U.S. AIR FORCE

The Joint Improvised Explosive Device Defeat Organization (JIEDDO) Proposal Value Model

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Outline

- Background
- Problem
- Model Development
- Model Enhancements
- Analysis & Validation
- Conclusions

IEDs

- Primary source of US and coalition casualties
- Wide variety of devices
  - Fuse, explosive fill, detonator and power supply, and a container
- Generally difficult to detect and protect against

JIEDDO Background

- Army IED Task Force (2003)
- Joint IED Defeat Task Force (2004)
- Joint IED Defeat Organization (JIEDDO) (2006)
- Intended to synchronize all available resources and streamline acquisition process for IED defeat technologies

JIEDDO reports directly to DepSecDef

JIEDDO Background

JIEDDO Mission

To focus (lead, advocate, coordinate) all DoD actions in support of COCOMs and their respective JTFs' efforts to defeat IEDs as weapons of strategic influence.

- DODD 2000.19E

JIEDDO Background

- JIEDDO Objectives:
  - Reduce Effect of IEDs against friendly forces
  - Provide leaders with single POC for C-IED efforts
  - Establish JCOP of IEDs and their employment
  - Provide Joint forum to synchronize efforts
  - Provide leaders with method for identifying issues requiring interservice resourcing
- Provide Joint forum to identify C-IED efforts to be rapidly implemented and developed
- Provide for interservice, interagency, industry and international coordination of IED defeat

Current IED Defeat Practices

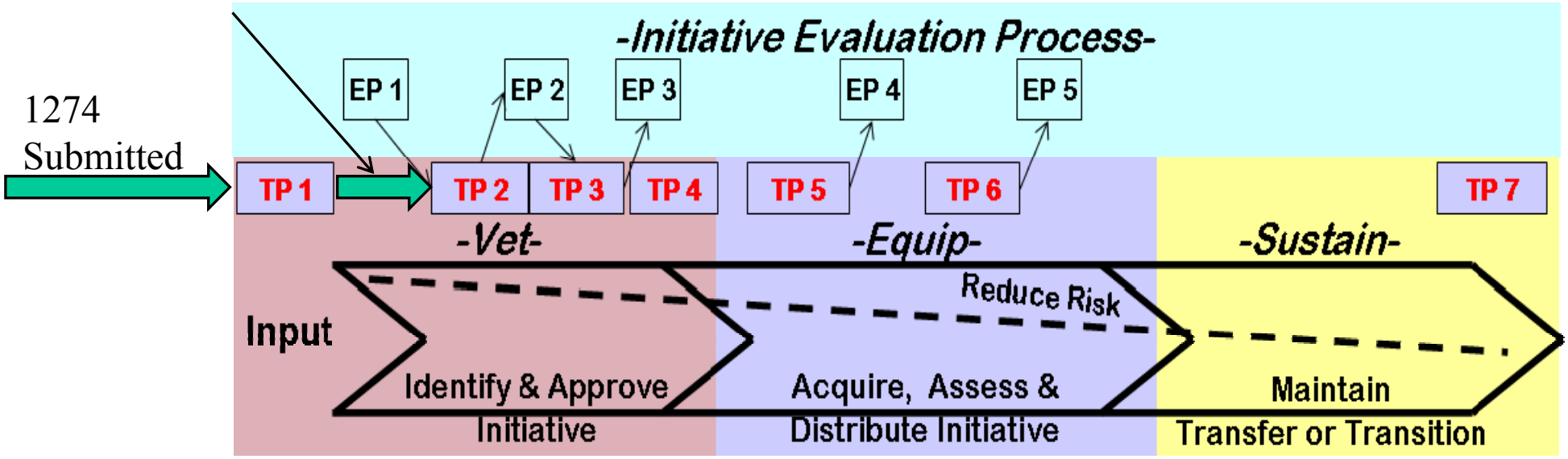
- Lines of Operation
  - Attack the Network
    - Predict/Prevent
  - Defeat the Device
    - Detect
    - Neutralize
    - Mitigate
  - Train the Force
    - Train

JIEDDO's Process

- Joint IED Defeat Capability Approval and Acquisition Management Process (JCAAMP)
- Broad Area Announcement (BAA)
- BAA Information Delivery System (BIDS)

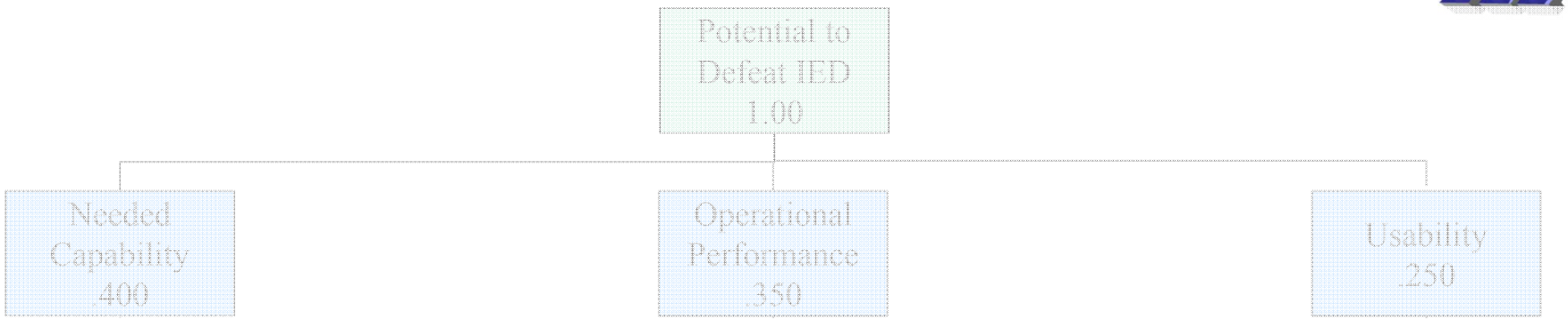
JCAAMP Process

447 Passed
Initial Review



- Why the model?
  - Extremely large budget ($4.37B)
  - Enables traceable, repeatable, and defensible selection decisions

The Model



Additive Value Function:

$$V(X) = .176v_{Gaps}(x_i) + .112v_{TimeToCounter}(x_i) + .110\,v_{TechPerf}(x_i) + .100v_{WorkLoad}(x_i) + .091v_{Interop}(x_i) + .087v_{OpsBurden}(x_i) + .056v_{Tenets}(x_i) + .056v_{Classification}(x_i) + .056v_{Suitability}(x_i) + .056v_{FieldingTimeline}(x_i) + .050v_{TrainingTimeline}(x_i) + .037v_{TechRisk}(x_i) + .013v_{ProgramMaturity}(x_i)$$

Dawley, Marentette, & Long (2008)

Model Verification Proposal Selection

- Wide variety of proposals—30 in all
- Previously evaluated in BIDS
  - 13 accepted/17 rejected
  - Crossed all 5 tenets
  - Offensive & defensive
  - Materiel & non-materiel
  - Kinetic & non-kinetic
  - Aircraft, vehicle & soldier-mounted
  - Feasible & highly speculative

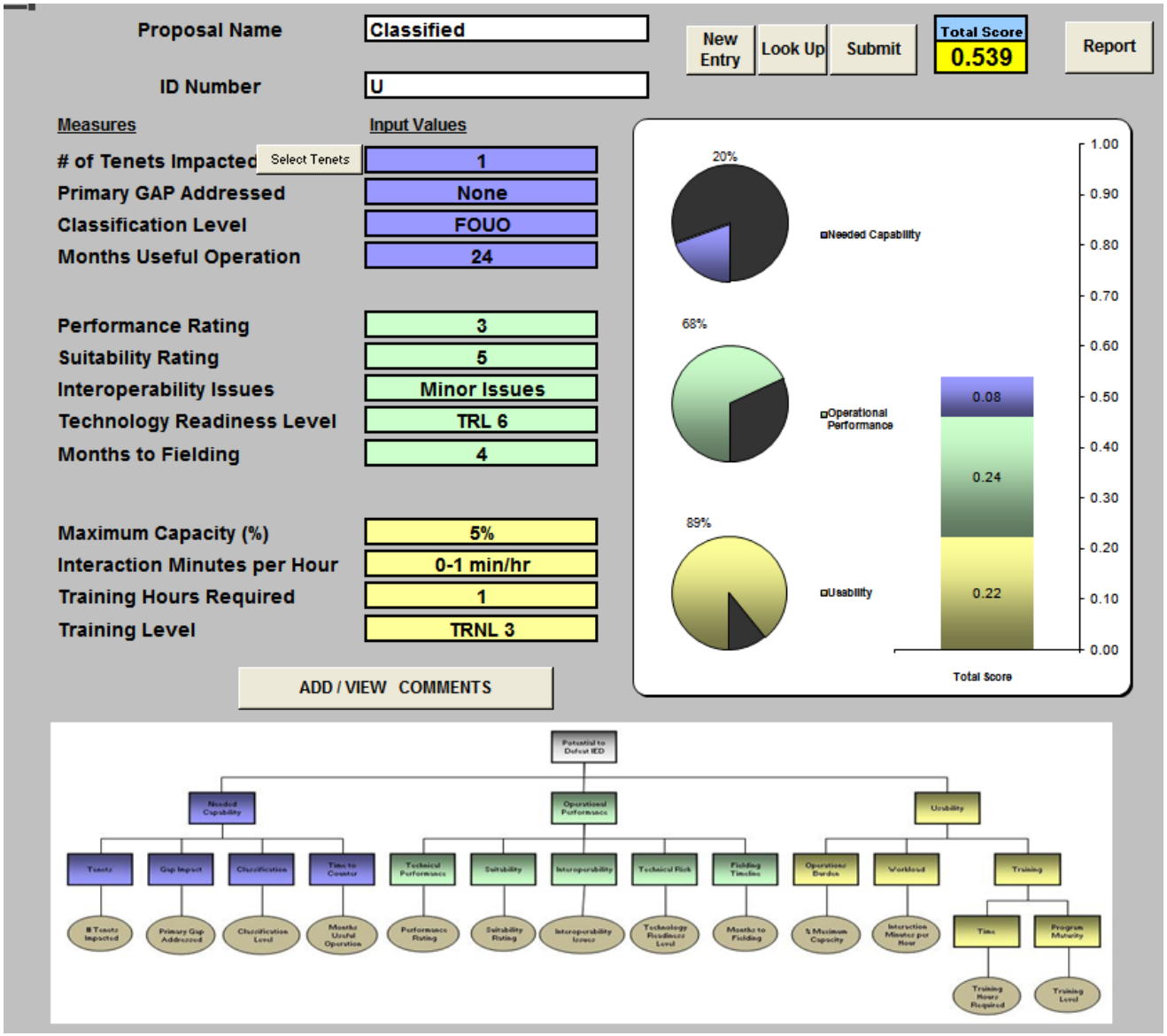
Results and Analysis

- R&D proposals
- High correlation to BIDS accept/reject decisions
- Outliers in the accepted and rejected regions
  - Worst case scenario not intuitive

Proposal	Score
BB	.822
CC	.708
F	.683
E	.672
CC	.668
AA	.600
Z	.562
J	.599
B	.585
R	.562
W	.546
U	.539
D	.539
S	.528
P	.552
W	.486
U	.489
D	.539
C	.528
L	.494
G	.488
I	.483
Q	.473
O	.446
N	.420
A	.393
K	.387
V	.366
M	.363
H	.168

Rejected Proposals

The Tool


Proposal Name
Classified
ID Number
U
New Entry
Look Up
Submit
Total Score
0.539
Report
Measures
Input Values
# of Tenets Impacted
Select Tenets
1
Primary GAP Addressed
None
Classification Level
FOUO
Months Useful Operation
24
Performance Rating
3
Suitability Rating
5
Interoperability Issues
Minor Issues
Technology Readiness Level
TRL 6
Months to Fielding
4
Maximum Capacity (%)
5%
Interaction Minutes per Hour
0-1 min/hr
Training Hours Required
1
Training Level
TRNL 3
ADD / VIEW COMMENTS
20%
Needed Capability
68%
Operational Performance
89%
Usability
0.08
0.24
0.22
Total Score
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

Further Model Verification

- Used Discriminant Analysis to see if a discriminant function could be built to classify proposals into either a funded or not funded
  - Data splitting technique
  - Discriminant function creation for each population type

$$\hat{d}_i^Q = -\frac{1}{2}\ln|S_i| - \frac{1}{2}(\underline{X}_0 - \bar{X}_i)' S_i^{-1}(\underline{X}_0 - \bar{X}_i) + P_i$$

Specific observation seeking classification

Mean for variables in population *i*

Prior Probability

Covariance Structure

Bauer (2008)

Was this technique successful?

Confusion Matrix: Dillon & Goldstein (1984)

Actual JIEDDO Decision		Predicted Membership DF Categorization: Accept	Predicted Membership DF Categorization: Reject
	Accept	13	0
	Reject	0	17

where:

N_{iC} = # of class i classified correctly
$N_{i\underline{C}}$ = # of class i classified incorrectly
1 = Actual Membership accept
2 = Actual Membership reject

It is possible to create a function that will predicted whether a proposal will be accepted or rejected

Multi-Dimensional Sensitivity Analysis

Minimize $\sum_{i=1}^{k}(W_i - w_i)^2$

subject to:

$$\sum_{i=1}^{k}(v^A(x_i) - v^B(x_i))w_i = 0 \quad \forall A \neq B$$

$$\sum_{i=1}^{k} W_i = 1$$

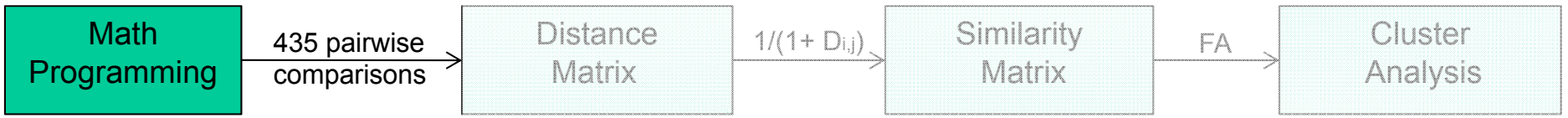
$$\sum_{i=1}^{k} w_i = 1$$

$$0 \leq w_i, W_i \leq 1 \quad \forall i = 1...k$$

W_i = the initial weights defined by the decision maker

w_i = the weights found that minimize the measure

$v^A(x_i)$ = value score of attribute i for alternative A

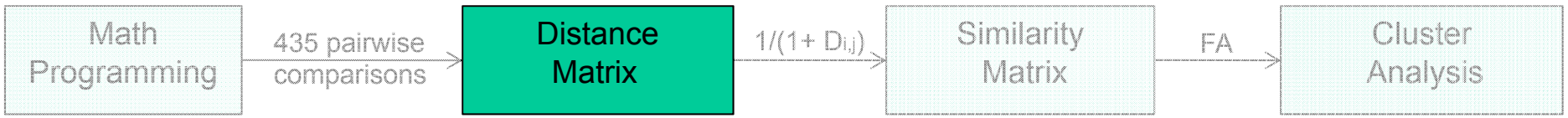


Sensitivity Analysis

- For the set of 30 JIEDDO proposals, there were 435 unique pairwise comparisons
- Objective function values are stored in a distance matrix

0	$D_{1,2}$	$D_{1,3}$	…		…	$D_{1,30}$
$D_{2,1}$	0	$D_{2,3}$	…	…	…	$D_{2,30}$
$D_{3,1}$	$D_{3,2}$	0	…	…	…	$D_{3,30}$
…	…	…	0	…	…	…
…	…	…	…	0	…	…
…	…	…	…	…	0	$D_{29,30}$
$D_{30,1}$	…	…	…	…	$D_{30,29}$	0

The distances between proposal scores will shed light on their sensitivity

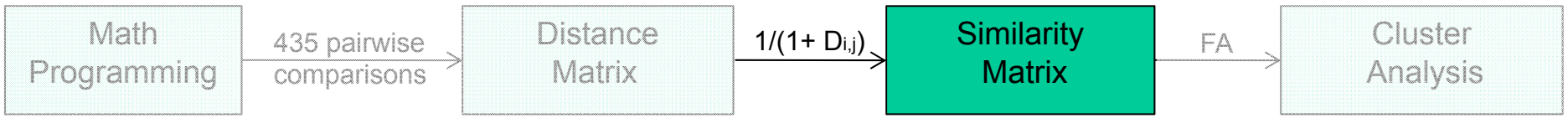


Sensitivity Analysis

- Distance matrix has far apart a given pair of proposals are from one another in the weight space
- Similarity matrix characterizes how similar the sets are to one another

$$S_{i,j} = 1/(1+D_{i,j})$$

$1/(1+0)$	$1/(1+D_{1,2})$	$1/(1+D_{1,3})$	…	$1/(1+D_{1,30})$
$1/(1+D_{2,1})$	$1/(1+0)$	$1/(1+D_{2,3})$	…	$1/(1+D_{2,30})$
…	…	$1/(1+0)$	…	…
…	…	…	$1/(1+0)$	$D_{29,30}$
$1/(1+D_{30,1})$	…	…	$1/(1+D_{30,29})$	$1/(1+0)$



Loading Matrix Results

Proposal Ranked	Factor 1	Factor 2	Factor 3	Score
1	0.358	-0.461	0.711	0.822
2	0.439	-0.300	0.849	0.727
3*	0.500	-0.435	0.716	0.683
4	0.522	-0.377	0.746	0.672
5*	0.521	-0.443	0.701	0.672
6	0.598	-0.459	0.636	0.620
7	0.718	-0.350	0.587	0.613
8*	0.669	-0.496	0.523	0.599
9	0.743	-0.414	0.517	0.584
10	0.681	-0.521	0.491	0.576
11	0.668	-0.515	0.525	0.565
12	0.693	-0.504	0.492	0.563
13*	0.770	-0.459	0.446	0.561
14	0.692	-0.531	0.473	0.561
15	0.746	-0.479	0.439	0.555
16	0.686	-0.524	0.484	0.554
17	0.732	-0.491	0.459	0.539
18*	0.687	-0.541	0.461	0.539
19*	0.670	-0.557	0.463	0.528
20*	0.630	-0.629	0.422	0.502
21*	0.597	-0.636	0.460	0.491
22*	0.623	-0.619	0.443	0.488
23*	0.584	-0.653	0.435	0.477
24*	0.518	-0.703	0.441	0.447
25*	0.488	-0.740	0.457	0.420
26*	0.484	-0.807	0.317	0.401
27*	0.452	-0.827	0.305	0.387
28	0.447	-0.804	0.329	0.367
29*	0.435	-0.868	0.252	0.364
30*	0.159	-0.800	0.476	0.170
Varimax	10.772	10.235	8.095	
Proportional variance explained	36%	34%	27%	

Factor Analysis: utilized to simplify complex relationships that exist among a set of observed variables by uncovering common factors that link together the seemly unrelated variables

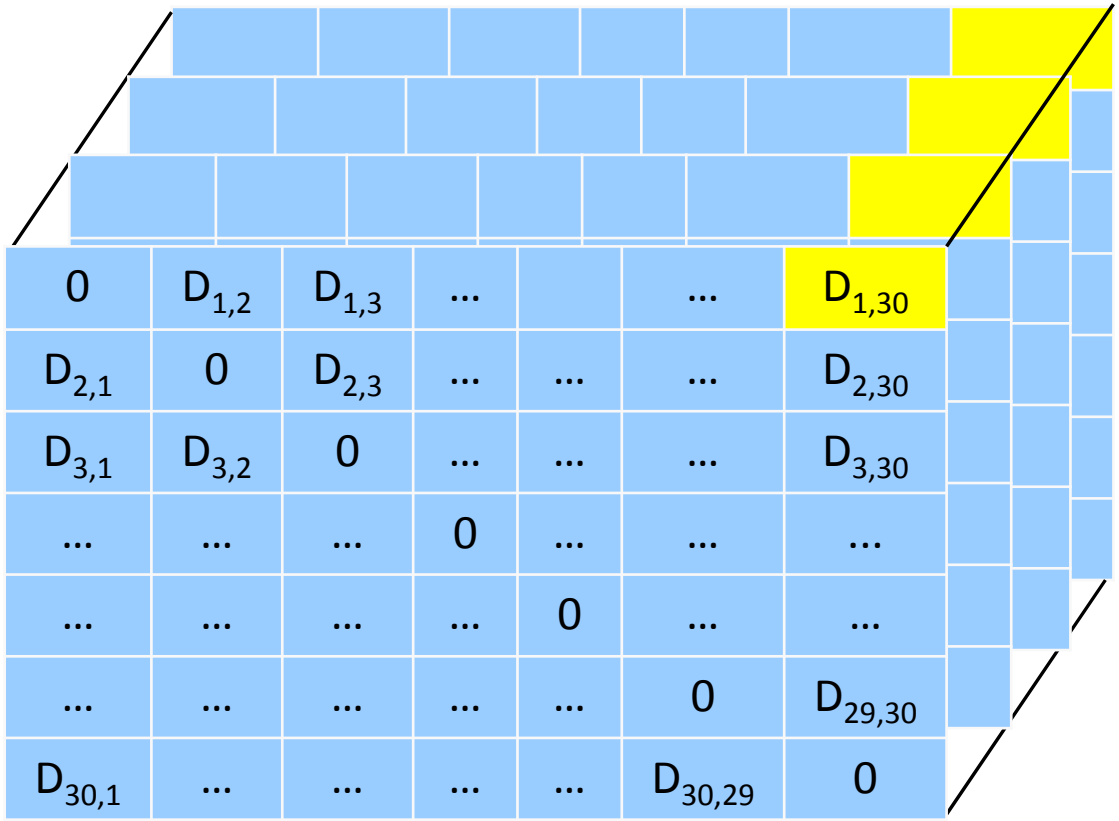
- The number of retained factors based on eigenvalues
- Underlying variable contribution is determined using loading matrix

$$L = \sqrt{e_{value}} * e_{vector}$$

L = loading matrix
e_{value} = eigenvalue
e_{vector} = eigenvector

What does this tell us about the sensitivity of a specific proposal?

Utilizing the information captured in the distance matrix, it is possible to extract information regarding how well a proposal scored as compared to competitors



0	$D_{1,2}$	$D_{1,3}$	…		…	$D_{1,30}$
$D_{2,1}$	0	$D_{2,3}$	…	…	…	$D_{2,30}$
$D_{3,1}$	$D_{3,2}$	0	…	…	…	$D_{3,30}$
…	…	…	0	…	…	…
…	…	…	…	0	…	…
…	…	…	…	…	0	$D_{29,30}$
$D_{30,1}$	…	…	…	…	$D_{30,29}$	0

Each $D_{i,j}$ has a unique 13 dimensional weight vector tied to it

Applying the Technique

Proposal Ranked #	Gap Impact	Time to Counter	Technical Performance	Work Load	Interoperability	Operations Burden	Tenets Impacted	Classification	Suitability	Fielding Timeline	Training Time	Technical Risk	Program Maturity
1													
2													
3*													
4													
5*													
6													
7													
8*													
9*													
10													
11													
12													
13*													
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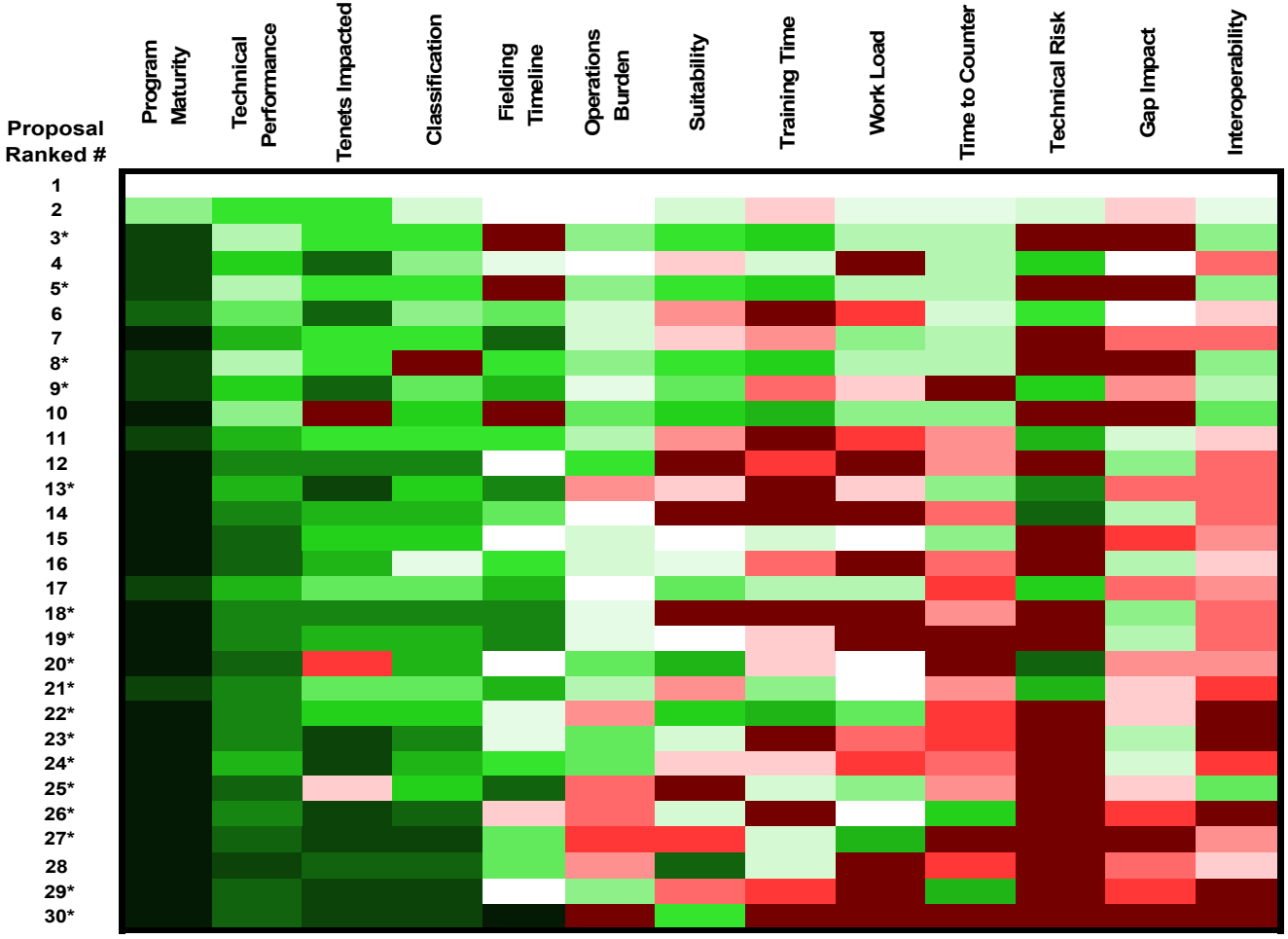
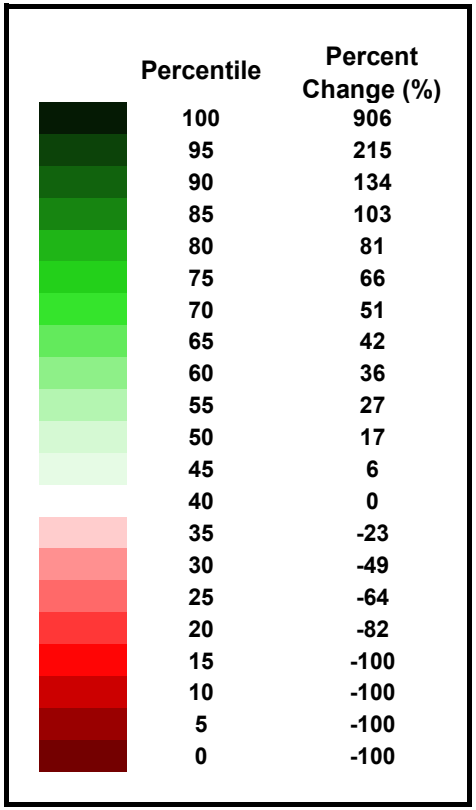
27*													
28													
29*													
30*													

Percent Change for Proposal 1
Sorted by Average % Weight Change

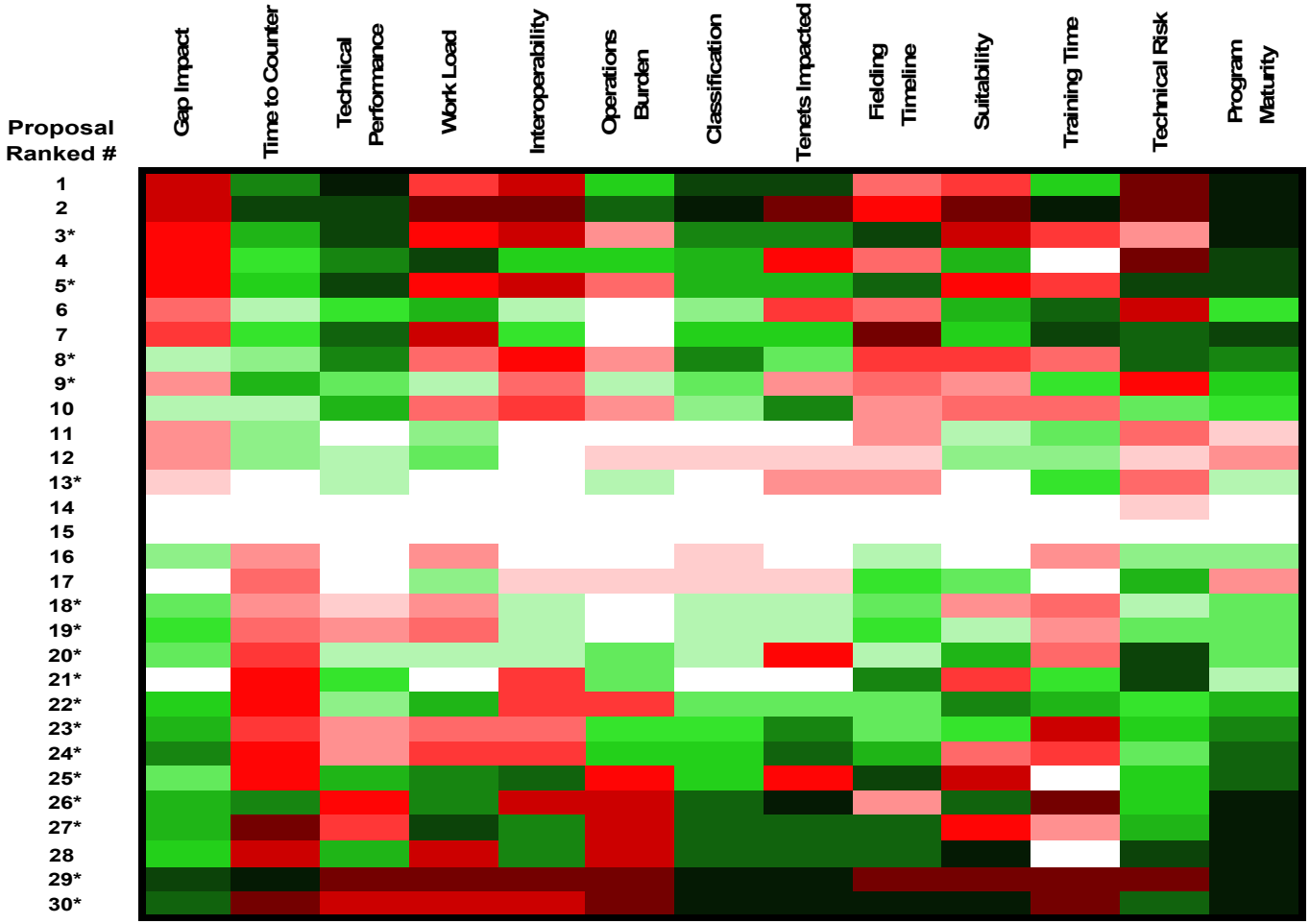


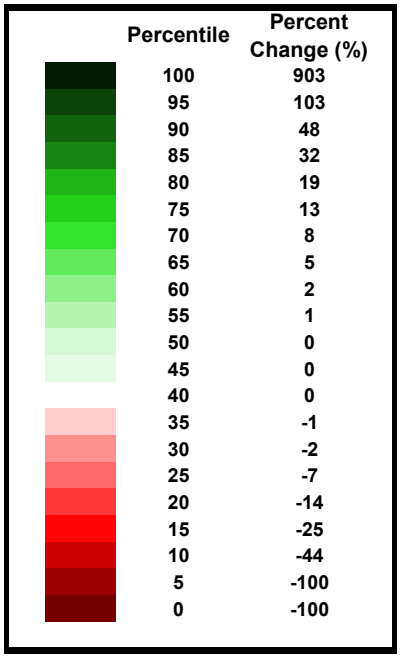


	Program Maturity	Technical Performance	Tenets Impacted	Classification	Fielding Timeline	Operations Burden	Suitability	Training Time	Work Load	Time to Counter	Technical Risk	Gap Impact	Interoperability
Original Global Weights	0.013	0.110	0.056	0.056	0.056	0.087	0.056	0.050	0.100	0.112	0.037	0.176	0.091
Average % Weight Change	306	81	79	64	33	-4	-10	-30	-34	-35	-40	-42	-46

* Indicates JIEDDO rejected proposal

Percent Change for Proposal 15

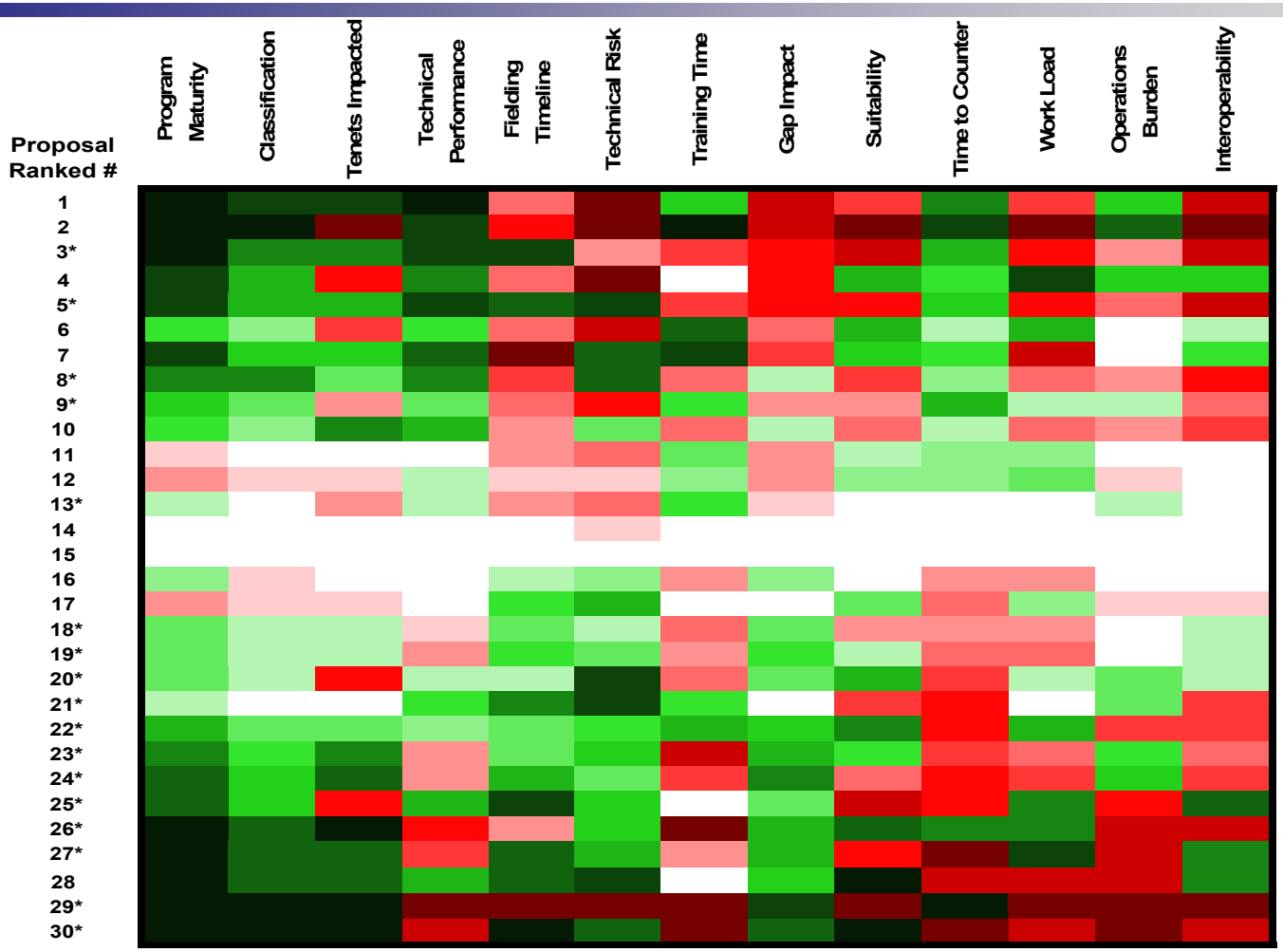


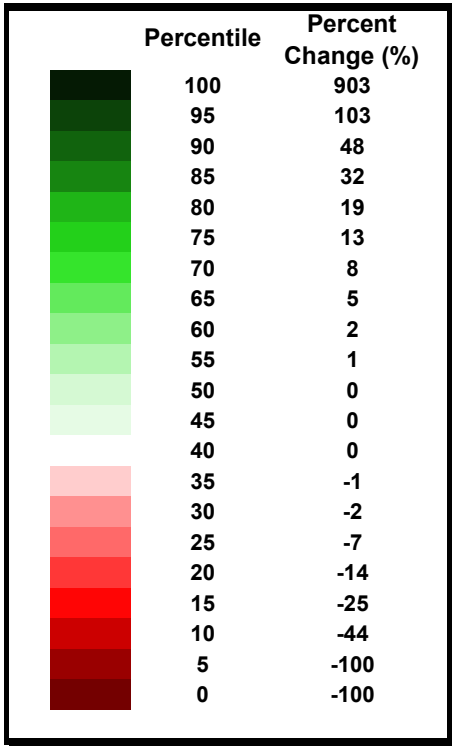


Original Global Weights	0.176	0.112	0.110	0.100	0.091	0.087	0.056	0.056	0.056	0.056	0.050	0.037	0.013
Average % Weight Change	-2	-7	10	-12	-19	-14	25	19	8	-4	1	1	106

* Indicates JIEDDO rejected proposal

Percent Change for Proposal 15 Sorted by Percent Change





	Program Maturity	Classification	Tenets Impacted	Technical Performance	Fielding Timeline	Technical Risk	Training Time	Gap Impact	Suitability	Time to Counter	Work Load	Operations Burden	Interoperability
Original Global Weights	0.013	0.056	0.056	0.110	0.056	0.037	0.050	0.176	0.056	0.112	0.100	0.087	0.091
Average % Weight Change	106	25	19	10	8	1	1	-2	-4	-7	-12	-14	-19

* Indicates JIEDDO rejected proposal

Further Model Modifications

How does one create a value model which accurately and succinctly captures factor interactions without an unduly lengthy DM solicitation?

Past Methodology: Formulae

- Complicated To Explain
- Requires many extra solicitations and value comparisons
- End value function comprised of $2^n - 1$ terms

New Methodology: Requirements

- New model does:
  - Allow interaction not require it
  - Maintain VFT-like structure
  - Possess two-way monotonicity for combined measures
  - Minimize DM solicitation

- New model does not:
  - Examine interactions above 2nd degree
  - Require Single Dimensional Value Functions a priori

New Methodology: Overview

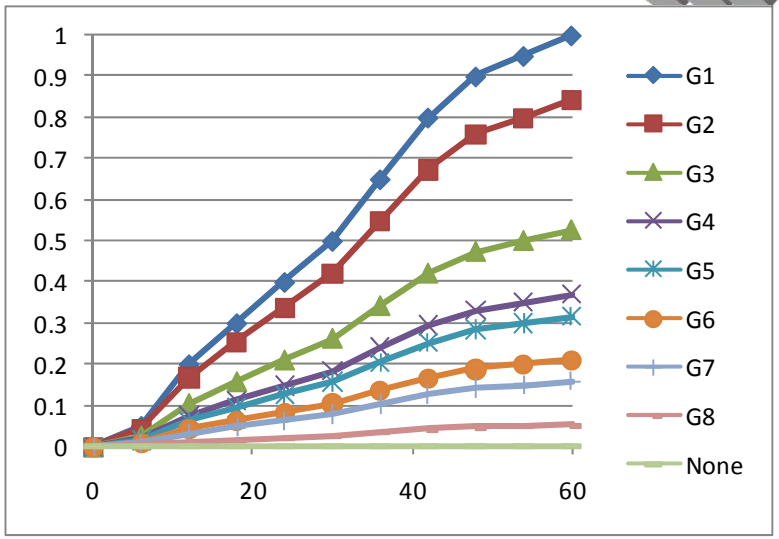
- Solicit subset of interactions
- Interpolate remaining values
- Define equations for continuous gaps
- Combine value function contributions

Primary Gap Addressed	0	6	12	18	24	30	36	42	48	54	60
G1	0	0.05	0.2	0.3	0.4	0.5	0.65	0.8	0.9	0.95	1
G2	0	0.04	0.17	0.25	0.34	0.42	0.55	0.67	0.76	0.8	0.84
G3	0	0.03	0.11	0.16	0.21	0.26	0.34	0.42	0.47	0.5	0.53
G4	0	0.02	0.07	0.11	0.15	0.18	0.24	0.29	0.33	0.35	0.37
G5	0	0.02	0.06	0.09	0.13	0.16	0.21	0.25	0.28	0.3	0.32
G6	0	0.01	0.04	0.06	0.08	0.11	0.14	0.17	0.19	0.2	0.21
G7	0	0.01	0.03	0.05	0.06	0.08	0.1	0.13	0.14	0.15	0.16
G8	0	0	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.05
None	0	0	0	0	0	0	0	0	0	0	0
	Months Useful Operaton										

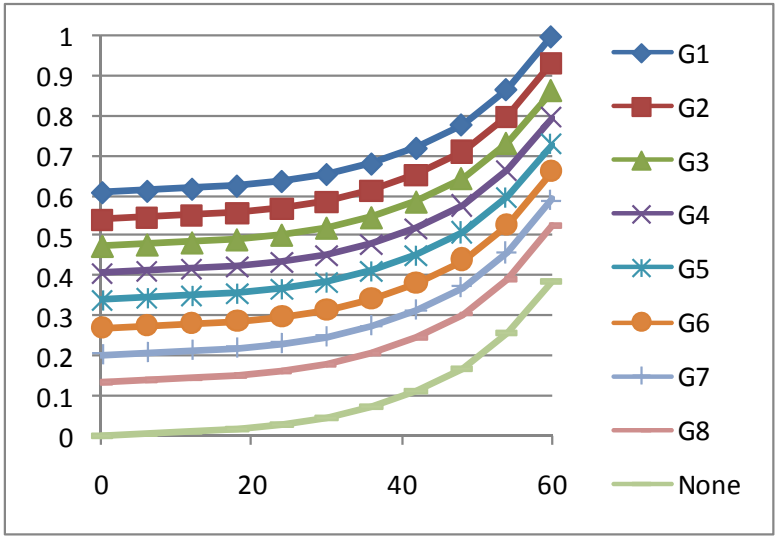
$$V(X) = .056\,v(Tenets) + .\mathbf{288}\,\boldsymbol{v(TimeToCounterGap)} + .056\,v(Class) + .11\,v(TechPerf) + .056\,v(Suit) + .091\,v(Interop) + .037\,v(TechRisk) + .056\,v(FieldTime) + .087\,v(OpsBurden) + .1\,v(Workload) + .05\,v(TrngTime) + .013\,v(TrngMaturity)$$

Analysis and Validation: Value Function Comparison

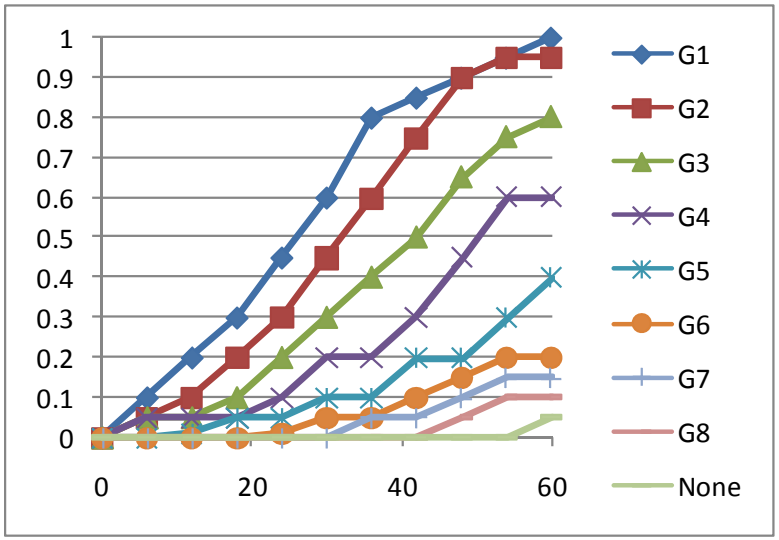
- Gap Impact & Time to Counter
  - Original v. Complete
    - Average difference of 0.22
    - Maximum difference of 0.61
  - Partial v. Complete
    - Average difference of < 0.01
    - Maximum difference of 0.27



Partial



Original



Complete

Analysis and Validation: Group Rankings

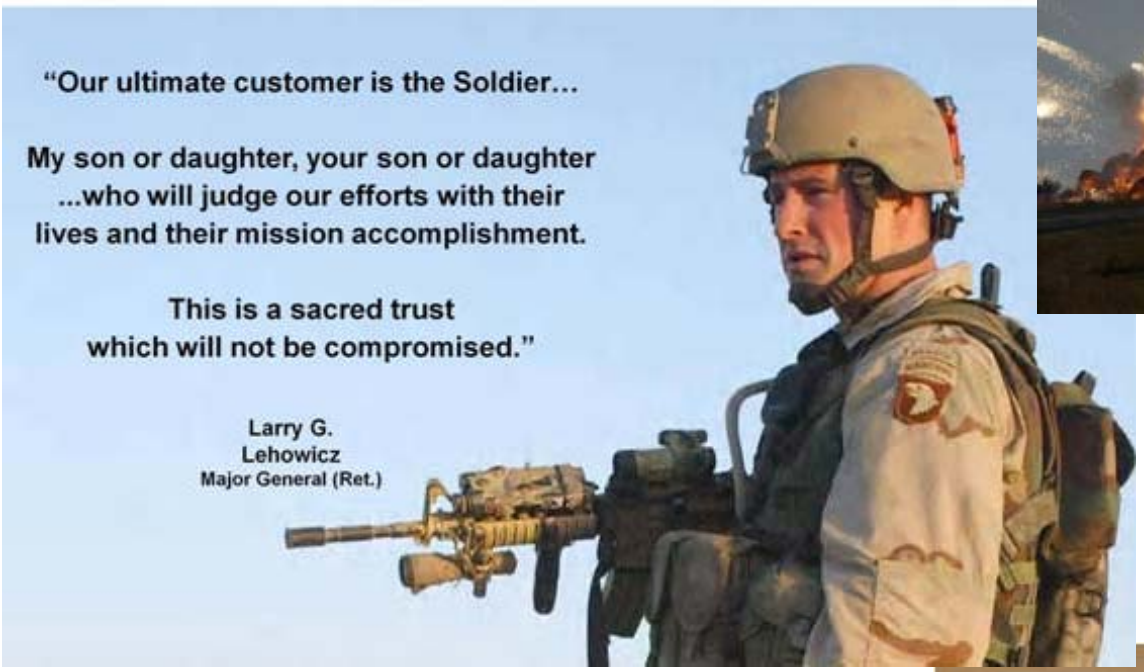
	Group Ranks

- Top tier rankings
- Model as a filter
  - Interpolated model produces sam
  - Discrete alternative sets
  - Original model shares only half c
  - Group size decided by DM

Group Size	Complete Solicit τ		Critical Values		
	v. Original	v. Partial	α=.05	α=.025	α=.005
1 (n=30)	0.628	0.862	0.218	0.255	0.333
3 (n=10)	0.733	0.887	0.467	0.511	0.644
5 (n=6)	0.733	1	0.733	0.867	1

This has to be done RIGHT!

Questions?



Improvised Explosive Device