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# Systems Engineering for Rapid Prototyping: Friendly Marking Device

**9th SE Conference**
**Oct 2006**

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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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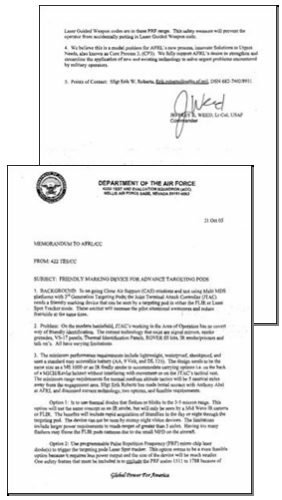
# Background

"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."



DEPARTMENT OF THE AIR FORCE

MEMORANDUM TO AFRL/CC

FROM: 422 TES/CC

SUBJECT: FRIENDLY MARKING DEVICE FOR ADVANCE TARGETING PODS

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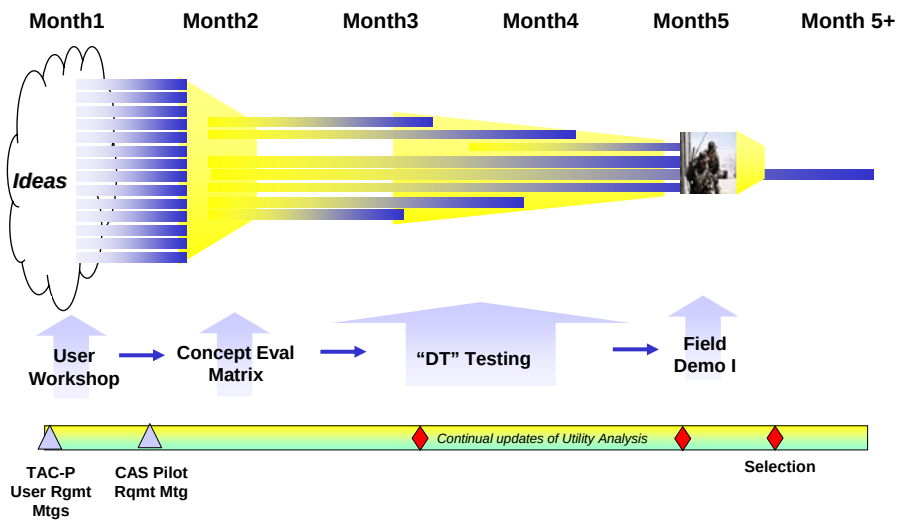
# Rapid Reaction Prototyping

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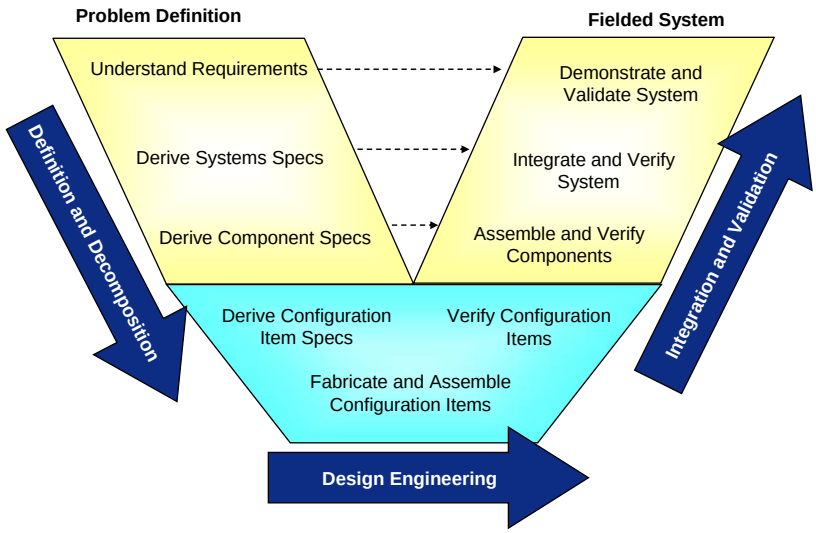
# Classic V-Model



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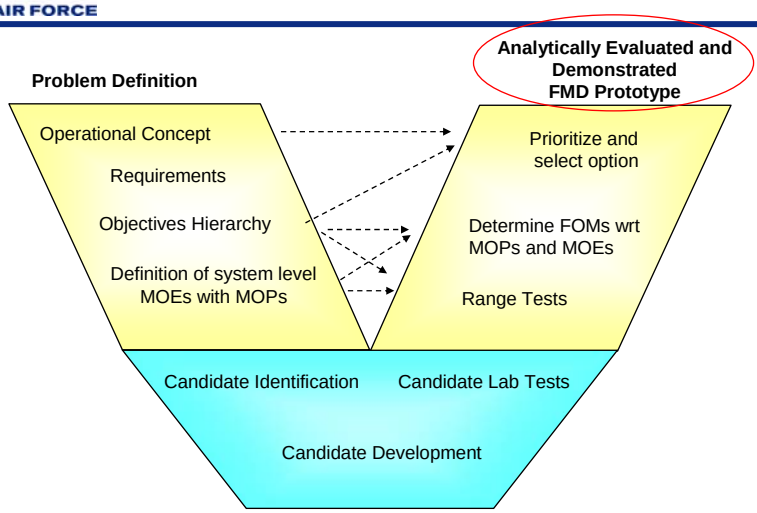
# Prototyping



# Prototyping Method – Down the V

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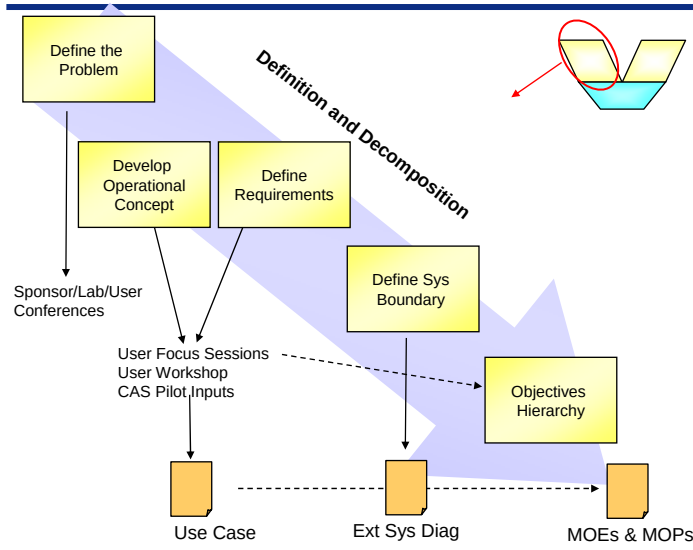




# Prototyping Method - Across

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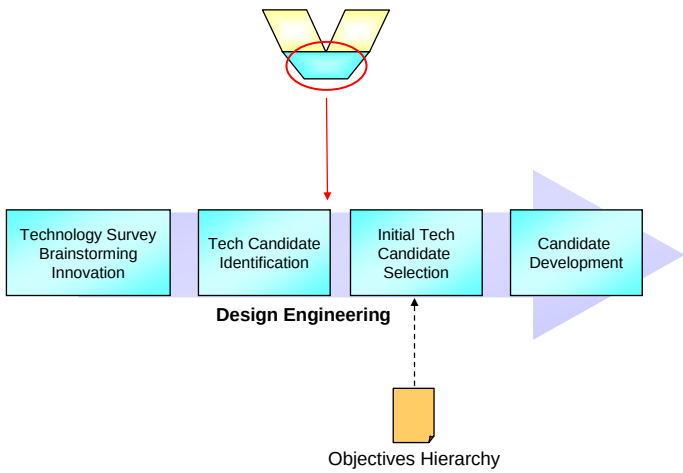

# Prototyping Method – Up the V

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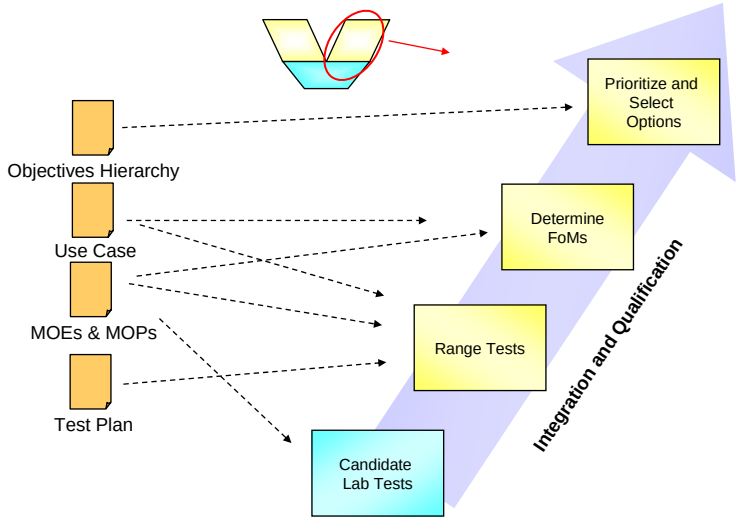




# FMD Rapid Prototyping Context

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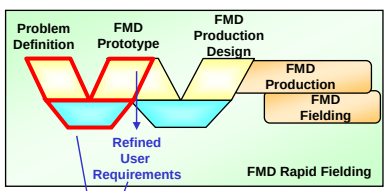
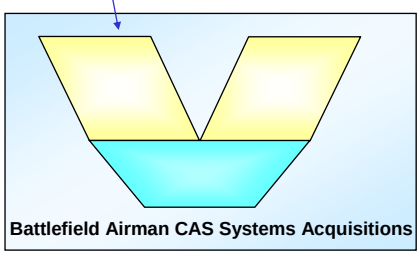
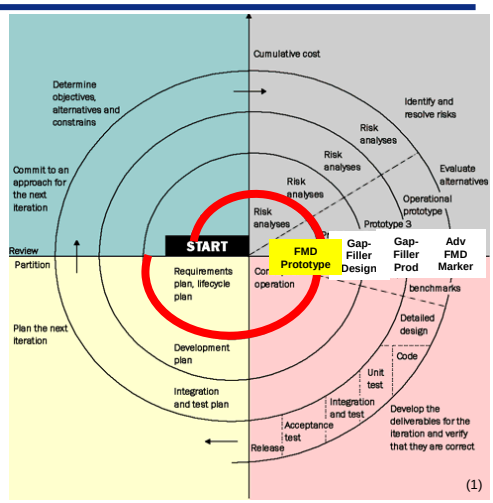
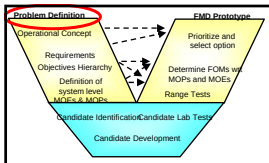



**CAS Friendly ID Long Term Solution**
**Battlefield Airman ICD/CDD**



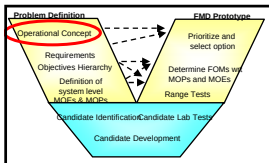

(1) (Bkgd Spiral Model Image from en.wikipedia.org/wiki/sprial_model)




# Problem Definition

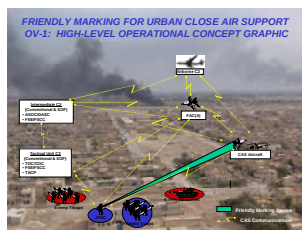
- Pubs on Close Air Support (JP 3-09.3, Sep 05):
- Stakeholder Interviews (JTACs and CAS pilots)
  - User Requirement Questions
- Analysis Criteria
- Constraints identification
- Restated problem as:
  - ***The Joint Terminal Attack Controller (JTAC) lacks a covert means to quickly and accurately mark 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.***

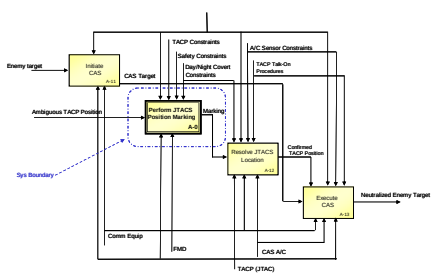


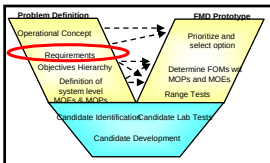



# Develop an Operational Concept

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



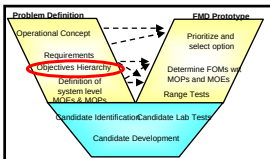



# Requirements Analysis

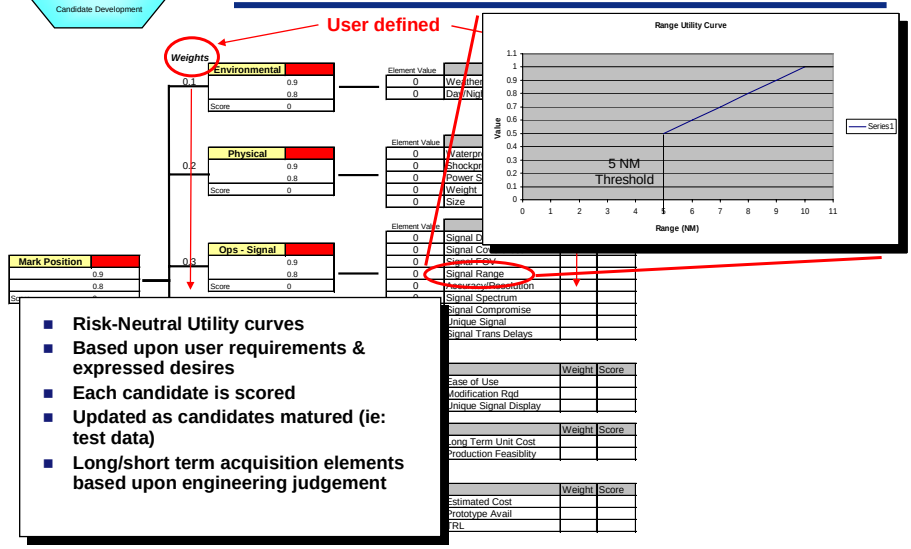
- Use Case refinement
- User Requirements with weights
  - JTACs
  - CAS Pilots
- FURPS+ model
  - Functional
  - Usability
  - Reliability
  - Performance
  - Supportability
  - "plus" other requirements such as Implementation, Interface, Operations, Packaging, Legal, etc.

| 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 |

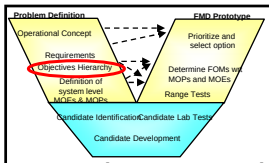





# Objectives Hierarchy

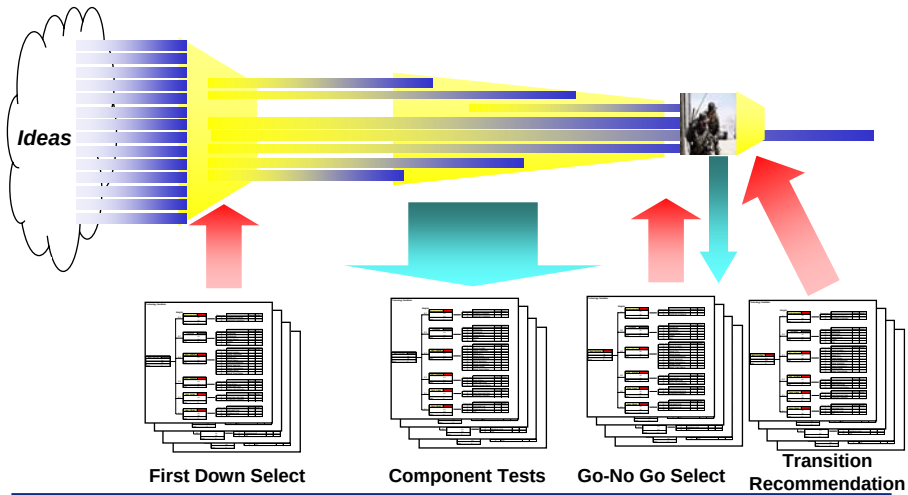



- Risk-Neutral Utility curves
- Based upon user requirements & expressed desires
- Each candidate is scored
- Updated as candidates matured (ie: test data)
- Long/short term acquisition elements based upon engineering judgement



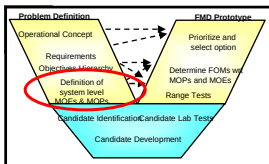

# Objectives Hierarchy: "Living Tool"

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



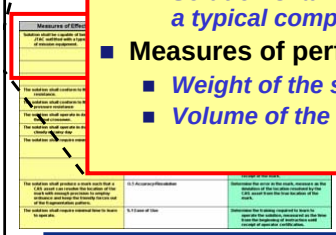

**First Down Select** **Component Tests** **Go-No Go Select** **Transition Recommendation**

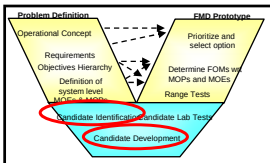





# Definition of system level MOEs and MOPs

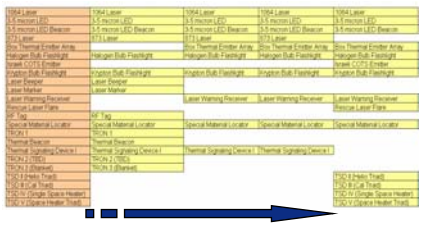
- **Originating Requirements**
  - *Weight : 4 – 6 oz without batteries*
  - *Volume : 25.1 in³ , "Less than a Coke can "*
- **Critical operational issues (COI)**
  - *The JTAC carries a variety of mission equipment to execute a mission. The JTAC has limited excess space and weight capacity for carrying 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.*



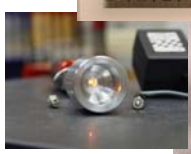



# Identify/ Develop Technology Candidates

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



Thermal Emitter Box Array



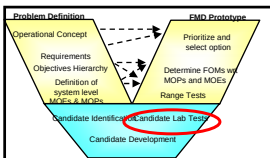
Thermal Emitters

Special Materials

LEDs

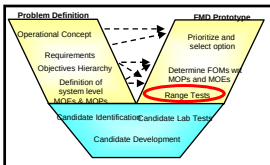
Laser





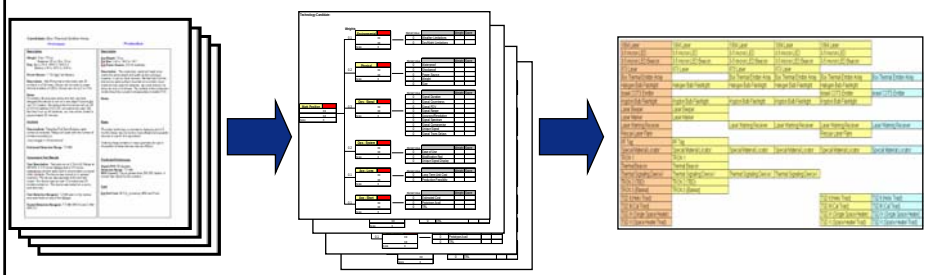

# Candidate Lab Tests

- **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

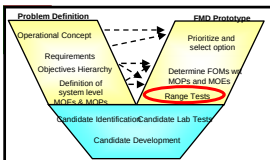



# Range Test Go/No-Go Selection

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

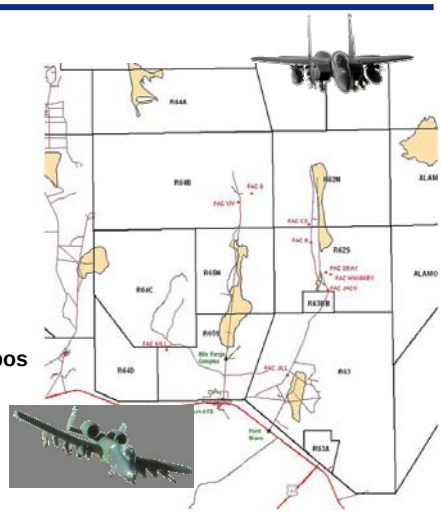




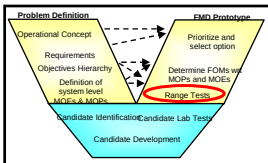



# Range Test Plan

- **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**

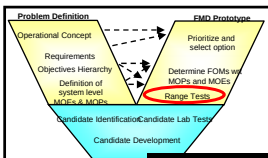


**Nevada Test & Training Range**

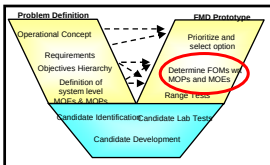



# Example Test Setup






# Range Test (A-10 at 11nm)

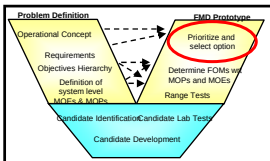



# Summary Test Results

- 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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