference between the ideal and the minimum acceptable can help decision makers to arrive at the ideal. It will make it more realizable.

In most situations and in classes the best practice is to perform the MODA analysis and then create a hybrid alterative. The platform resilience and hybrid approach can help not just create a hybrid alternative but with *Figures 16, 17, and 18;* the decision maker has insight not only into which alternatives can be combined, but also insight into where the top alternatives can add mission and platform resilience.

Overall, thinking of the extra value above the threshold as platform and mission resilience can help the DoD. It is very simple view but it is useful. It allows decision makers to include resilience in their decisions and align with capability based planning. It also allows decision makers to see where they can assess and improve the resilience of their designs.

4. Future Research

Over the next two years, further research will be done at the University of Arkansas into the relationship between value-focused thinking and resilience. The University of Arkansas will also research new and different ways to approach resilience decision. They are currently working on a framework to approach how to make resilience decisions and visualizing what value can be earned in platform and mission resilience. They will look at a MODA model of platform and mission resilience. Moreover, they will research whether the mathematics used in this paper can be generalized to all problems. In early May, research groups from around the country working for Engineered Resilient Systems will meet to discuss the definition of resilience and the direction of their research. Both this method and the framework will be discussed. The research into the relationship between value-focused thinking and resilience will also be presented at the Industrial and Systems Engineering Research Conference (ISERC) in May.

5. Conclusion

In conclusion, in light of the goals and direction of the Military and Engineered Resilient Systems, value-focused thinking can provide benefits to decision makers. Unlike requirements analysis and alternative-focused thinking, value-focused thinking aligns with capability based planning. In addition, thinking of the extra tradespace added by VFT can allow decision makers to develop platforms that have the ability to adapt to the rapidly changing world and systems that are better able to repel, resist, absorb, and recover from threats. Moreover, not only can it allow for decision makers to make decisions to achieve these goals, but it can also identify where they need to improve their alternatives to have more resilient systems.

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