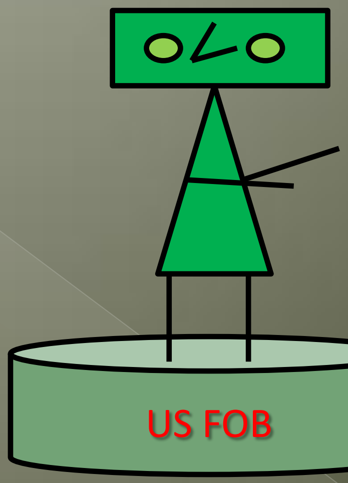
Systems Analysis

ROBOCOP – Team Delta

- **Christine Brennan**
  - Systems Engineering Process Team Lead
  - Based out of TARDEC in Warren, MI
- **Bill Berklich**
  - Architecture and Logical Design Lead
  - Based out of TARDEC in Warren, MI
- **Steve Mazza**
  - Requirements Lead
  - Based out of CERDEC in APG, MD
- **Michael Oexmann**
  - Systems Integration Lead
  - Based out of CERDEC in APG, MD
- **Ralph Pinnock**
  - Reliability, Availability, Maintainability – Test (RAM-T) Lead
  - Based out of TARDEC in Warren, MI
- **Dan Torres**
  - Risk and Technical Planning Lead
  - Based out of TARDEC in Warren, MI



"Our Mission is to ensure you complete yours"

Table of Contents

Cost Estimate Per Variant

Detection System	Assessment System	Communication System	Defense System
Passive Infrared Detector	Blue Force Tracker	Computer	CROWS
Radar	Biometric Scanner	Siren	Semi Autonomous Armed UGV
Semi Autonomous UMS	Computer SW	Intrabase Network	Deployable Tire Spikes
	IR/Thermal/NV Imaging		
	Threat Prioritization Matrix SW		
Radar	Blue Force Tracker	Siren	Semi-Autonomous Armed UGV
Infrared Camera	IR/Thermal/NV Imaging	Intrabase Network	Deployable Tire Spikes
Camcorder	Vector Analysis	Server System	
	Video		
	Threat Prioritization Matrix SW		
Microphone	IR/Thermal/NV Imaging	Radio	Semi-Autonomous Armed UGV
Boomerang	Biometric Scanner	Lights	Deployable Tire Spikes
Radar	Computer SW	Computer System	
	Threat Prioritization Matrix SW		
Inertia Sensor	Ground Sensor	Satellite	Semi – Autonomous Weapon
Microphonic System	Sonic Signature	Phone	Deployable Tire Spikes
Unmanned Aerial Vehicle (UAV)	Computer SW	Computer	
	Response Matrix SW		

Expensive
Moderately Expensive
Affordable

Cost Estimate Per Variant (Con't)

	1	2	1	3	
	2	2	1	3	
1	3	1	3	1	**6.38**
		2			
		1			
	2	2	1	3	
	1	2	3	1	
2	1	1	2		**5.25**
		1			
		1			
	1	2	1	3	
3	2	2	1	1	**4.81**
	2	1	2		
		1			
	1	2	3	3	
4	2	2	1	1	**5.06**
	3	1	1		
		2			

A general estimate of cost for each variant using a roll-up method whereby each of the subsystems was assigned a color for the relative figure-of-merit cost. Red was assigned to those systems deemed to be expensive either based on existing cost, estimated component cost or cost of potential development. Yellow was assigned to systems that are close to fielding or have been fielded and have high lifecycle costs. Green was assigned to existing, low-tech solutions that have had extensive use in the field and because of generally low cost are ubiquitous, easy to procure and easy to support, that is they have a low lifecycle cost.

The process of determination of the relative figure of merit consisted of breaking down and categorizing the types of subsystems within each of the proposed options. Then SMEs, SEs and acquisition experts were consulted regarding relative cost. These relative rankings were averaged binned to reach the R/Y/G rank.

Based on the relative cost rank of the systems option #3 is the best cost solution using a series of low-tech and midrange subsystems.

Life cycle cost differences

Technologies have been assessed and estimated for procurement, development and life cycle cost:

Concept 1:

- Unmanned Aerial Vehicles, semi autonomous weapons, and unmanned ground vehicles all have relatively high up front development costs and high operating costs. (Power budgets may also be a concern for the smaller FOBs, where no power infrastructure is available to integrate with.)
- In addition UMS have a relatively low reliability and more expensive specialized components for replacement which will ultimately drive up the cost of the O&S.
- Radar's reasonable procurement system cost is somewhat offset by higher operational costs due to very high power consumption (again possibly a feasibility criteria for use on smaller FOBs due to power budget)
- Intrabase network costs are expected to be very high for procurement, as a variety of interconnections and associated hardware components may be required to link previously disconnected local area FOBs and camp outposts

Concept 2:

- Radar's reasonable procurement system cost is somewhat offset by higher operational costs due to very high power consumption (again possibly a feasibility criteria for use on smaller FOBs due to power budget)
- Intrabase network costs are expected to be very high for procurement, as a variety of interconnections and associated hardware components may be required to link previously disconnected local area FOBs and camp outposts

Concept 3:

- Microphone based shot detection systems such as Boomerang will have medium-high up front development costs, as calibrations will be required for the variety of sonic signatures from different munitions in a range of environments
- Radar's reasonable procurement system cost is somewhat offset by higher operational costs due to very high power consumption (again possibly a feasibility criteria for use on smaller FOBs due to power budget)

Concept 4:

- A dedicated satellite launch is anticipated to be a need in order to support the network of FOB automated base defense systems, which accounts for the high system element cost assigned
- Unmanned Aerial Vehicles, semi autonomous weapons, and unmanned ground vehicles all have relatively high up front development costs and high operating costs. (Power budgets may also be a concern for the smaller FOBs, where no power infrastructure is available to integrate with.)
- In addition UMS have a relatively low reliability and more expensive specialized components for replacement which will ultimately drive up the cost of the O&S.
- Microphone based shot detection systems such as Boomerang will have medium-high up front development costs, as calibrations will be required for the variety of sonic signatures from different munitions in a range of environments
- Sensor types may experience reliability performance shortfalls, as this could mark the first fixed battlefield usage for some, potentially requiring ruggedization during development or after first deployment and many spares

Value System Weighting

Prioritized Stakeholders Assessment of Priority

Stakeholder	Weight	Detection Range	Classification Accuracy	Data Latency	Warning Time	Threats Neutralized	Reliability	Availability
Infantry Soldier	9	9	7	7	9	9	7	7
FOB Commander	7	9	9	7	7	9	7	7
Maintainer	5	3	3	5	5	7	9	7
Logicians	3	1	3	1	1	5	7	5
Trainer	1	1	1	3	1	1	3	1
Guard	9	5	9	7	7	9	7	7

Stakeholder	Weight	Detection Range	Classification Accuracy	Data Latency	Warning Time	Threats Neutralized	Reliability	Availability
Infantry Soldier	9	81	59	59	81	77	59	63
FOB Commander	7	63	63	46	49	60	49	49
Maintainer	5	15	15	23	23	33	45	35
Logicians	3	3	9	3	3	15	21	15
Trainer	1	1	1	3	1	1	1	1
Guard	9	45	81	63	63	81	63	63
Total		**208**	**228**	**196**	**220**	**266**	**238**	**226**
Overall Weighting		**0.132**	**0.144**	**0.124**	**0.139**	**0.168**	**0.150**	**0.143**
Overall Importance		**6**	**3**	**7**	**5**	**1**	**2**	**4**

Variant Value Score

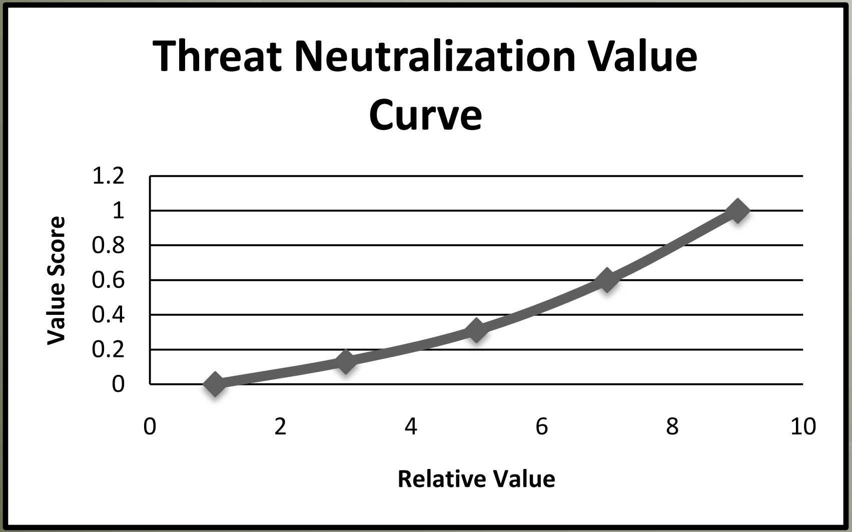
Attribute Swung from worst to best	Consequences to compare	Rank	Rate	Weight
Benchmark	500,0.95,400,3,0.95,750,0.9	8	0	**0**
Best Detection Range	**1500**,0.95,400,3,0.95,750,0.9	6	61	**0.116046**
Best Classification Accuracy	500,**0.99**,400,3,0.95,750,0.9	3	81	**0.155205**
Best Data Latency	500,0.95,**100**,3,0.95,750,0.9	7	46	**0.088348**
Best Warning Time	500,0.95,400,**1**,0.95,750,0.9	5	70	**0.13276**
Best Threat Neutralization	500,0.95,400,3,**0.99**,750,0.9	1	100	**0.191022**
Best Reliability	500,0.95,400,3,0.95,**1000**,0.9	2	91	**0.174308**
Best Availability	500,0.95,400,3,0.95,750,**0.92**	4	75	**0.142311**

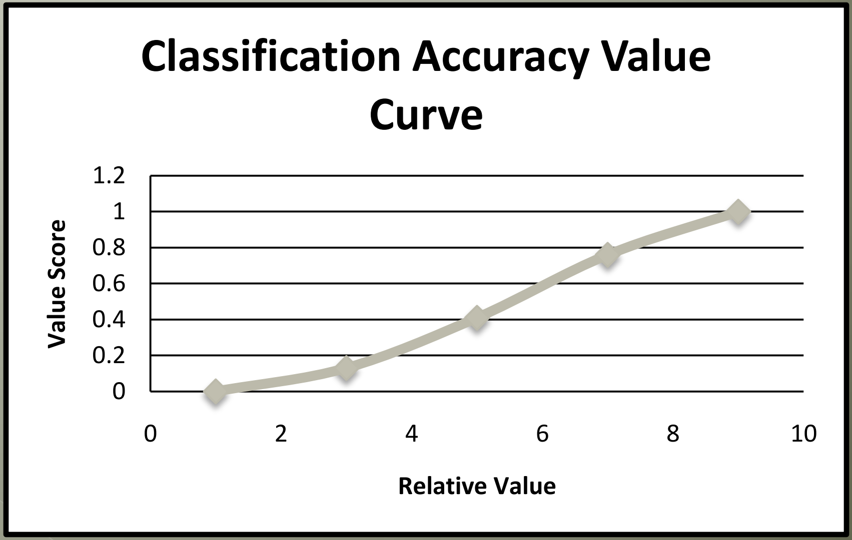
Variant Value Score

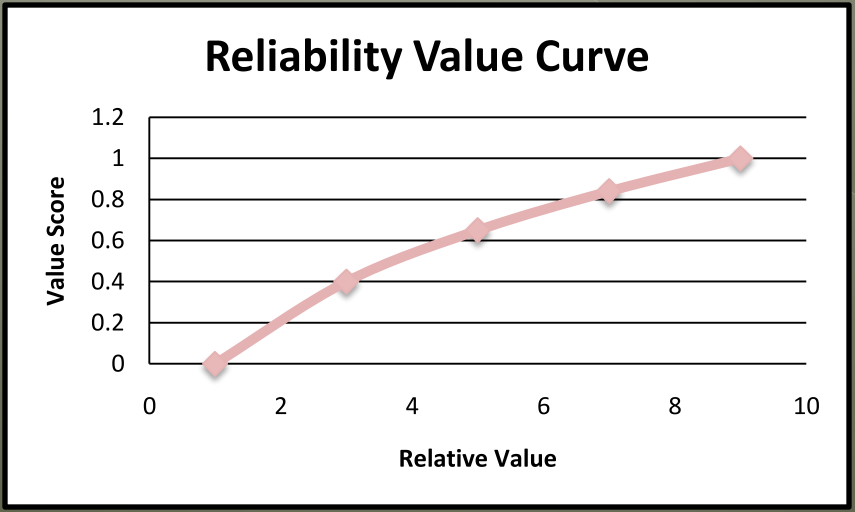
	Raw Data Table	Max Detection Range	Max Classification Accuracy	Min Data Latency	Min Warning Time	Max Threats Neutralized	Min Mean Time Between Failures	Max Operational Availability		
	Threshold/Goal	500-1500	95-99	400-100	3-1	95-99	750-1000	0.90 - 0.92		
	Unit of Measure	meters	%	milliseconds	seconds	%	Hours	No Units		
		MIB	MIB	LIB	LIB	MIB	LIB	MIB		
	Weights	0.116045845	0.155205349	0.08834766	0.132760267	0.191021968	0.174307545	0.142311366		
Variant	Description									Relative MO
Semi Autonomous	Most Effective	7	5	7	5	7	5	5	Relative Perf of variant wrt attribute	5.79083
Video Based	Lowest Development Risk	3	5	7	5	5	7	7		5.57784
Sonar	Lowest Cost	5	3	5	3	5	5	7		4.70869
Satellite Based	Most Effected by Weather	9	3	3	3	5	3	5		4.36294

	Raw Data Table	Max Detection Range	Max Classification Accuracy	Min Data Latency	Min Warning Time	Max Threats Neutralized	Min Mean Time Between Failures	Max Operational Availability		Total
	Threshold/Goal	500-1500	95-99	400-100	3-1	95-99	750-1000	0.90 - 0.92		
	Unit of Measure	meters	%	milliseconds	seconds	%	Hours	No Units		
		MIB	MIB	LIB	LIB	MIB	LIB	MIB		
	Weights	0.116045845	0.155205349	0.08834766	0.132760267	0.191021968	0.174307545	0.142311366		1
Variant	Description									OMOE
Semi Autonomous	Most Effective	0.76	0.41	0.93	0.49	0.6	0.65	0.69		0.62515
Video Based	Lowest Development Risk	0.26	0.41	0.93	0.49	0.31	0.84	0.85		0.56762
Sonar	Lowest Cost	0.5	0.13	0.77	0.29	0.31	0.65	0.85		0.47821
Satellite Based	Most Effected by Weather	1	0.13	0.46	0.29	0.31	0.4	0.69		0.4425

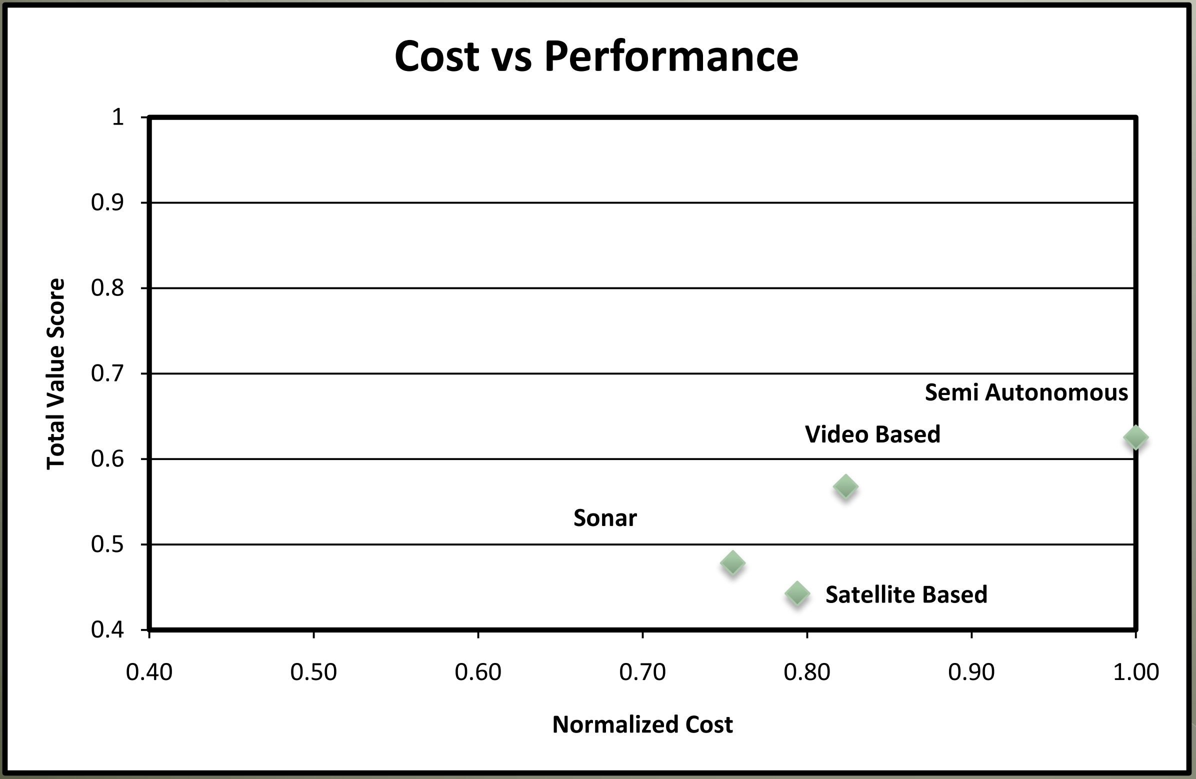
Value Curves







OMOE vs Cost Evaluation



Concept	Cost Score	Performance Score
1	1.00	0.6252
2	0.82	0.5676
3	0.75	0.4782
4	0.79	0.4425

- Assessed the performance based on the previously prioritized stakeholders and their importance placed on the individual Evaluation measures used to determine the value system.
- The Evaluation Measures were weighted based upon the importance to the stakeholders and the weighting placed on the individual stakeholders.
- The performance was then normalized.
- The cost was determined utilizing a high level assessment of expensive, moderately expensive and affordable (1,2,3 respectively) that was then summed up and normalized as well.
- Those normalized numbers were then graphed against each other

Preferred Concept Alternative

Concept	Normalized Cost Score	Cost Weight (.20)	Normalized Performance	Performance Weight (.80)	System Total (Performance - Cost)
1	1.00	0.20	0.63	0.50	**0.30**
2	0.82	0.16	0.57	0.45	**0.29**
3	0.75	0.15	0.48	0.38	**0.23**
4	0.79	0.16	0.44	0.35	**0.20**

Concept	Detection System	Assessment System	Communication System	Defense System
Semi Autonomous	• Passive Infrared Detector • Radar • Semi Autonomous UMS	• Blue Force Tracker • Biometric Scanner • Computer SW • IR/Thermal/NV Imaging • Threat Prioritization Matrix SW	• Computer • Siren • Intrabase Network	• CROWS • Semi Autonomous Armed UGV • Deployable Tire Spikes

Justification:

- There is no cost constraint , however we are aware that cost is never a non factor. It was assessed independently and then utilized to help determine the best ROI for the system.
- We took all the data for the OMOE and the cost and we normalized that data. Utilizing a formula to account for the higher cost we weighted the cost of the system to be a 20% impact to the overall system total. We are also aware that performance is of great importance to the user because of the nature of the system which will help alleviate adverse mission impacts and loss of life due to small FOB attacks.
- The chosen system has a higher level of risk because it is a semi autonomous system, however it will be progressively advanced and will meet the requirement of automating lower level functions such as detection, target acquisition, threat assessment and automated warnings.
- The system is slightly more expensive then the other concept options, however we feel this system will be the most efficient because it will rely heavily on those automated responses and require only the input of the user to make decisions such as commands to mobilize, command to apprehend or command to engage.

SV-7

ROBOCOP SV-7				
Increment		FY12 Baseline	FY14 Inc One	FY16 Inc Two
Increment Purpose			Increase the detection capability to allow for more stand off time.	Decrease the amount of time needed to communicate, warn, and kill threat.
System		Performance Range (Threshold and Objective) Measures		
Detection Package	Detection Range (meters)	(500/1500)	(750/2000)	(750/2000)
	Location Accuracy (% Correct)	(92/95)	(92/95)	(92/95)
Assessment Package	Identification Accuracy (% Correct)	(92/99)	(92/99)	(92/99)
	Classification Accuracy (% Correct)	(92/99)	(92/99)	(92/99)
Communication System	Data Latency (milliseconds)	(400/100)	(400/100)	(200/75)
Warning System	Warning Time (seconds)	(3/1)	(3/1)	(2/1)
Weapon System	Kill Time (seconds)	(50/30)	(50/30)	(45/20)
	Threat Neutralized (% Neutralized)	(95/99)	(95/99)	(95/99)

Summary:
This Systems Measures Matrix shows the eight most crucial metrics for successful mission achievement. Each of the metric includes performance measures to achieve the mission goals. Increment One will be released in FY14 and will drastically increase detection range around the perimeter of the FOB, allowing for a substantially quicker response to threats. Increment Two will be released in FY16 and continues to quicken the response time toward threat. Increment Two accomplishes this by reducing data latency time, time required to warn personnel, and time required to kill threat.

SV-9

ROBOCOP SV-9			
IBDS Service	Technology Forecast		
	Short Term (0-6 Months)	Mid Term (6-18 months)	Long Term (18-36 Months)
Detection Devices			
RADAR	Blighter B402	Blighter B422	Blighter B442
UMS	Tele Operated Talon	Semi Autonomous UMS (ALFUS level 3)	Semi Autonomous UMS (ALFUS level 5)
Assessment Devices			
Blue Force Tracker	Blue Force Tracker	Blue Force Tracker 2	Blue Force Tracker WP
Biometric Scanner	SEEK II	LR SEEK II	Behavioral
Computer	E6400 XFR		VICTORY Compliant
Infrared Imaging	Fusion-IR Panther XLR	Extended Range Panther XLR	
Threat Prioritization Matrix SW	Automated Threat Prioritization SW	Automated Threat Prioritization SW II	
Communication Systems			
Computer	E6400 XFR		VICTORY Compliant
Siren	COTS Siren		
Intrabase Network	Wired Fiber Optic LAN		VICTORY Compliant LAN
Defense Systems			
Semi Autonomous Weapon	CROWS	Slue-to-Cue	Active Protection System
Semi Autonomous Armed UGV	Tele Operated Armed UGV	Semi Autonomous Armed UGV (ALFUS level 3)	Semi Autonomous Armed UGV (ALFUS level 5)
Tire Spikes	Manual		Automatic

System Baseline

System Baseline
Sensing Subsystem
Passive Infrared Detector
Locating Subsystem
Blighter B402
Tracking Subsystem
Tele Operated Talon (UMS)
Identification Subsystem
Blue Force Tracker
SEEK II
Classification Subsystem
SEEK II
E6400 XFR
Determination of Intent Subsystem
E6400 XFR
Determination of Capability Subsystem
E6400 XFR
Fusion-IR Panther XLR

System Baseline
Prioritization Subsystem
Automated Threat Prioritization SW
Dissemination of Information Subsystem
E6400 XFR
Wired Fiber Optic LAN
Warning Subsystem
COTS Siren
Data Transportation Subsystem
Wired Fiber Optic LAN
Engagement Subsystem
CROWS
Semi Autonomous Armed UGV
Penetration Prevention Subsystem
Manually Deployable Tire Spikes

Summary of Results

- Due to the fact that cost was not a major contributing factor is system selection, we determined that the best system for the base defense was the Semi Autonomous Concept.
  - This is a high cost, high risk, high reward system. One of the trade offs that was made is that there is a baseline of technologies for the system that will come close to meeting all the requirements. However there is a large opportunity for improvement as far as performance and additional gaps that may be able to be addressed.
  - We were able to identify some of the risks involved in the system and had to make decisions based on some of the requirements put forth by the user. For example, the stakeholders identified the need for automated lower level functions, now that carries a greater technical and schedule risk than manual systems. However, we initially may have to trade off the requirement for limited contractors in the field due to the specialty nature of the unmanned systems and the maintenance training required.
    - Ultimately the goal would be to transition many of those contractors out and to become a more organic Army, however that will require the specialization and potential MOS of unmanned or robotic systems.
- Additionally, we identified that there was a very close system value between the Autonomous Concept and the Video Based Concept, however the Autonomous Concept offered more performance than the video based system, therefore we chose the higher cost system of the two ultimate choices.
- There is more analysis to do however, we are confident that with the trade studies we have performed we are ready to recommend the Semi Autonomous Concept and accept the risks involved by implementing mitigation plans to work them.

Appendices

Appendix A

- See Attached Appendix

Appendix B
Test Program Plan (Type 2)

Overview

The ROBOCOP IBDS is designed to protect smaller FOBs from threats such as RPGs, VBIEDs, Hostile Civil Disturbances and small arms fire. The system consists of multiple subsystems that can be individually tested. However, one of the greatest challenges is integration of subsystems. Below is a outline of the Type 2 Testing to be performed.

1) Performance Test

Performance testing will be completed on the following subsystems:

- Detection System
  - Sensor System
  - Radar System
  - Tracking System
- Assessment System
  - Identification System
  - Classification System
- Communication System
  - Warning System
  - Data System
- Weapon System
  - Remote Weapon System
  - Penetration Prevention System

- Integration and System Level Testing

  The final test that will be required will be to ensure that the subsystem can perform without degradation to the mission or individual components when working together. The component level testing can be completed at the contractor facilities, however integration testing and system performance testing will be conducted at a government facility to ensure the conditions remain stable.

2) Environmental Qualification Test

The system will be exposed to a variety of environmental tests that will be dictated by both MIL-STDs and any extreme conditions identified in the mission profile. Therefore the following environmental testing will be conducted:

- Temperature Cycling
- Shock
- Vibration
- Humidity
- Wind
- Dust and Sand
- Explosion proofing
- Electromagnetic interference

All of the environmental testing will be completed at government facilities.

3) Structural Tests

The material that will be used in the development of the IBDS will undergo the following structural tests:

- Stress
- Strain
- Fatigue
- Bending
- Torsion

This testing will be done at the contractor facilities, as it will be conducted on the individual component materials and no on the system as a whole. Some of the subsystem may not require structural tests depending on the material usage. All results will be reported to the government in the form of CDRLs.

4) Reliability Qualification Test

Reliability testing will be conducted at both the subsystem and system level. At the subsystem level this will consist of individual reliabilities since the overall system reliability is defined as:

$R_{system} = R_1*R_2*R_3*R_4*R_n$

It is important to understand the subsystem reliability because it ultimately drives the system level reliability. Component level reliability testing will be done at the contractor facilities. This will also include durability testing to determine Mean Time between Failures (MTBF). The system level reliability testing will be completed at the government facilities. These test results will also provide insight into the Operation Availability which is defined as:

$$A_O = \frac{MTBF}{MTBF + MTTR + MLDT}$$

5) Maintainability Demonstration Test

Maintainability Demonstrations will be conducted to demonstrate the mean time to repair (MTTR), both preventative and corrective, as well as if special tools are required. Initially demonstrations can take place at the contractor facility. However, the demonstrations will be conducted at the government facilities as well, with the personnel that will be performing the maintenance. These results will also influence the Operation Availability (see above).

6) Support Equipment Compatibility Test

Support equipment compatibility test will be conducted to ensure compatibility with current handling and transportation equipment, specifically sling load testing for SWAP. These tests will be conducted at the government facilities to ensure the correct equipment and personnel are available.

7) Software Verification

Software Verification will be conducted to ensure software in the following systems is compatible, reliable and performs as required with specified systems:

- Intent Determination Software
- Capability Level Software
- Prioritization Software

Testing can be conducted at the contractor facilities.

Top Instantiated Concepts - Review

Concept	Detection System	Assessment System	Communication System	Defense System
1	• Passive Infrared Detector • Radar • Semi Autonomous UMS	• Blue Force Tracker • Biometric Scanner • Computer • RF Detection • Threat Prioritization Matrix	• Computer • Siren • Intrabase Network	• Semi Autonomous Weapon • Semi Autonomous Armed UGV • Deployable Tire Spikes
2	• Radar • Infrared Camera • Camcorder	• Blue Force Tracker • IR/Thermal/NV Imaging • Vector Analysis • Video • TPM	• Siren • Intrabase Network • Server System	• Semi-Autonomous Armed UGV • Deployable Tire Spikes
3	• Microphone • Boomerang • Radar	• IR/Thermal/NV Imaging • Biometric Scanner • Computer • Threat Prioritization Matrix	• Radio • Lights • Computer System	• Semi-Autonomous Armed UGV • Deployable Tire Spikes
4	• Inertia Sensor • Microphonic Systems • Unmanned Aerial Vehicle (UAV)	• Ground Sensor • Sonic Signature • Computer • Response Matrix	• Satellite • Phone • Computer	• Semi – Autonomous Weapon • Deployable Tire Spikes

MOEs, TPMs and KPP Mappings

MOE	TPMs	KPPs
Percentage of Potential threat Detections in the AOR	The IBDS shall detect a 0.3m object in the AOR form 50 to 1500m The IBDS shall detect a XXX mortar or rocket inbound from 5km to 50m	The IBDS shall correctly identify common objects, including common military objects, animal, person, environmental etc, with a 92%(T), 99%(O) accuracy. Rationale: Identification of object within the AOR is key to classification and threat/intent assessment.
Percentage of correctly classified threats	The shall identify Friend, Foe and munitions from 50m to 1500m with a latency of 400ms(T), 100ms(O)	The IBDS shall correctly classify the potential threat as friend, foe, munition or neutral with an accuracy of 95%(T), 99%(O). Rationale: Correct classification including threat/intent is critical to providing an early warning to personnel and QRF.
Percentage of Personnel cleared of danger area and ready for mobilization	The IBDS shall output an audible warning automatically within 3s(T), 1s(O) of the recognition of an incoming munition.	The IBDS shall provide 30s warning to Base personnel and QRF in response to incoming threat based on flight time of XXX Mortar round at XXX distance (See Classified Annex). Rationale: With appropriate detection a 30s warning to scramble the QRF and to clear base personnel will reduce the number of casualties.
Percentage of threats neutralized without damage to the personnel, facilities or equipment	The IBDS shall render a threat neutral (unable to cause damage) within 50s(T), 30s(O) of recognition of the potential threat.	The IBDS shall render 95%(T), 99%(O) of the incoming munitions neutralized. Rationale: Neutralization of the incoming munitions/attacking forces will prevent/reduce damage to base infrastructure and personnel as well as acting as a deterrent to future attacks.
Availability of .9	The IBDS shall have an Operational Availability of 0.90	The IBDS shall be operationally available 90% (T) 92% (O) of the time
Mean time between failures of 750 hours	The IBDS shall have an MTBF of 750 hours	The system shall have a reliability of 750 (T) 1000 (O) hours mean time between failures