Air Force Institute of Technology

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Systems Engineering for Rapid Prototyping: Friendly Marking Device

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“Can a prototyping development effort be responsive enough to react to critical needs while still benefiting from the rigor of systems engineering?”

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Introduction

- Close Air Support (CAS) Background
- Prototyping Approach
- Friendly Marking Device (FMD) Results
- Conclusion/ Observations

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The Problem

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Background

- **IAW JP 3-09.3 (2 Sep 05):**
  - **Close air support (CAS) is air action by fixed- and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and which require detailed integration of each air mission with the fire and movement of those forces.**

- **Urban CAS considerations**
  - **Closer proximity to the enemy**
  - **Reduced communication time**
  - **Presence of noncombatants**
  - **Potential for collateral damage**
  - **Increased risk of fratricide**

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Challenge/ Constraints

- **AF Research Lab Rapid Reaction (Core Process 3)**
  - **Compressed schedule - 5 months from emerging need to prototypes**
  - **No modifications to the CAS aircraft or pods**
  - **Technology maturity**
  - **Resource availability**
  - **Operational limitations**
  - **Cost**

- **Project Objective: *Develop, demonstrate and transition a marking solution that enables a Joint Terminal Attack Controller (JTAC) to establish a common point-of-reference with a Close Air Support (CAS) asset such that the CAS asset can attack an intended target while avoiding fratricide.***

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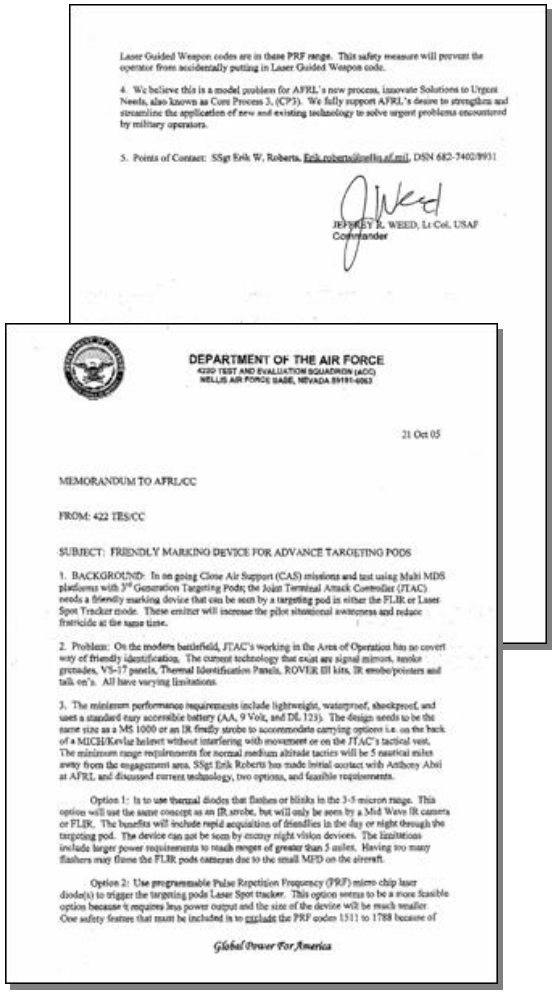
Background

"In on going Close Air Support (CAS) missions and test using MDS platforms with 3rd Generation Targeting Pods; the Joint Terminal Attack Controller (JTAC) working in the Area of Objective has no covert way of friendly identification."

"The JTAC needs a friendly marking device that can be seen by a targeting pod in either the FLIR or Laser Spot Tracker mode. These emitters will increase the pilot situational awareness and reduce fratricide at the same time."



Laser Guided Weapon codes are in these PRF range. This safety measure will prevent the operator from accidentally putting in Laser Guided Weapon code.

4. We believe this is a model problem for AFRL's new process, innovate Solutions to Urgent Needs, also known as Core Process 3, (CP3). We fully support AFRL's desire to strengthen and streamline the application of new and existing technology to solve urgent problems encountered by military operators.

5. Points of Contact: SSgt Erik W. Roberts, Erik.roberts@nellis.af.mil, DSN 682-7402/8931

JEFFREY R. WEED, Lt Col, USAF
Commander

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21 Oct 05

MEMORANDUM TO AFRL/CC

FROM: 422 TES/CC

SUBJECT: FRIENDLY MARKING DEVICE FOR ADVANCE TARGETING PODS

1. BACKGROUND: In on going Close Air Support (CAS) missions and test using Multi MDS platforms with 3rd Generation Targeting Pods; the Joint Terminal Attack Controller (JTAC) needs a friendly marking device that can be seen by a targeting pod in either the FLIR or Laser Spot Tracker mode. These emitter will increase the pilot situational awareness and reduce fratricide at the same time.

2. Problem: On the modern battlefield, JTAC's working in the Area of Operation has no covert way of friendly identification. The current technology that exist are signal mirrors, smoke grenades, VS-17 panels, Thermal Identification Panels, ROVER III kits, IR strobe/pointers and talk on's. All have varying limitations.

3. The minimum performance requirements include lightweight, waterproof, shockproof, and uses a standard easy accessible battery (AA, 9 Volt, and DL 123). The design needs to be the same size as a MS 1000 or an IR firefly strobe to accommodate carrying options i.e. on the back of a MICH/Kevlar helmet without interfering with movement or on the JTAC's tactical vest. The minimum range requirements for normal medium altitude tactics will be 5 nautical miles away from the engagement area. SSgt Erik Roberts has made initial contact with Anthony Abel at AFRL and discussed current technology, two options, and feasible requirements.

Option 1: Is to use thermal diodes that flashes or blinks in the 3-5 micron range. This option will use the same concept as an IR strobe, but will only be seen by a Mid Wave IR camera or FLIR. The benefits will include rapid acquisition of friendlies in the day or night through the targeting pod. The device can not be seen by enemy night vision devices. The limitations include larger power requirements to reach ranges of greater than 5 miles. Having too many flashers may flame the FLIR pods cameras due to the small MFD on the aircraft.

Option 2: Use programmable Pulse Repetition Frequency (PRF) micro chip laser diode(s) to trigger the targeting pods Laser Spot tracker. This option seems to be a more feasible option because it requires less power output and the size of the device will be much smaller. One safety feature that must be included is to exclude the PRF codes 1511 to 1788 because of

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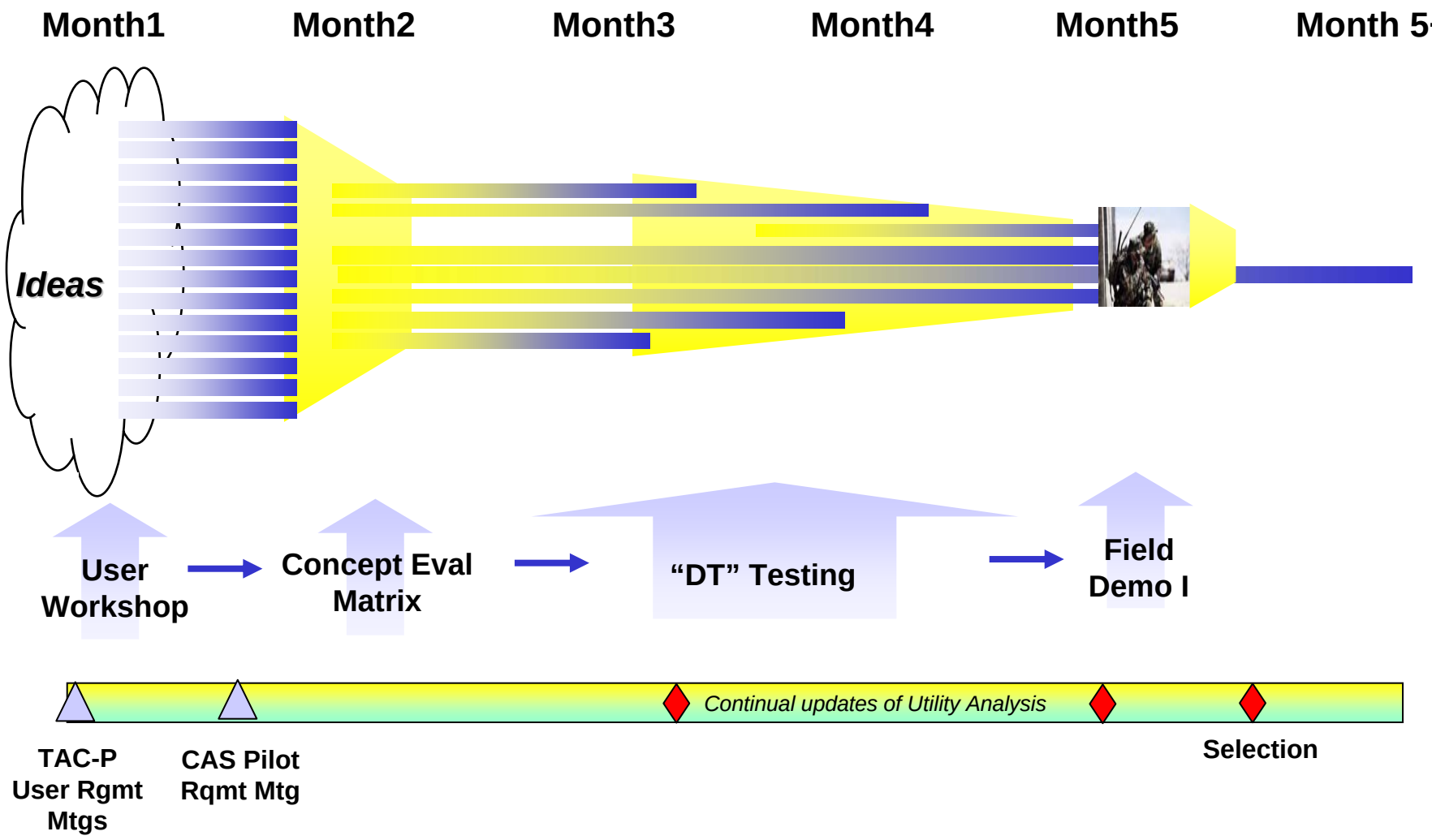
Rapid Reaction Prototyping



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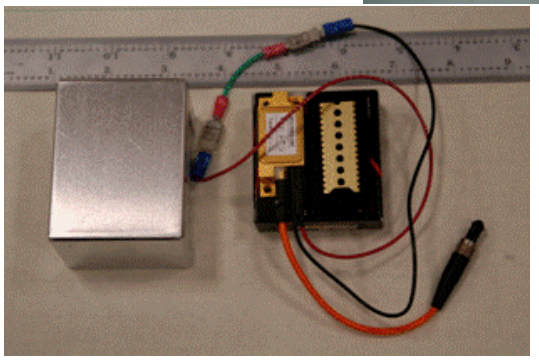
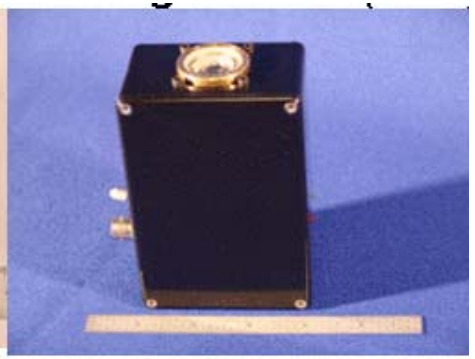
Ideas

* Patent Pending





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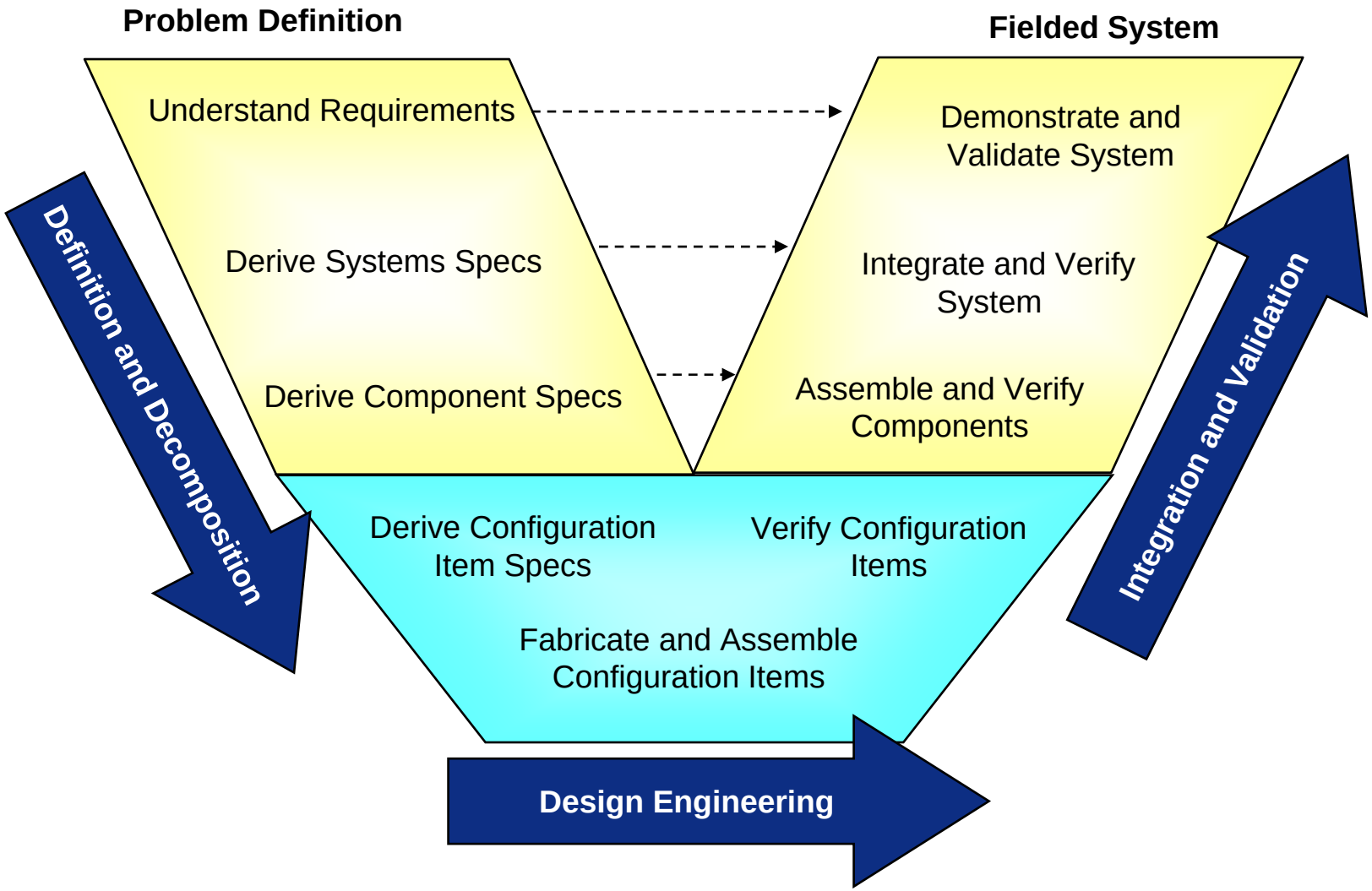
Classic V-Model



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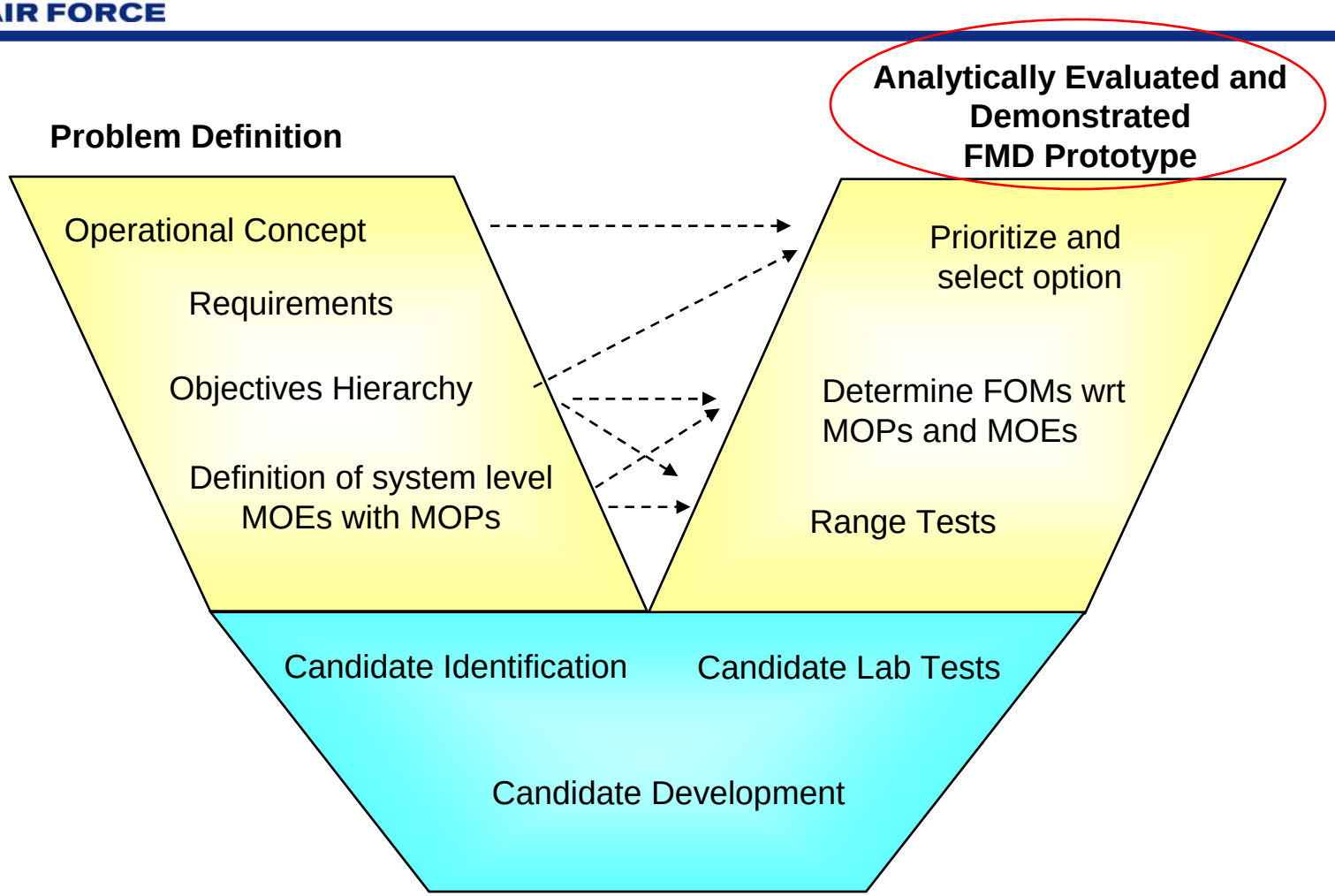
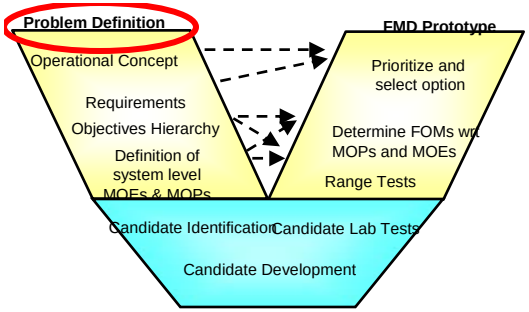
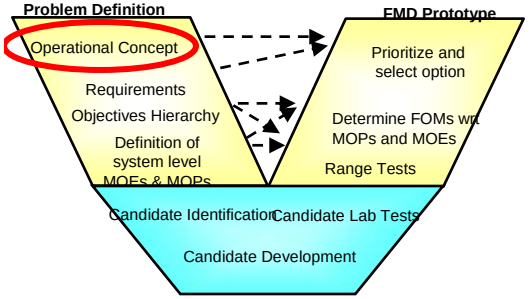
Prototyping





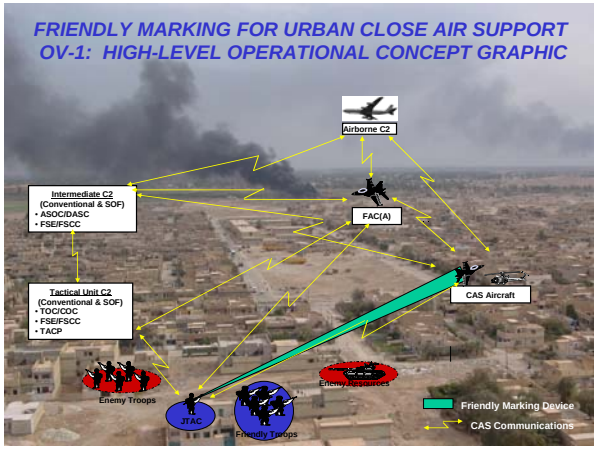
Problem Definition

- **Pubs on Close Air Support (JP 3-09.3, Sep 05):**
- **Stakeholder Interviews (JTACs and CAS pilots)**
  - **User Requirement Questions**
- **Analysis Criteria**
- **Constraints identification**
- **Restated problem as:**
  - ***The Joint Terminal Attack Controller (JTAC) lacks a covert means to quickly and accurately mark the location of friendly forces as a common point-of-reference with a Close Air Support (CAS) asset such that the JTAC can direct a CAS attack with minimum risk of fratricide.***



Develop an Operational Concept

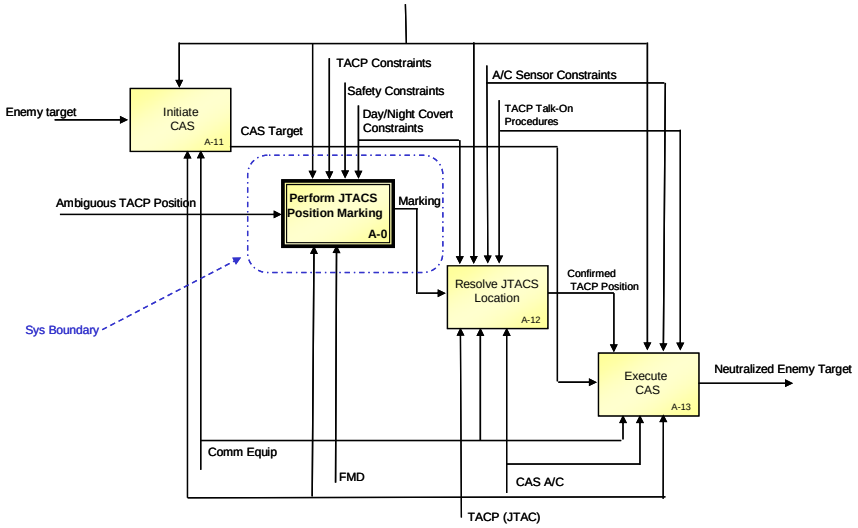
- **DoDAF OV-1, High-Level Operational Concept Graphic**
- **DoDAF OV-5 External Systems Diagram**
- **Use Cases (RUP template)**

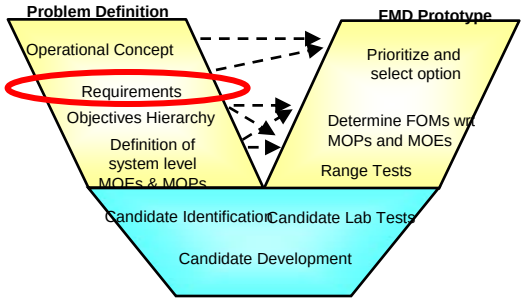


Success Guarantee	• CAS aircraft provides bombs on target. • There is no fratricide of friendly forces.

Urban Close Air Support Use Case

Use Case Name	Name: Urban Close Air Support
	Brief Description: This use case describes the process of briefing target location to the CAS aircraft when the target's coordinates are unknown, target is a moving target, the close proximity to friendly forces requires higher degree of accuracy, or when time/situation does not allow for a long CAS brief.
Actors Involved	Joint Tactical Air Controller (JTAC) – "A qualified (certified) Service member who, from a forward position, directs the action of combat aircraft engaged in close air support and other offensive air operations" (JP 3-09.3). • Goal – To accurately identify CAS target and friendly position to the CAS Aircraft. • To prevent fratricide. Close Air Support (CAS) aircraft – Aircraft tasked to support close air support operations. • Goal – To accurately and quickly acquire CAS target and friendly position. • To prevent fratricide. Air Support Operations Center (ASOC) – "The principal air control agency of the theater air control system responsible for the direction and control of air operations directly supporting the ground combat element. It processes and coordinates requests for immediate air support and coordinates air missions requiring integration with other supporting arms and ground forces" (JP 3-09.3).
Preconditions	• JTAC has constant communication with ASOC. • Target coordinates are not known, target is a moving target, the close proximity to friendly forces requires higher degree of accuracy, or when time/situation does not allow for a long CAS brief. • JTAC contacts the ASOC to request CAS • ASOC contacts CAS aircraft and passes them CAS information (coordinates, frequencies, JTAC info, etc.) • CAS Aircraft contacts JTAC



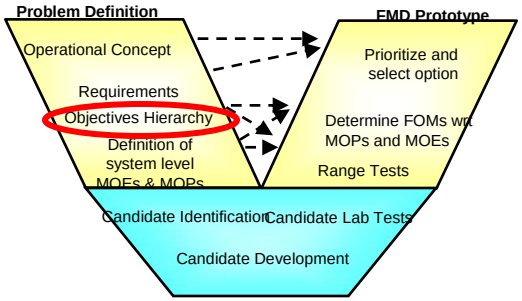


Requirements Analysis

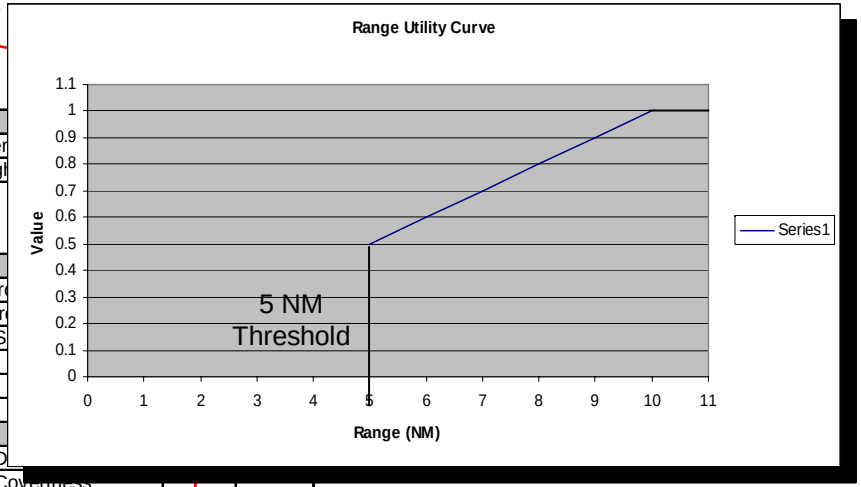
- Use Case refinement
- User Requirements with weights
  - JTACs
  - CAS Pilots
- FURPS+ model
  - Functional
  - Usability
  - Reliability
  - Performance
  - Supportability
  - "plus" other requirements such as Implementation, Interface, Operations, Packaging, Legal, etc.

User requirements with weights	
Types of Requirements	**Requirements**
Environmental	Weather Limitations
	Day/Night Limitations
Physical	Waterproof
	Shockproof
	Power Source
	Weight
	Size Dimensions
Operational (signal)	Signal Duration
	Signal Covertness
	Signal Field of View
	Signal Range
	Accuracy Resolution
	Signal Spectrum
	System Compromise
	Unique Signal
	Signal Transmission Delays
Operational (system)	Ease of use / training required
	Modification required
	Unique Signal display
Acquisition (Long term)	Long-term unit cost
	Product Feasibility
Acquisition (Short term)	Estimated cost
	Prototype availability
	System Maturity/ estimated TRL
	Factors influencing prototype development

Objectives Hierarchy



User defined



Weights

0.1	Environmental	
		0.9
		0.8
	Score	0
0.2	Physical	
		0.9
		0.8
	Score	0
0.3	Ops - Signal	
		0.9
		0.8
	Score	0
	Mark Position	
		0.9
		0.8

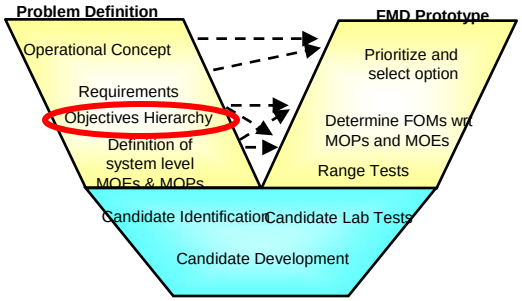
Element Value	
0	Weather
0	Day/Night
0	Waterproof
0	Shockproof
0	Power S
0	Weight
0	Size
0	Signal D
0	Signal Covertness
0	Signal FOV
0	Signal Range
0	Accuracy/Resolution
	Signal Spectrum
	Signal Compromise
	Unique Signal
	Signal Trans Delays

	Weight	Score
Ease of Use		
Modification Rqd		
Unique Signal Display		

	Weight	Score
Long Term Unit Cost		
Production Feasiblity		

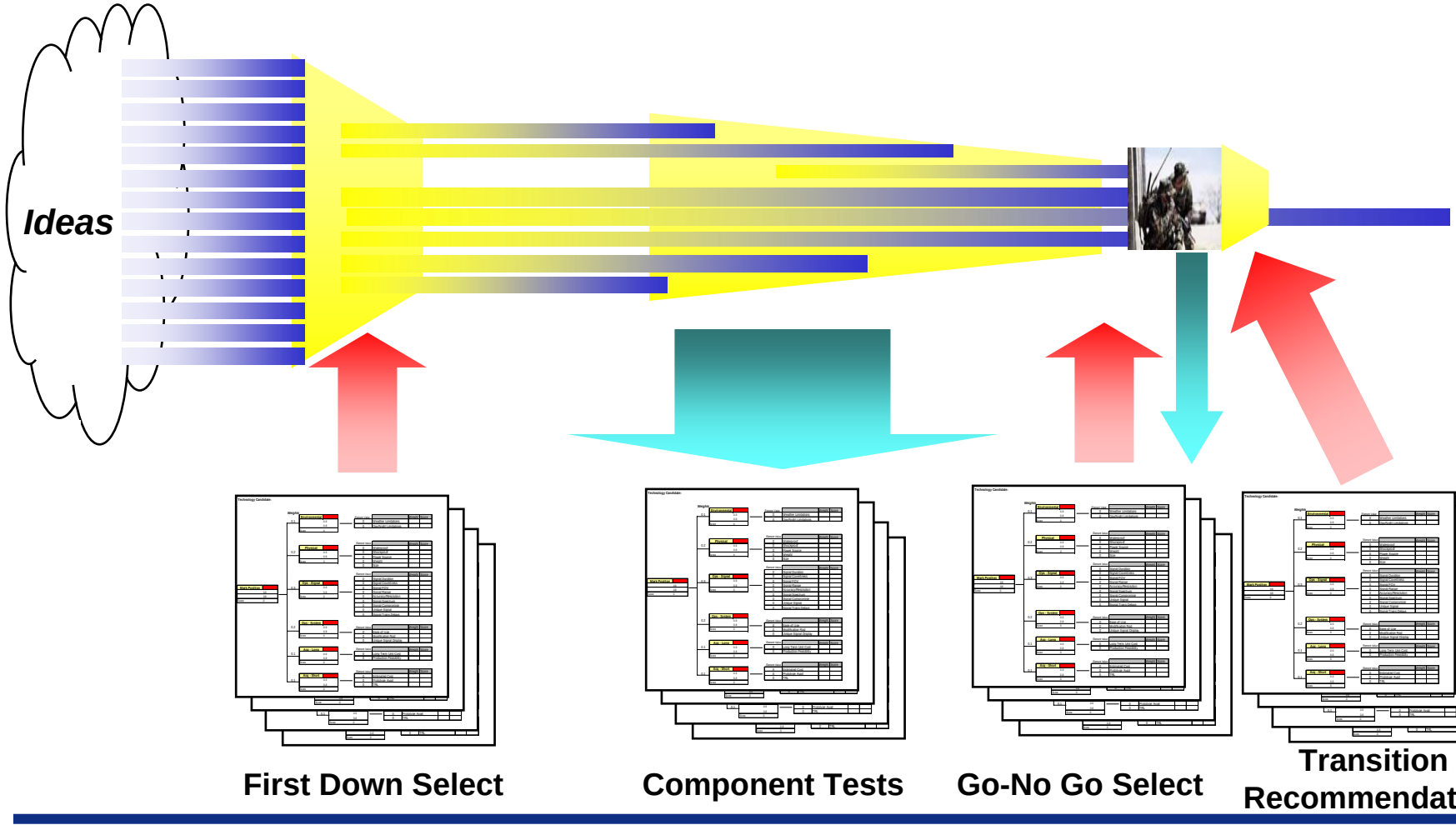
	Weight	Score
Estimated Cost		
Prototype Avail		
TRL		

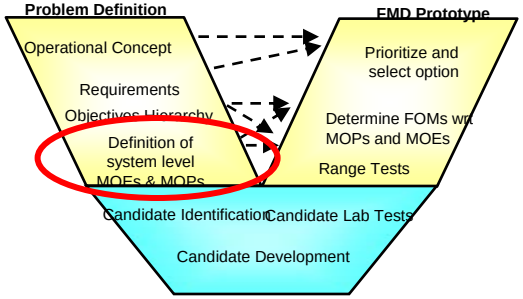
- **Risk-Neutral Utility curves**
- **Based upon user requirements & expressed desires**
- **Each candidate is scored**
- **Updated as candidates matured (ie: test data)**
- **Long/short term acquisition elements based upon engineering judgement**



Objectives Hierarchy: "Living Tool"

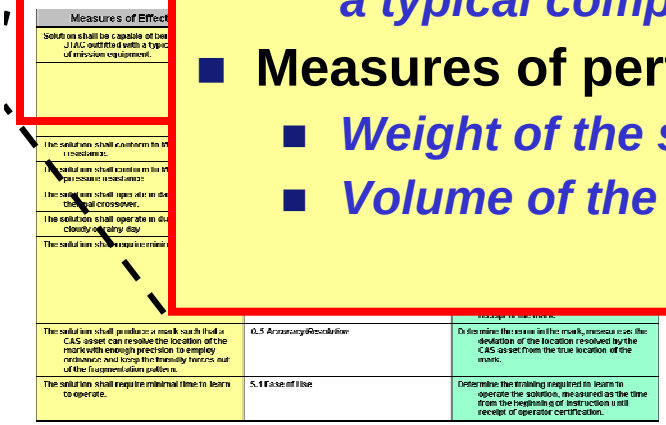
Month1 **Month2** **Month3** **Month4** **Month5** **Month 5+**

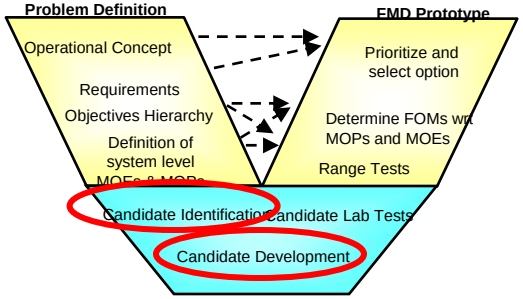




Definition of system level MOEs and MOPs

- **Originating Requirements**
  - *Weight : 4 – 6 oz without batteries*
  - *Volume : 25.1 in³ , "Less than a Coke can "*
- **Critical operational issues (COI)**
  - *The JTAC carries a variety of mission equipment to execute a mission. The JTAC has limited excess space and weight capacity for carrying new mission equipment.*
- **Measures of effectiveness (MOE)**
  - *Solution shall be capable of being carried by a JTAC outfitted with a typical complement of mission equipment.*
- **Measures of performance (MOP)**
  - *Weight of the solution including packaging and expendables.*
  - *Volume of the solution including packaging and expendables.*

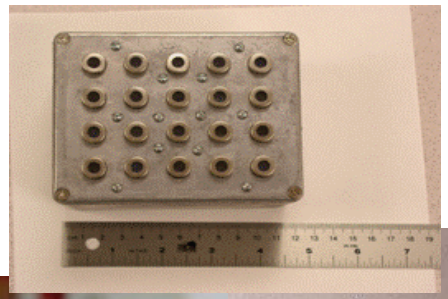




Identify/ Develop Technology Candidates

- **AF Research Lab (AFRL) already had many concept ideas**
- **Team utilized several "*brain storming*" sessions to refine possible technologies**

1064 Laser	1064 Laser	1064 Laser	1064 Laser	1064 Laser
3-5 micron LED	3-5 micron LED	3-5 micron LED	3-5 micron LED	3-5 micron LED
3-5 micron LED Beacon	3-5 micron LED Beacon	3-5 micron LED Beacon	3-5 micron LED Beacon	3-5 micron LED Beacon
873 Laser	873 Laser	873 Laser	873 Laser	
Box Thermal Emitter Array		Box Thermal Emitter Array	Box Thermal Emitter Array	Box Thermal Emitter Array
Halogen Bulb Flashlight	Halogen Bulb Flashlight	Halogen Bulb Flashlight	Halogen Bulb Flashlight	Halogen Bulb Flashlight
Israeli COTS Emitter				Israeli COTS Emitter
Krypton Bulb Flashlight	Krypton Bulb Flashlight	Krypton Bulb Flashlight	Krypton Bulb Flashlight	Krypton Bulb Flashlight
Laser Beeper	Laser Beeper			
Laser Marker	Laser Marker			
Laser Warning Receiver		Laser Warning Receiver	Laser Warning Receiver	Laser Warning Receiver
Rescue Laser Flare				Rescue Laser Flare
RF Tag	RF Tag			
Special Material Locator	Special Material Locator	Special Material Locator	Special Material Locator	Special Material Locator
TRON 1	TRON 1			
Thermal Beacon	Thermal Beacon			
Thermal Signaling Device I	Thermal Signaling Device I	Thermal Signaling Device I	Thermal Signaling Device I	
TRON 2 (TBD)	TRON 2 (TBD)			
TRON 3 (Blanket)	TRON 3 (Blanket)			
TSD II (Helio Triad)				TSD II (Helio Triad)
TSD III (Cal Triad)				TSD III (Cal Triad)
TSD IV (Single Space Heater)				TSD IV (Single Space Heater)
TSD V (Space Heater Triad)				TSD V (Space Heater Triad)



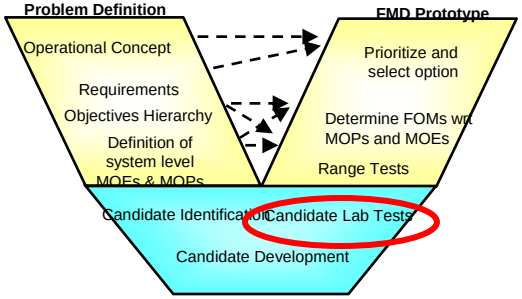
Thermal Emitter Box Array

Thermal Emitters

Special Materials

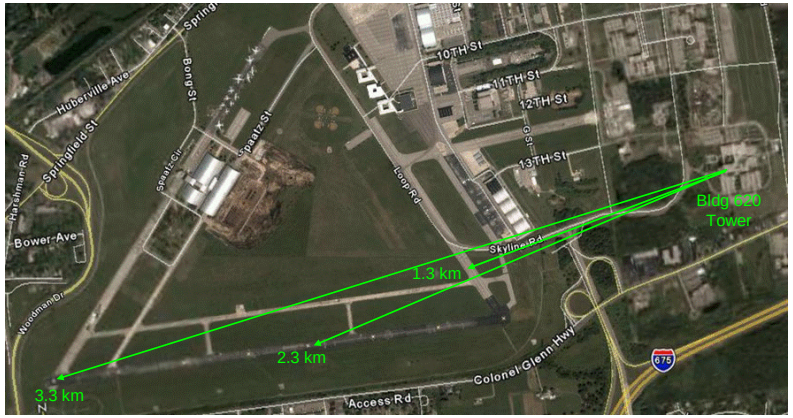
LEDs

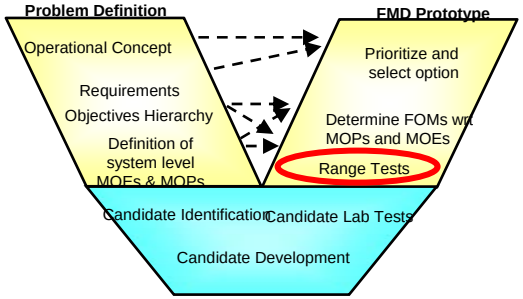
Laser



Candidate Lab Tests

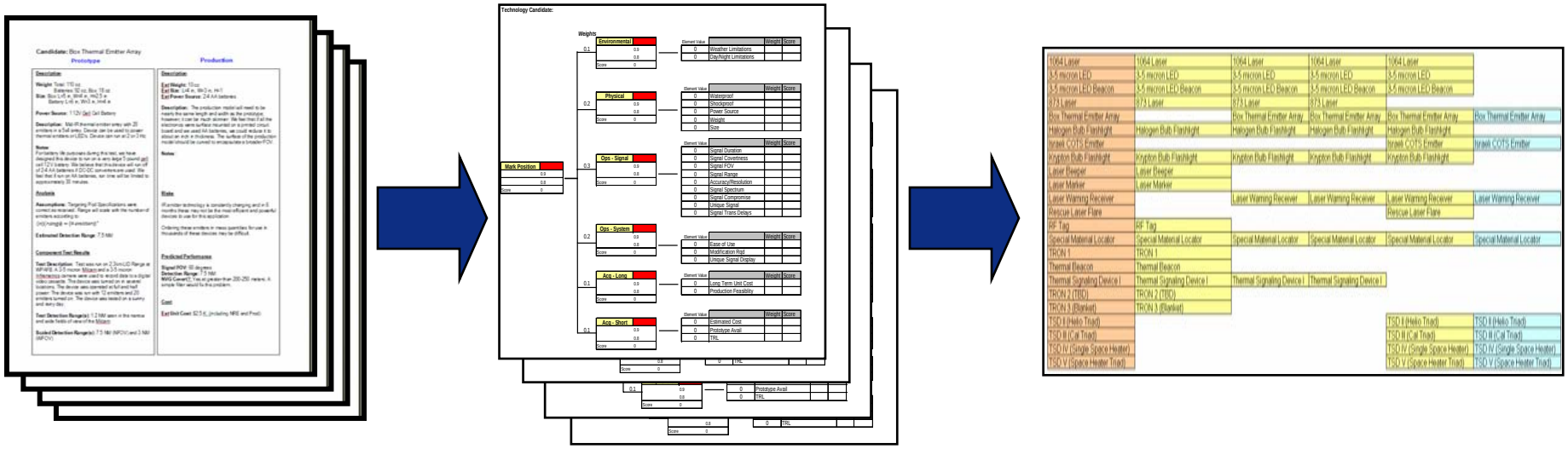
- **Component level testing conducted during prototype development**
  - Integration of all the pieces
  - Evaluate Signal Quality / Duration
  - Determine a Signal Detection Range
  - Identify Risk Areas / Limitations

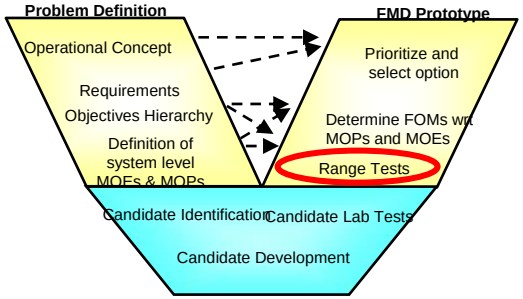




Range Test Go/No-Go Selection

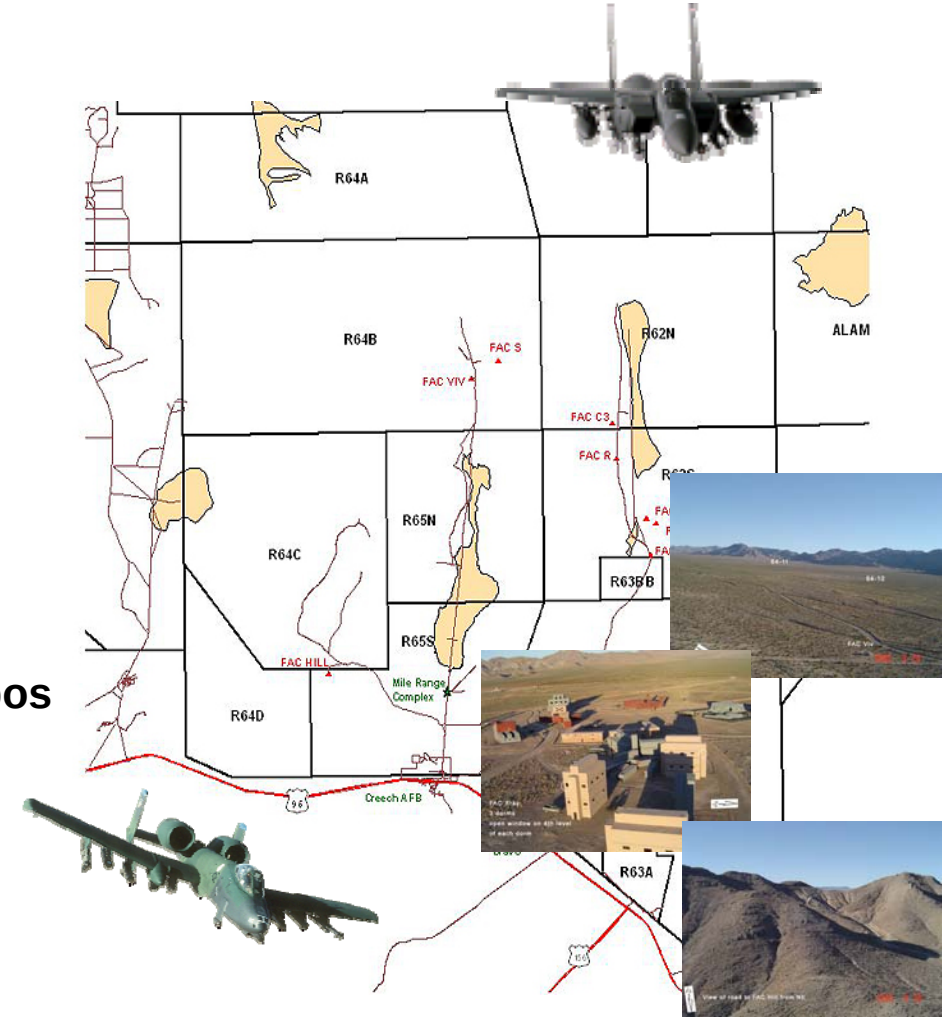
- **Prototype Testing & Production Estimates**
  - **Confirming pre test mathematical analysis**
  - **Component test results – *Detection Range***
- **Objective Hierarchy updates**
- **Final Go / No-Go Selection**



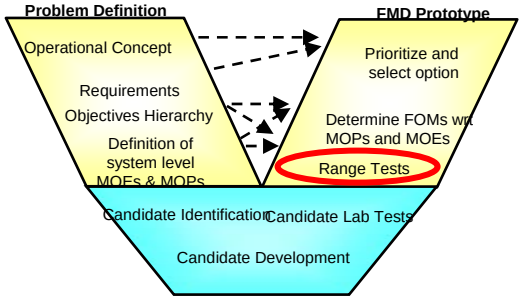


Range Test Plan

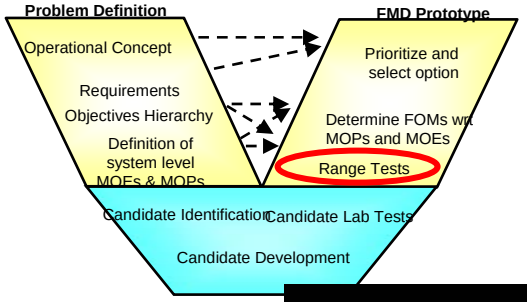
- **Development of Prototype Test Plan**
  - **Prioritized Test Point Matrix**
  - **Highest weighted areas in Objective H**
- **Objectives**
  - **Determine Detection Range**
  - **Operator Usability Assessment**
- **Flight Profiles**
  - **Profile 1 - Open, flat terrain**
  - **Profile 2 - Urban complex**
  - **Profile 3- Elevated terrain, stand- off pos**
- **Evaluation**
  - **Sniper & LITENING pods**
  - **F-15E, F-16, A-10 aircraft mix**



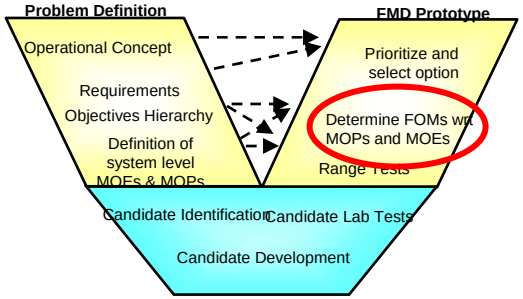
Nevada Test & Training Range



Example Test Setup



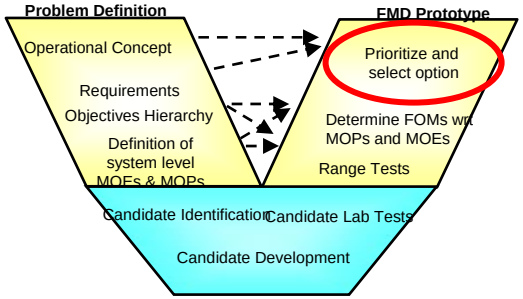
Range Test (A-10 at 11nm)



Summary Test Results

- TEB & TSD V longest detection range
- Aircrew assessment
  - Pod Narrow Field of View - best
  - Modulated signal easier to pick out
  - Current configurations good for convoy support now
- JTAC assessment
  - Detection ranges exceed expectation
  - Instant turn on and off
  - Hands free operation preferable
  - NVG Covert still nice to have
  - Multiple modulation rates

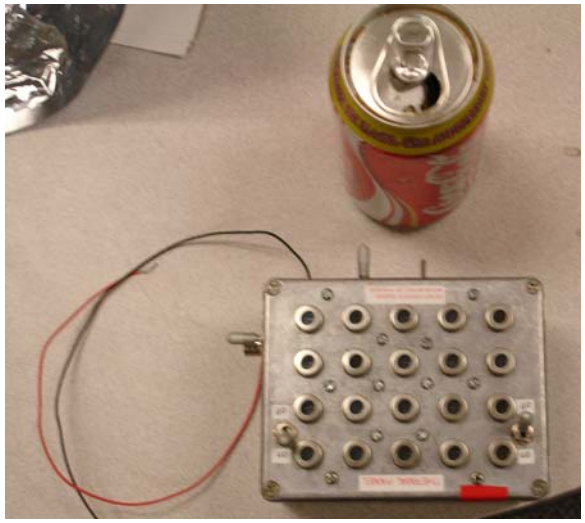
Device	F-15E Sniper	Predator	A-10 - LITENING
TEB (20)	12 nm	9.5 nm	18 nm
TEB (12)	6 nm	10 nm	not tested
TSD II	4 nm	11 nm	11 nm
TSD III	3 nm	12 nm	11 nm
TSD IV	11 nm	11.5 nm	10 nm
TSD V	not tested	10 nm	18 nm
LED	no detection	no detection	not tested
Israeli	not tested	no detection	not tested
LWR	not tested	not tested	dead battery



Prioritize and Select Options

Thermal Emitter Box

- **Detection distance greater than 10 nm**
- **Potential to miniaturize for helmet mounting (hands-free)**



Thermal Emitter Box Array

Thermal Emitter Beacon (Box array)	0.86
Special Material Locator Marker	0.82
Thermal Signalling Device II	0.65
Thermal Signalling Device III	0.65
Thermal Signalling Device IV	0.60
Thermal Signalling Device V	0.60
LED (3-5 mic)	0.47

Special Material Locator Marker

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Conclusion

- Application of systems engineering rigor compatible under “rapid response”
- Technology available to identify friendly forces during urban CAS
- Several SE Observations
  - SE can be tailored to rapid prototyping while maintaining rigor
  - Understanding key constraints and the larger context provided a decision-making framework for the project
  - Proven techniques from software engineering were applicable in a rapid hardware prototyping effort
  - Selection of SE tools facilitated the decision-making process
  - The systems engineering team helped link users and technology providers together to produce an effective collaboration
  - Parallel COTS Integration reduced overall risk of the project
  - Priority given to the project varied across participants
  - Rapid prototyping requires a creative transition plan

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? QUESTIONS ?

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