NDIA 11th Annual Systems Engineering Conference

"The Value of Architecture"

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Outline

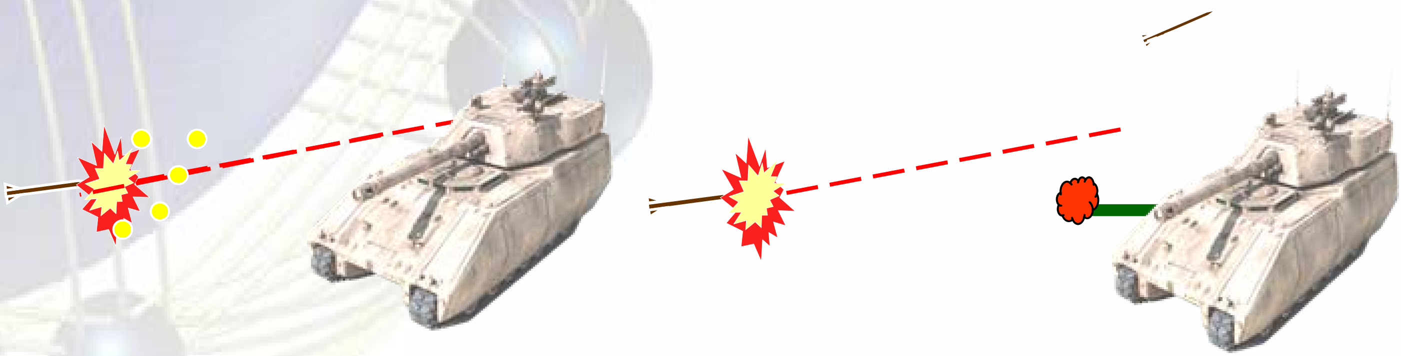
- Architecture
- Operational View
- Goal Hierarchy
- Process Flow
- 7.0 Identify and Define Alternatives
- Tools Architecture
- Summary

Architecture

- During the systems engineering process architectures are generated to better describe and understand the system
- Architectures provide a description of how subsystems join together to form a system.
  - The Functional Architecture identifies and structures the allocated functional and performance requirements.
  - The Physical Architecture depicts the system product by showing how it is broken down into subsystems and components.
  - The System Architecture identifies all the products (including enabling products) that are necessary
  - Operational Views provide a frame of reference that the project work can be related to.

Operational View

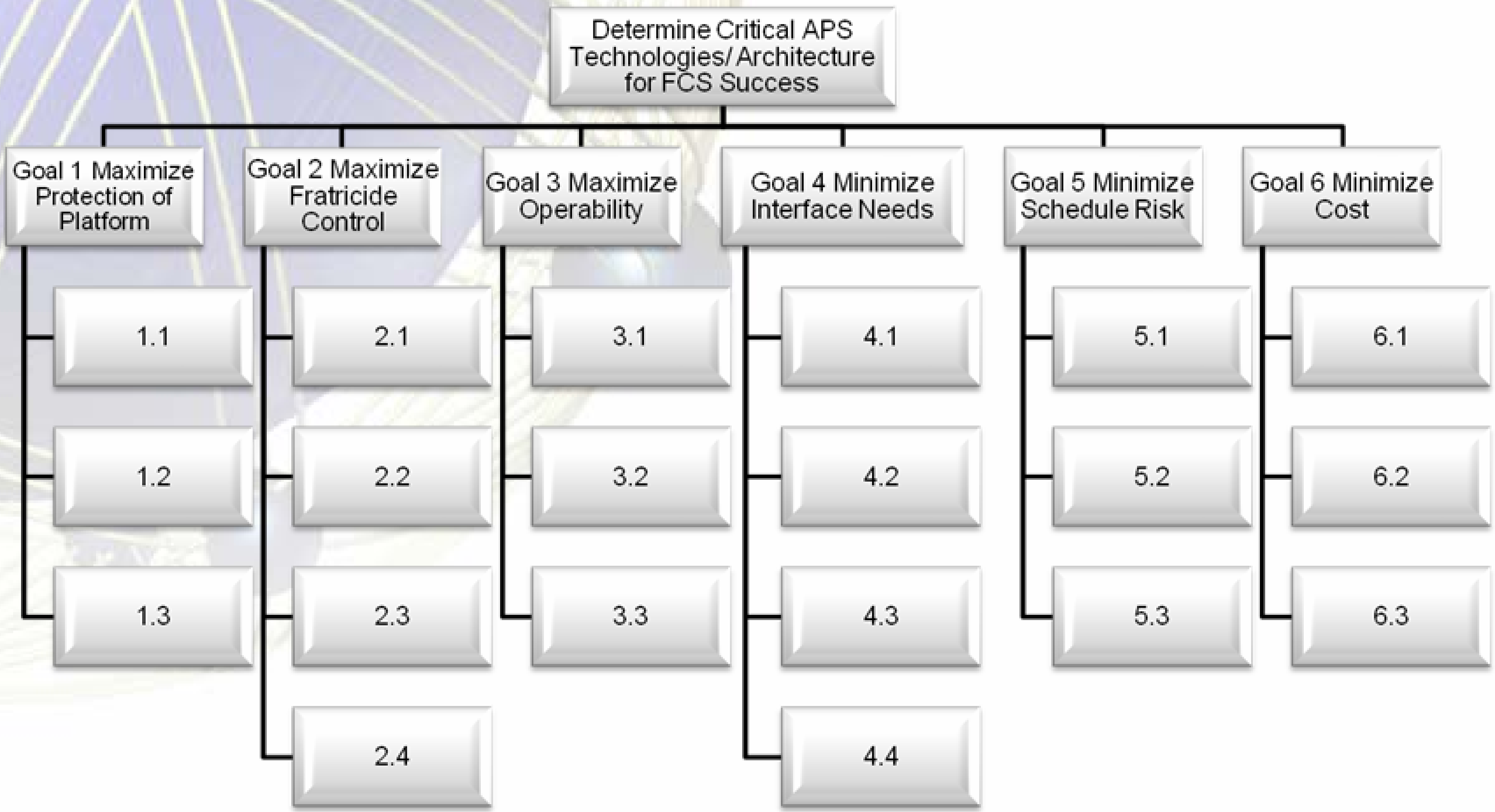
Identify, define, and evaluate potential Universal (Objective) Active Protection System (APS) approaches for the Future Combat System (FCS).



Provide decision makers the tools/data to help identify RDECOM's Science and Technology investments needed to get to an objective APS system.

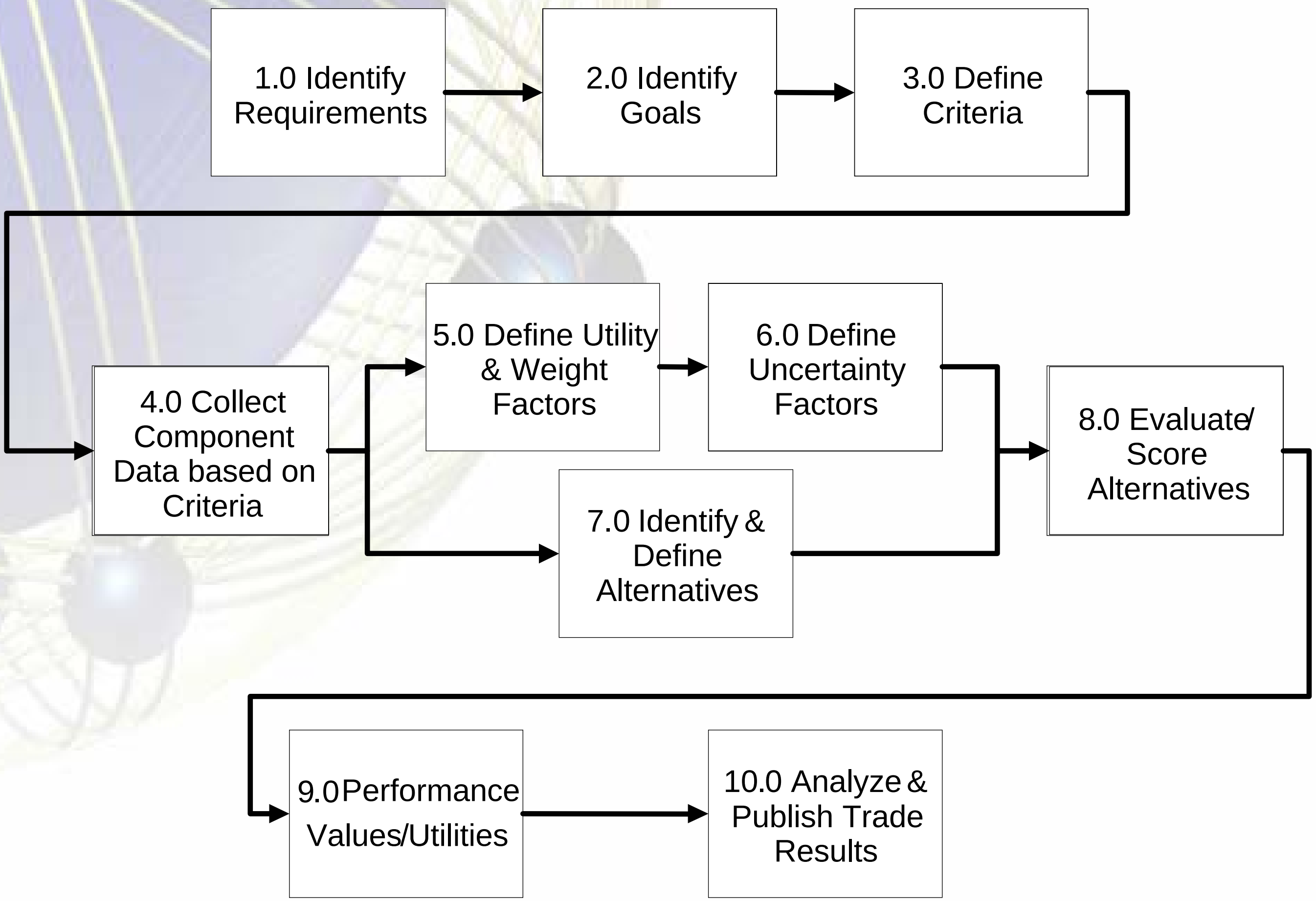
An Operational View was key. It gave everyone a common frame of reference to work from when executing their part of the analysis.

Goal Hierarchy



This was the Goal Hierarchy. Essentially an Arhcitecture. Without it we were not focused on what was important to consider in the trade study

Process Flow



Trade Study Process Flow Diagram was the Process Architecture used. It kept the team aligned and was a central communication tool

7.0 Identify & Define Alternatives

- List Systems/Components
- Previous Trades
- Component Data
- Requirements

- Existing Systems
- Analysis Method,Tools
- System Assumptions

- System Alternatives
- System ID

4 → **Candidate Systems 7.1** → **Evaluate Candidates 7.2** → **Define Alternatives 7.3** → 8

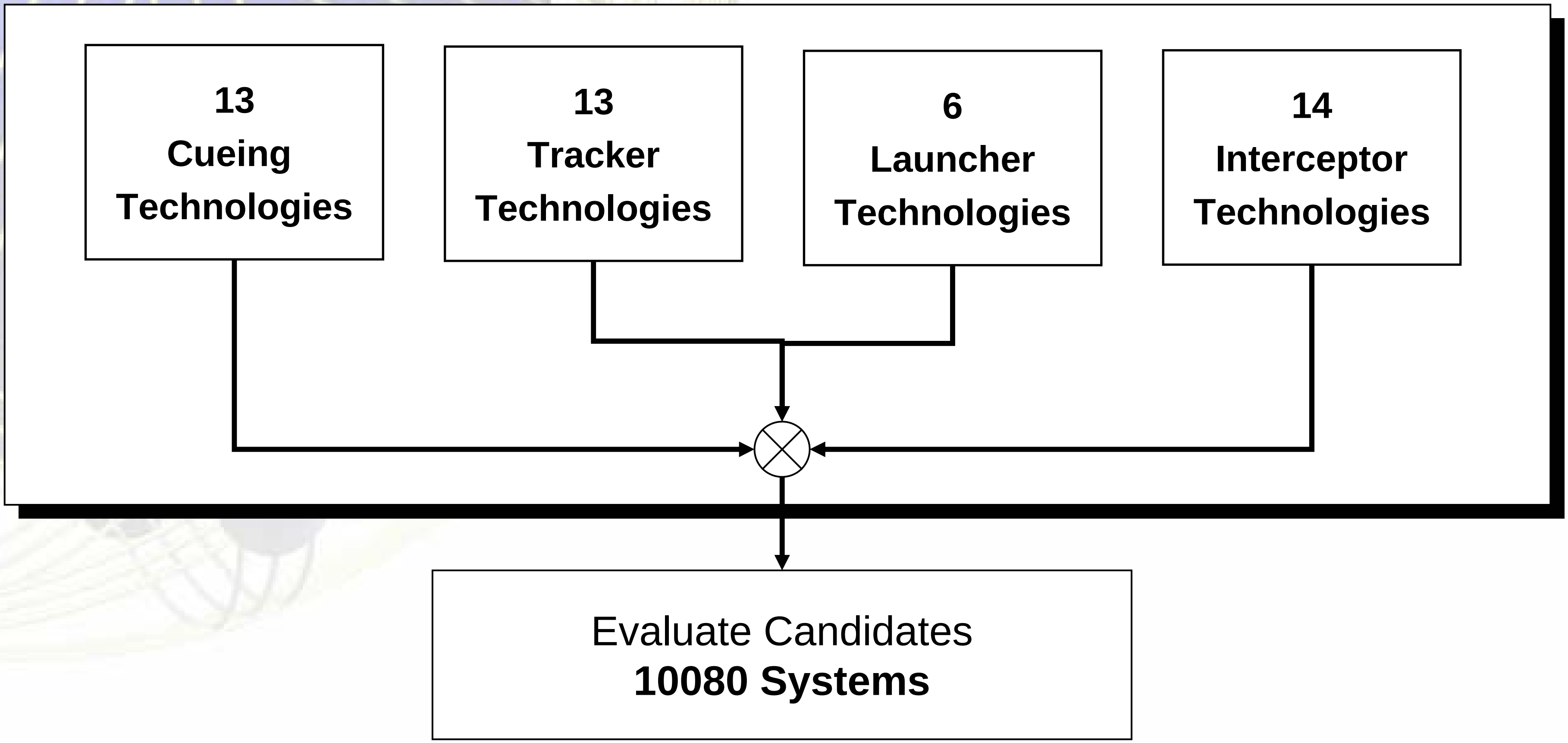
- Integrate System Candidates
- Organize Component Data
- ID Functional Architectures

•Analyze System Candidate Potential
- Timeline
- Accuracy
- Component Compatibility

Reach Consensus

System and Technology Architectures Required!!!!!

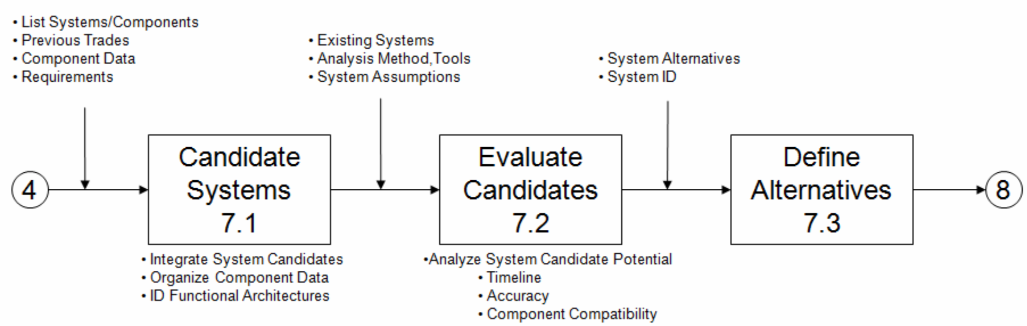
7.1 Candidate Systems (Physical Architecture)



The Physical Architecture was core to understanding the basic construct of an Active Protection System. All 10,080 Systems Evaluate had the same Physical Architectures

7.2 Evaluate Candidates (Functional Analysis and Allocation)

- **Major component of the trade study was the Functional Analysis and Allocation (FAA).**
  - It allowed for a better understanding of what the technologies could and had to be able to do to satisfy the performance requirements of the system, in what ways they could do it, and to some extent, the priorities and conflicts associated with lower-level functions.
  - It provided information essential to optimizing physical solutions.
  - Key tools were Functional Flow Block Diagrams, and the Time Line Analysis



7.2 Evaluate Candidates (System Functions)

Function	Definition
Detect, Acquire	Measure and report an event not due to ambient noise
Declare	Measure and report an persistent object that should be tracked
Classify	Measure and report what the persistent object is either by class or specific type/item.
Coarse Track	Measure and report an object and determine that it's trajectory point of closest approach to our platform is threatening. Classify and coarse track may be based on the same measured data set and completed at the same time
Initial Slew	Initial slew of launcher to launch position using fire control solution based on coarse track
Initial Tube Selection	Initial designation of launch tube or tubes in fixed system that need to be "warmed up" using fire control solution based on coarse track
Fine Track	Measure and report a target to enable calculation of a fire control solution
Fine Slew & Fire Control	Slew launcher to final position and launch an interceptor loaded with any required flight path, terminal guidance, and fuzing information
Final Tube Selection & Fire Control	Final designation of launch tube in fixed system and launch an interceptor loaded with any required flight path, terminal guidance, and fuzing information

Established a common vocabulary for understanding and describing how each for the systems studies operated.

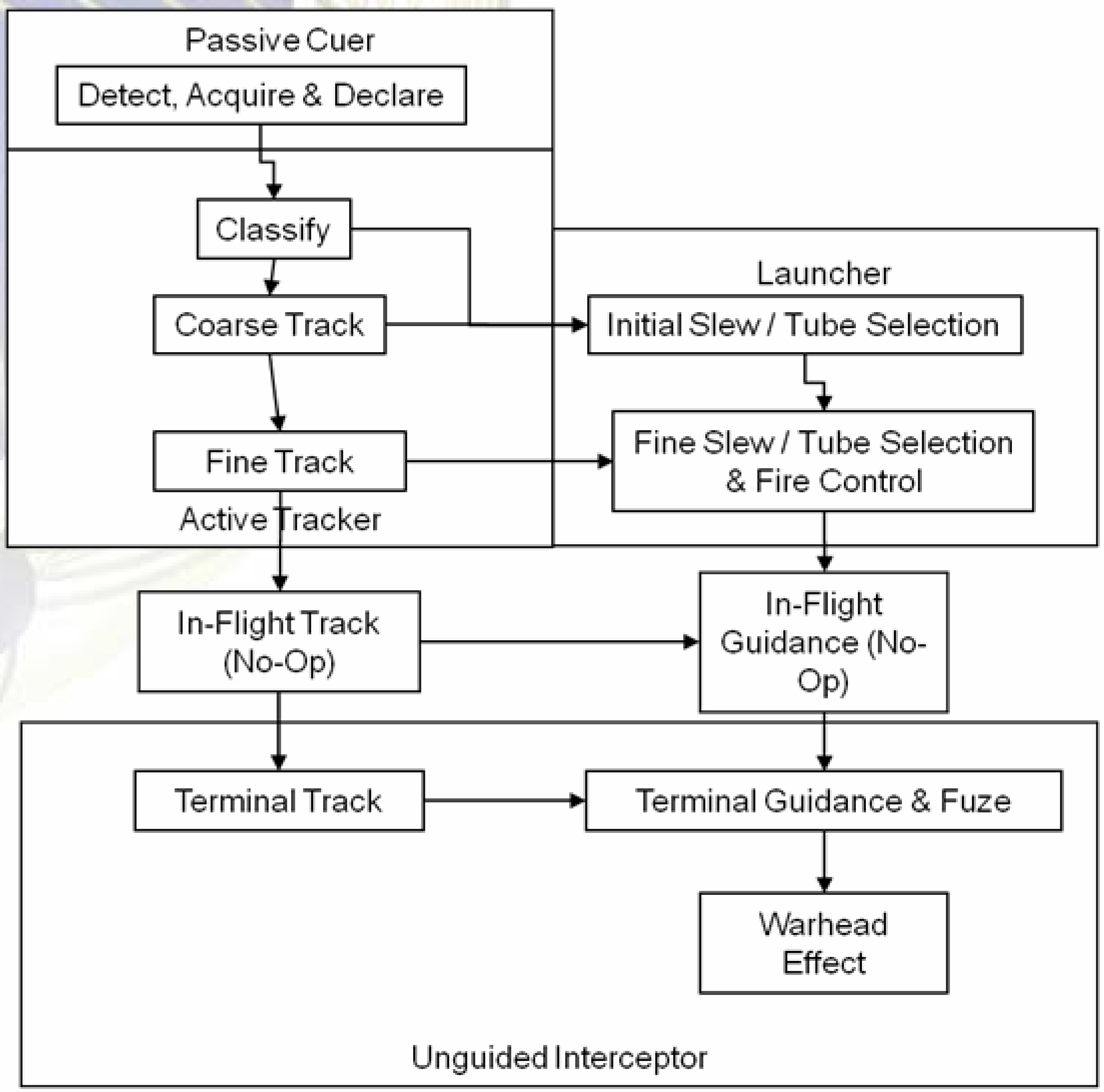
7.2 Evaluate Candidates System Functions (cont.)

Function	Definition
In-Flight Track	Measure and report a target trajectory to provide in-flight guidance to an interceptor
No-Op	“No operation” - used to designate function not performed
In-Flight Guidance	Propulsion to change flight path of interceptor
Terminal Track	Measure and report a target trajectory to provide terminal guidance & fuzing updates to an interceptor
Terminal Guidance & Fuze	Orient (focus) the warhead to produce the desired effect & initiate the effect at the prescribed time and / or the prescribed distance from target
Warhead Effect	Target negation

Established a common vocabulary for understanding and describing how each for the systems studies operated.

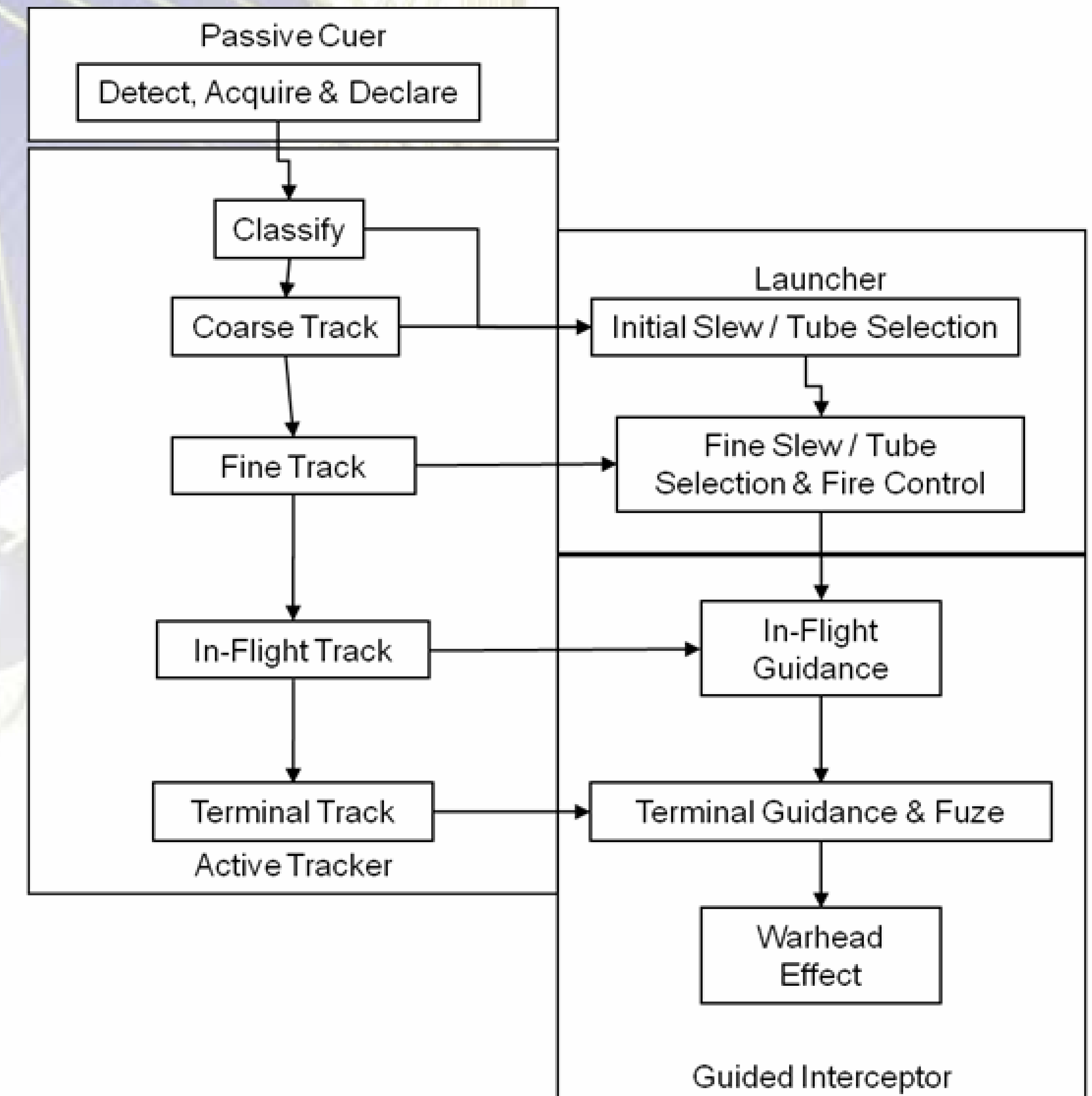
7.2 Evaluate Candidates

Functional Flow Block Diagram (Unguided Interceptor)



7.2 Evaluate Candidates

Functional Flow Block Diagram (Guided Interceptor)



7.2 Evaluate Candidates (Functional to Physical Allocation)

<table>
<tr><th colspan="2"></th><th colspan="4">Architectures for Unguided Interceptors</th><th colspan="4">Architectures for Guided Interceptors</th></tr>
<tr><th colspan="2"></th><th>U1</th><th>U2</th><th>U3</th><th>U4</th><th>G1</th><th>G2</th><th>G3</th><th>G4</th></tr>
<tr><td rowspan="11">System Functions</td><td>Detect, Acquire & Declare</td><td>Passive Cuer</td><td rowspan="3">Passive Cuer / Coarse Tracker</td><td>Passive Cuer</td><td rowspan="3">Active Cuer / Tracker</td><td>Passive Cuer</td><td rowspan="3">Passive Cuer / Coarse Tracker</td><td>Passive Cuer</td><td rowspan="3">Active Cuer / Tracker</td></tr>
<tr><td>Classify</td><td rowspan="2">Active Tracker</td><td rowspan="2">Passive or Active Coarse Tracker</td><td rowspan="2">Active Tracker</td><td rowspan="2">Passive or Active Coarse Tracker</td></tr>
<tr><td>Coarse Track</td></tr>
<tr><td>Initial Slew / Tube Selection</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td></tr>
<tr><td>Fine Track</td><td>Active Tracker</td><td>Active Fine Tracker</td><td>Active Fine Tracker</td><td>Active Cuer / Tracker</td><td>Active Tracker</td><td>Active Fine Tracker</td><td>Active Fine Tracker</td><td>Active Cuer / Tracker</td></tr>
<tr><td>Final Slew / Tube Selection & Fire Control</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td><td>Launcher</td></tr>
<tr><td>In-Flight Track</td><td rowspan="2">None</td><td rowspan="2">None</td><td rowspan="2">None</td><td rowspan="2">None</td><td>Active Tracker</td><td>Active Fine Tracker</td><td>Active Fine Tracker</td><td>Active Cuer / Tracker</td></tr>
<tr><td>In-Flight Guidance</td><td>Guided Interceptor</td><td>Guided Interceptor</td><td>Guided Interceptor</td><td>Guided Interceptor</td></tr>
<tr><td>Terminal Track</td><td rowspan="3">Unguided Interceptor</td><td rowspan="3">Unguided Interceptor</td><td rowspan="3">Unguided Interceptor</td><td rowspan="3">Unguided Interceptor</td><td>Active Tracker</td><td>Active Fine Tracker</td><td>Active Fine Tracker</td><td>Active Cuer / Tracker</td></tr>
<tr><td>Terminal Guidance & Fuze</td><td rowspan="2">Guided Interceptor</td><td rowspan="2">Guided Interceptor</td><td rowspan="2">Guided Interceptor</td><td rowspan="2">Guided Interceptor</td></tr>
<tr><td>Warhead Effect</td></tr>
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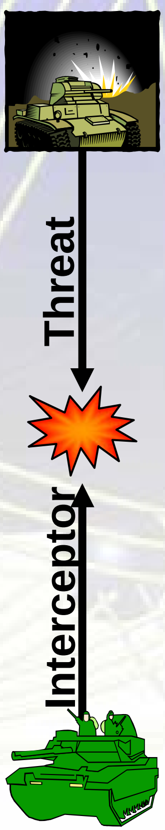
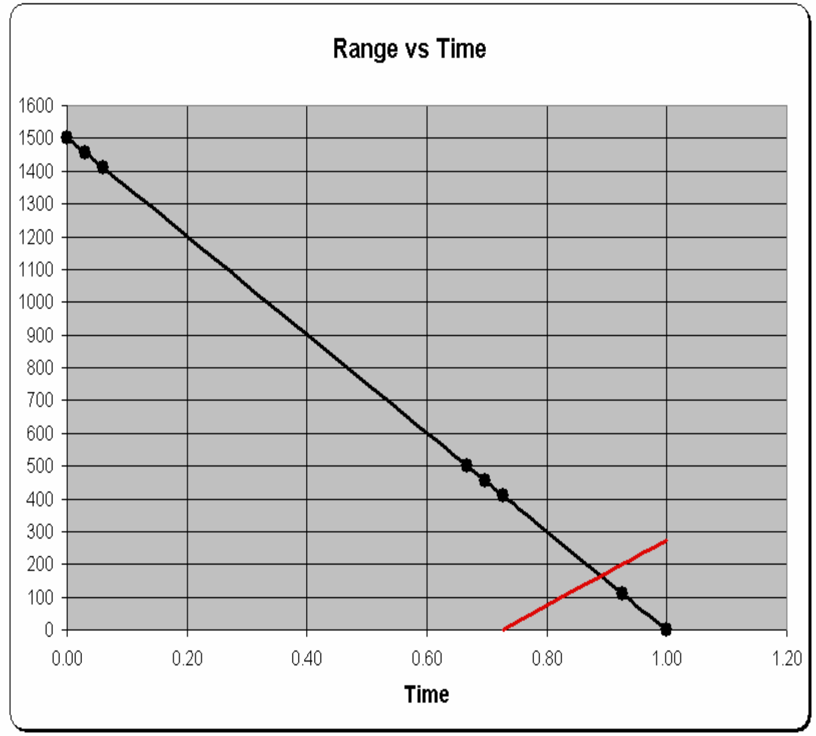
Functional allocation to physical components provided context for data provided on specific components and was critical in both the Timeline and Accuracy Analysis.

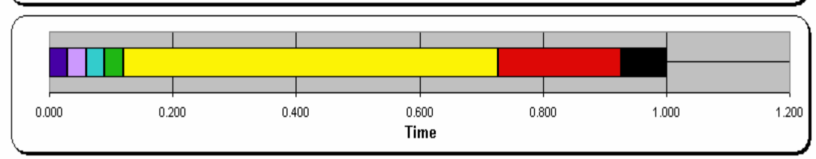
7.2 Evaluate Candidates Timeline Analysis



Threat	Threat Launch Range	1500.00	Meters
	Threat Average Velocity	1500.00	Meters/Second
	Time to impact Platform	1.00	Seconds
	Threat Time to Intercept Point	0.87	Seconds
Interceptor	Min Range to Defeat Threat	200.00	Meters
	Time to Min Range	0.20	Seconds
	Interceptor Average Velocity	1000.00	Meters/Second

System Functions		Function Time	Timeline	Threat Range to Platform	Interceptor Range to Threat
	Threat Launch	0.000	0.00	1500	
Cue	Cue	0.030	0.03	1455	
	Track Handoff	0.000	0.03	1455	
Track	Track Established	0.030	0.06	1410	
	Min Fire Control Time	0.000	0.06	1410	
Margin		0.607	0.67	501	
Launch	Slew	0.030	0.70	456	
	Stabilize	0.030	0.73	411	
Intercept	Initiate Interceptor	0.000	0.73	411	0
	Launch & Fly Out	0.200	0.93	111	200
	Platform Defeat	0.073	1.00	9.48E-13	273.33





Pass Screen

The results of the Functional Analysis and Allocation effort provided the basis for how time was to be calculated for each of the 10K plus systems to be evaluated.

7.2 Evaluate Candidates
Interface Compatibility Analysis

SCORING INSTRUCTIONS

Level	Component Compatibility Description
9	- Significant software integration with concurrently developed hardware.
3	- Hardware and/or software interfaces defined and analyzed so complexity is
1	- Software and/or hardware interfaces known but need to be revised with as
0	- Interfaces exist and no changes are required.

Hardware interface c

- Mechanical – envelope, attachment, obscuration, alignment
- Hydraulic and pneumatic - flow rates, pressures
- Mass – weight, moments of inertia, centers of gravity
- Environment – mechanical shock and vibration, particulate, ele
- Thermal - temperature limits, temperature control
- Electrical – signals, voltage, power

Software interface considerations include added requirements for

- Data encryption and encoding
- Data structures
- Data storage
- Data transfer rates
- Data communication protocols
- Data processing and algorithms

Cue - Track Results

Launch - Intercept Results

Experties

0	No experties, Don't fill out scores for anything you have no exp
1	If you have seen a briefing on the technology or have only rece
3	If you have a working knowledge (understand underlying physic
9	If you are intimately involved in designing, developing, and or in

Launch - Intercept Compatibility Results	Launchers						
Interceptors	Launcher 1	Launcher 2	Launcher 3	Launcher 4	Launcher 5	Launcher 6	Launcher 7
Interceptor 1	1	1	1	1		9	0
Interceptor 2	1	0	0	3		9	1
Interceptor 3	0	2	0	9	1	9	2
Interceptor 4	1	1	1		1		1
Interceptor 5	0	4	3	1		1	4
Interceptor 6	0	4	3	1		1	4
Interceptor 7		3	9	3	3	0	3
Interceptor 8		3	9		3		3
Interceptor 9		1	9	3	1	0	1
Interceptor 10		3	9	3	3	0	3
Interceptor 11		1	9	1	1	1	1
Interceptor 12		1	9	1	1	1	1
Interceptor 13	0	9	9		0		3

Physical to Functional Allocations helped in determining what the interfaces would be and gave us a way to make subjective evaluations of their maturity

7.3 Define Alternatives

7.2 Evaluate Candidates

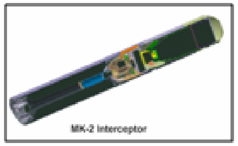
Define System Configuration 7.3.1

Define Alternative Architecture 7.3.2

Define Principle of Operation 7.3.3

5.3

System ID	Cuer	Tracker	Launcher	Interceptor
A-4986	Cuer 04	Tracker 09	Launcher 08	Interceptor 06



Principle of Operations

1 of 8 Physical Architectures

Cooled Single Color IR

Detect, Acquire & Declare

Classify

Coarse Track

Fine Track

W-Band Tracker

In-Flight Track (No-Op)

Terminal Track (No-Op)

360 Hemi Slewed Launcher

Initial Slew

Fine Slew & Fire Control

In-Flight Guidance (No-Op)

Terminal Guidance (No-Op) & Fuze

Warhead Effect

Unguided, Mark II, Command Fuze Interceptor

8.0 Evaluate / Score Alternatives

Physical to Functional Allocation allowed us to define the system configuration, system architecture, and principle of operation of each system analyzed.

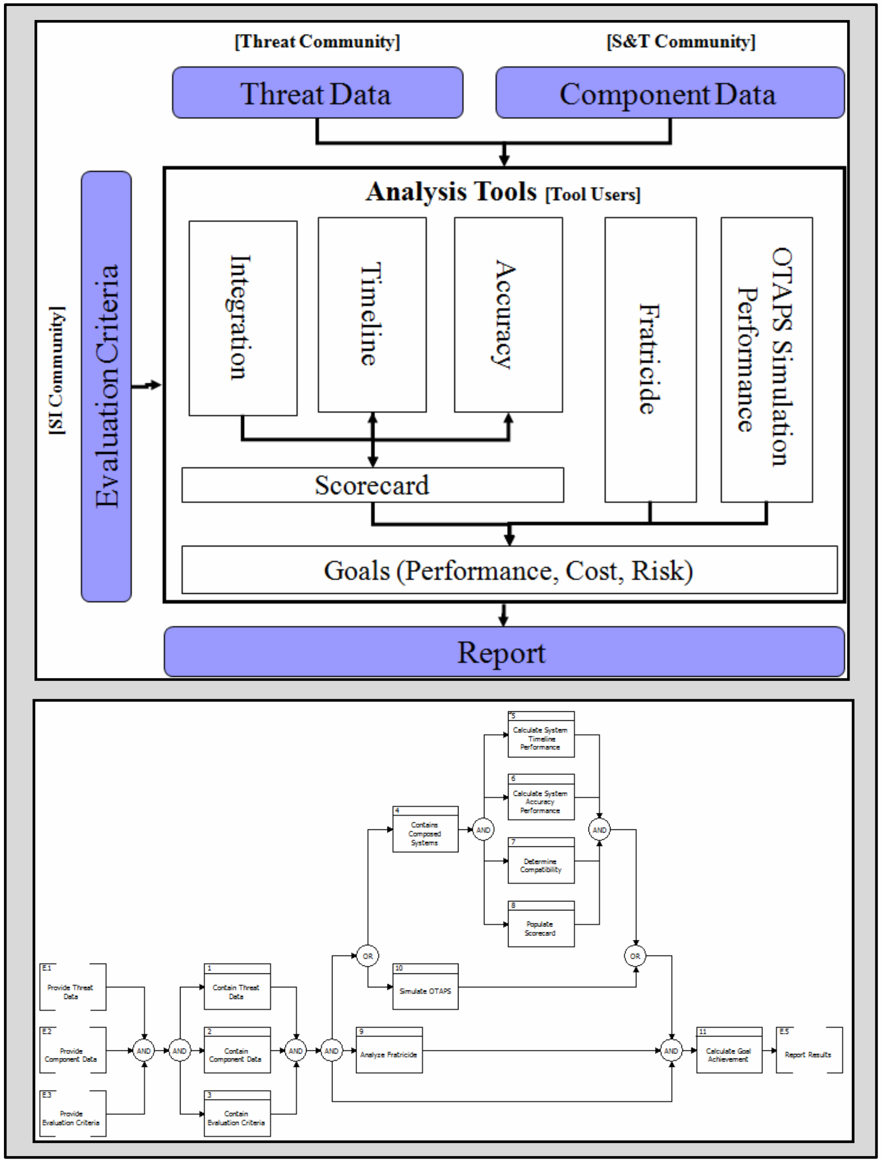
Tools Architecture

Abstract Architecture

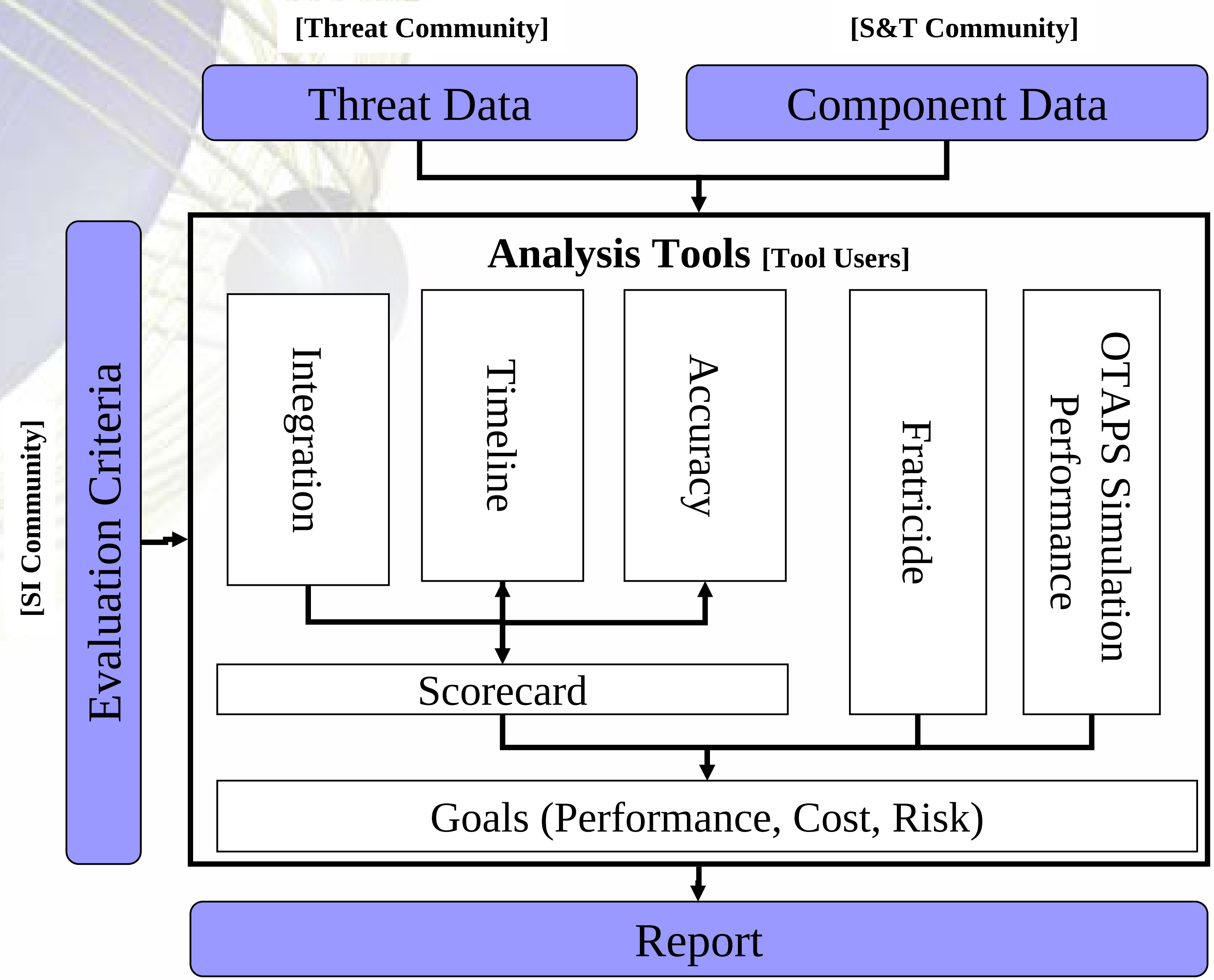
- ❑ **Schematic Block Diagrams**
  - **Physical Architecture**
  - **Interfaces**
  - **Data Flow**
  - **Easy to Read**
  - **Hard to Maintain**

Formal Architecture

- ❑ **IDEF0, FFBD, EFFBD, Hierarchy**
  - **Physical Architecture**
  - **Functional Architecture**
  - **Interfaces**
  - **Data Flow**
  - **Easy to Maintain**
  - **Hard to Read**

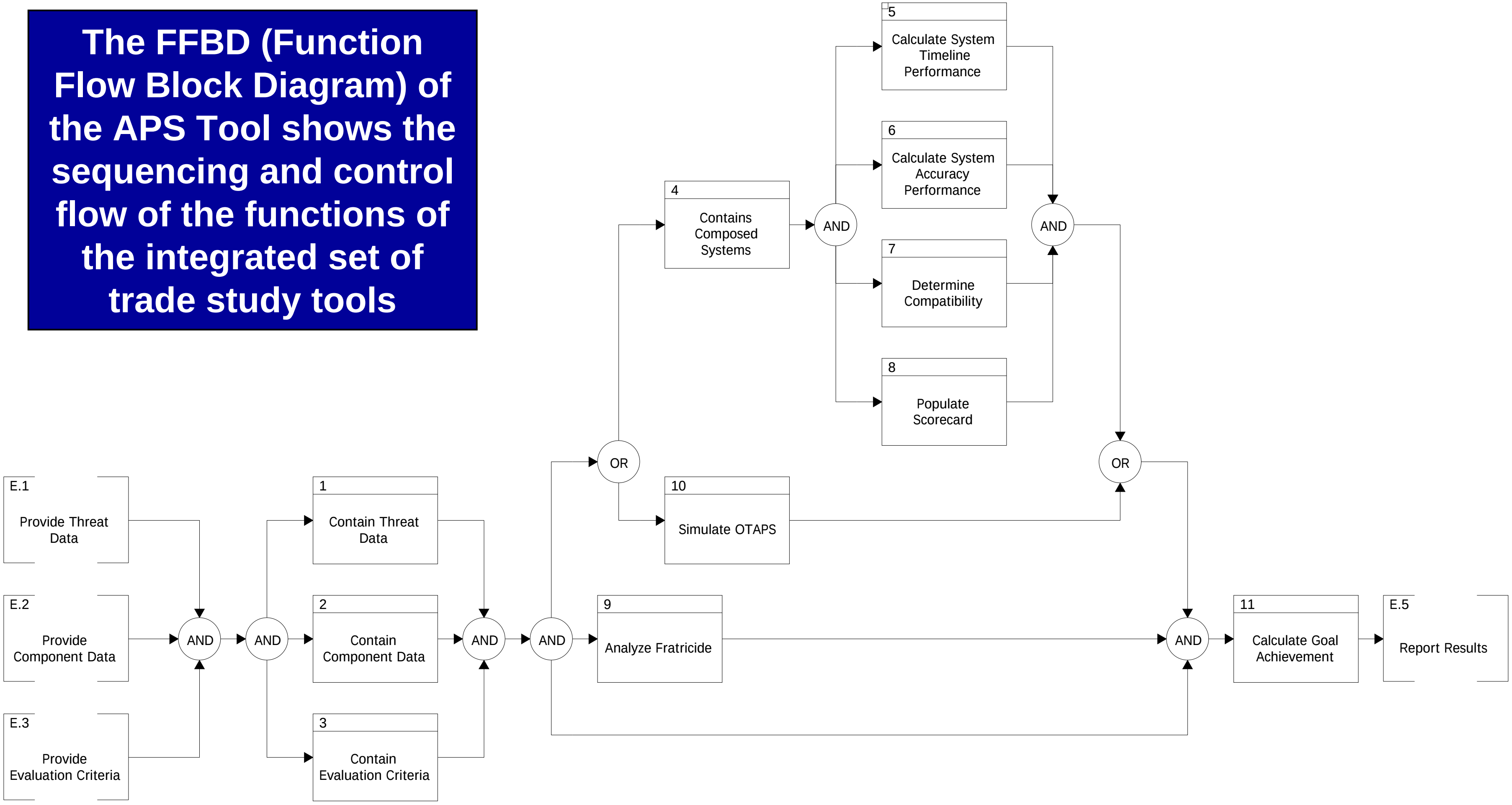


Schematic Block Diagram

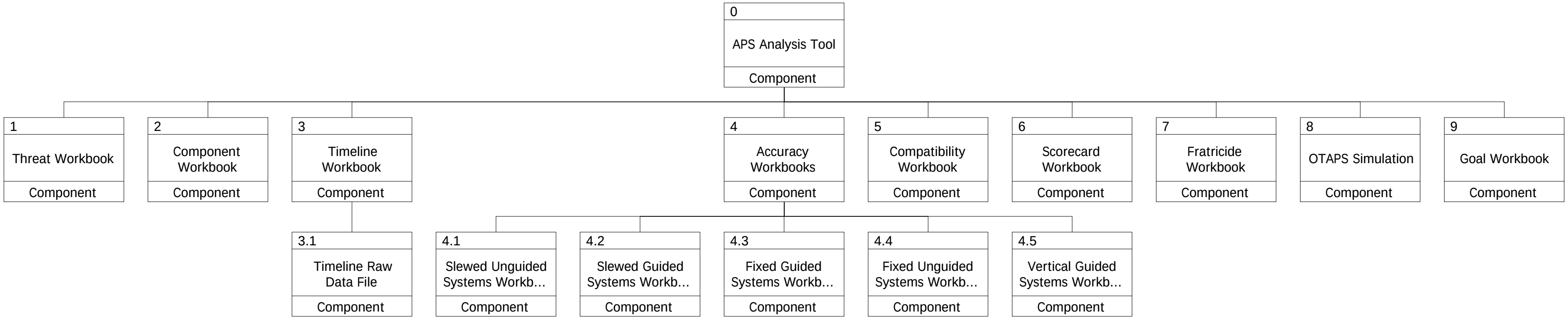


Perform APS Analysis
Functional Flow Block Diagram (FFBD)

The FFBD (Function Flow Block Diagram) of the APS Tool shows the sequencing and control flow of the functions of the integrated set of trade study tools



Hierarchy Diagram



The Hierarchy Diagram was a quick way to quickly capture all the Trade Study Tools and their Hierarchical relationships. These ultimately became the configuration items that were kept under version control.

Summary

- Use of Business Process Models helped everyone to understand the trade study approach that was being used.
- Using Hierarchy Diagrams helped the trade study team stay focused on the goals and criteria being evaluated.
- Physical Architecture, Functional Architectures provided the trade study team and the rest of industry a common language to work from. It also was core to defining systems, organizing data
- Functional Flow Block Diagrams and Functional To Physical Allocation was instrumental to establishing rules used to automating the evaluation of 10K plus system alternatives. More importantly it allowed the entire APS community to agree it was being done correctly in all 10k plus cases.
- Capturing System Architectures was essential to understand how to model system time function and communicate it to the community.
- Structured Physical and Functional decomposition made establishing a System ID scheme simple.
- Tool Architecture helped to communicate how each tool was used in the trade study process
  - ✓ many tool interface gaps were identified and fixed.