Modeling and Simulation of System of Systems
The History of the LPD 17 PRA Testbed

M&S Studies in the Context of T&E and Acquisition
LPD 17 PRA Testbed
Vincent M. Ortiz
AVW Technologies
8 March, 2006

OVERVIEW

- **LPD 17 San Antonio Ship Class**
- **LPD 17 Probability of Raid Annihilation (P_{RA}) Testbed Description and Architecture**
- **Testbed Development Organization**
- **Testbed Documents**
- **Testbed Requirements**
- **Testbed Development Process**
- **Testbed Spiral Development and Schedule**
- **Testbed Analysis and Scenario Development**

LPD 17 CAPABILITIES

- **The LPD 17 capabilities include:**
    - **State-of-the-art command and control suite**
    - **Advanced ship survivability features that enhance its ability to operate in the unforgiving littoral environment (low radar cross section)**
    - **Substantially increased landing force vehicle lift capacity (23,600 square feet of vehicle storage space),**
    - **Large flight deck (land 2 MV-22 or 4 CH-46) and well deck (holds 2 Landing Craft Air Cushion {LCAC})**
- **The LPD 17 is the first amphibious ship designed to accommodate the Marine Corps' "mobility triad"**
    - **Expeditionary Fighting Vehicle (EFV)**
    - **LCAC**
    - **MV-22 Osprey tilt rotor aircraft.**

OUR FOCUS WILL BE ON THE COMBAT SYSTEM
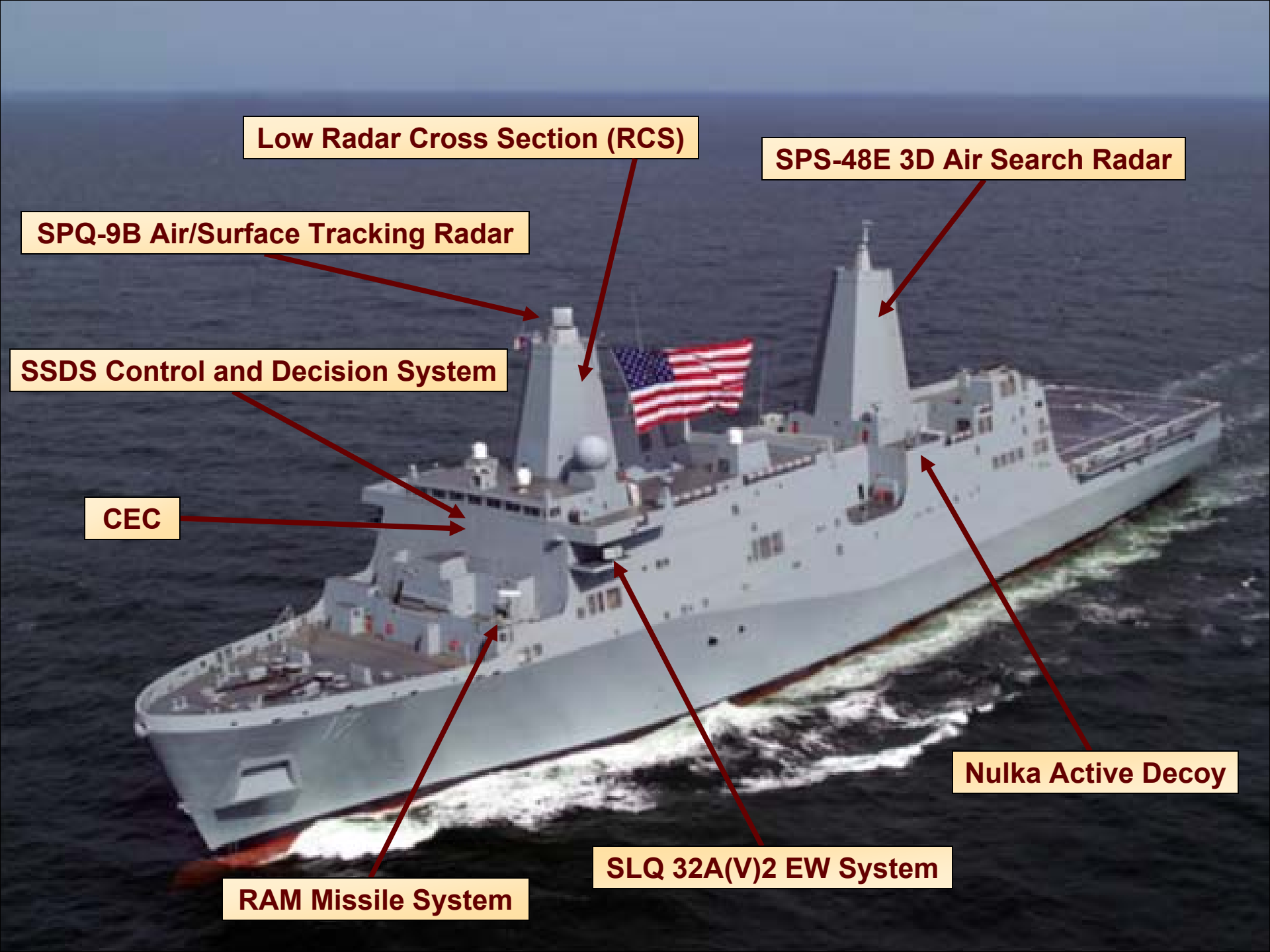
Low Radar Cross Section (RCS)

SPS-48E 3D Air Search Radar

SPQ-9B Air/Surface Tracking Radar

SSDS Control and Decision System

CEC

Nulka Active Decoy

RAM Missile System

SLQ 32A(V)2 EW System

BACKGROUND – P$_{RA}$

**OBJECTIVE: ASSESS LPD 17's P$_{RA}$
(ABILITY TO DEFEND ITSELF AGAINST INCOMING MISSILES)**

- **CNO's Anti-Air Warfare Capstone Requirements Document mandated the ship self defense capability for specific ship classes and established the Probability of Raid Annihilation (P$_{RA}$) as the primary Measure of Effectiveness (MOE) to assess ship combat system suites.**

- **P$_{RA}$ is defined as the ability of a particular stand-alone ship, as an integrated system, to detect, control, engage, and defeat a specified raid of anti-ship cruise missile (ASCM) threats with a specified level of probability in the operational environment.**

- **The P$_{RA}$ MOE is a system-of-systems measure which is levied on the ship defense suite as a whole to properly detect, control, and engage (annihilate) a raid of incoming threat ASCMs. Thus, it doesn't measure the performance of any particular ship defense element; rather it measures the system performance of all the ship defense elements across the complete battle timeline.**

- **The LPD 17 class is the first U.S. Naval ship class required to demonstrate its ability to defeat specific anti-ship cruise missile threats to achieve a statistical P$_{RA}$.**

NAVY'S SOLUTION TO PRA

- **PRA Assessment is a Three Pronged Approach**
  - **Test against actual ship (LPD 17)**
    - Pro – Test Drones Against the Actual Ship
    - Con – Limited Firing Events, Cannot Fire ASCM Against Manned Ship
  - **Test against Self Defense Test Ship (SDTS)**
    - Pro – Can Fire ASCM Against SDTS
    - Con – Limited Representation of the Actual Ship, Limited Firing Events
  - **Test using M&S (LPD 17 Testbed)**
    - Pro – Can Runs Numerous Different Scenarios, Events
    - Con – Developmental Cost, Limiting Assumptions
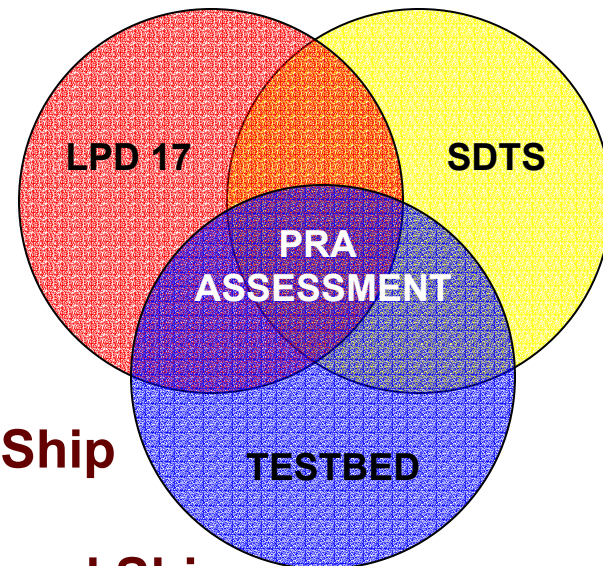
LPD 17 PRA TESTBED
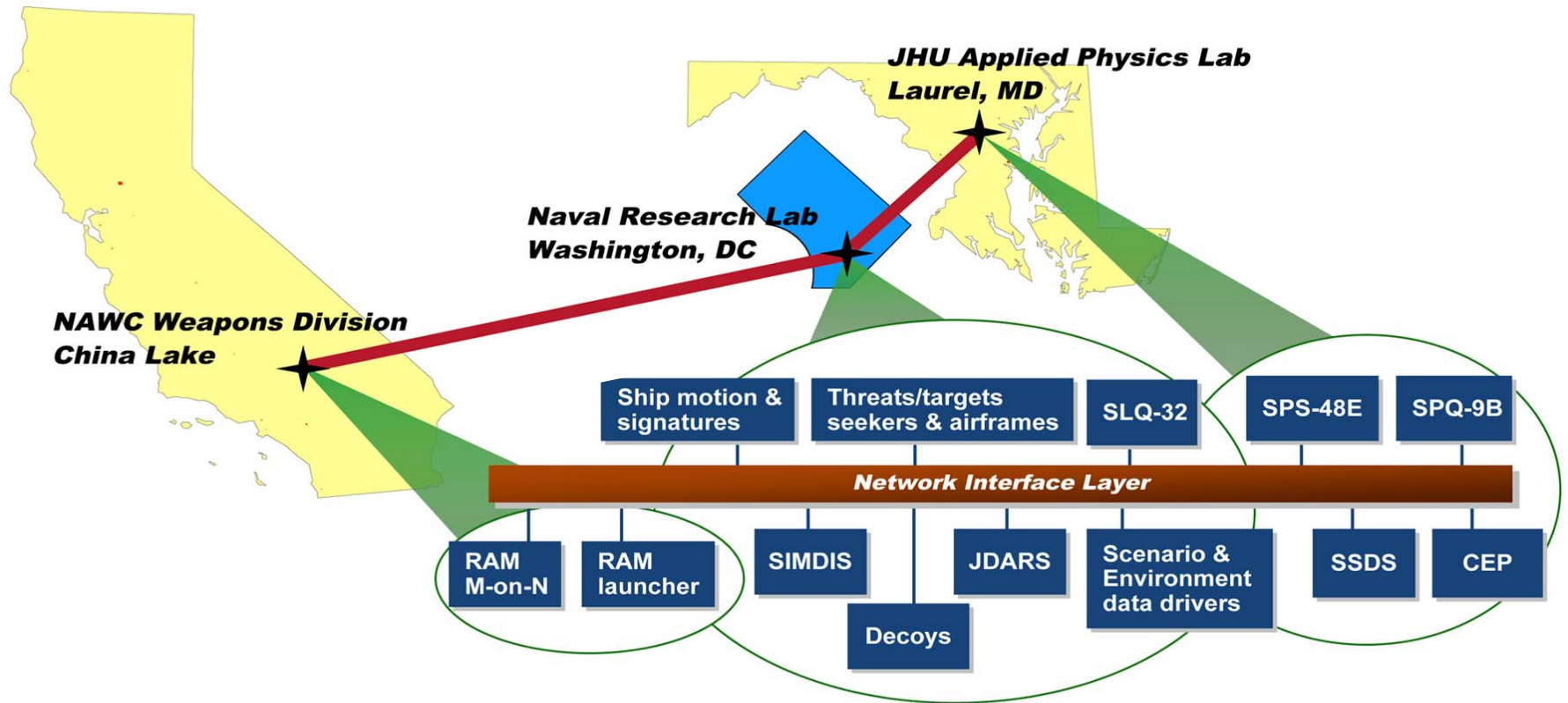
Geographically Distributed Federation of Tactical HWIL, Tactical SWIL and Digital Physics Based Models

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LPD 17 P~RA~ TESTBED OVERVIEW

AVW TECHNOLOGIES

MANAGEMENT APPROACH:

Organization
Meetings
Documents
Schedule

TECHNICAL APPROACH:

Physics - Based
Non – Real Time
Distributed, RTI Solution
HLA Compliant
Spiral Development

SYSTEM OF SYSTEMS SOLUTION

BOUND THE PROBLEM:

Testbed Requirements
Fidelity
Ship Configuration
Environment
Threat Types

BOUND THE ANALYSIS:

Finite Number of Runs
(Geographic Location
Ship Configuration
Season, Time of Day
Threat Types)

ROLES & RESPONSIBILITIES

- **PMS 317**
    - **Manages Funding**
    - **Drives Schedule**
    - **V&V Manager**
    - **DT Accrediting Authority**
- **PEO IWS CSE**
    - **Manages Testbed Design and Development**
- **NRL**
    - **Testbed Integrator**
- **NSWC Corona**
    - **Test Resource, Planning and Data Collection Agent**

- **Element PMs**
    - **Co-Chair SCP.**
    - **Review & Approve SOWs associated with M&S Development.**
    - **Manage/ Participate in Model Development.**
    - **Responsible for the Credibility of their Respective Models**
- **Model Developers**
    - **Develops/ Integrates Models**
- **COMOPTEVFOR**
    - **Participates as the OT Accrediting Authority**

LPD 17 P~RA~ ORGANIZATION

AVW TECHNOLOGIES

MANAGEMENT IPT

- LPD 17 Combat System Integration Manager
- LPD 17 Test Director
- Ship Self Defense Combat Systems Engineer
- Deputy SSD CSE

WORKING IPT

Development	VV&A
Integration	Test Planning
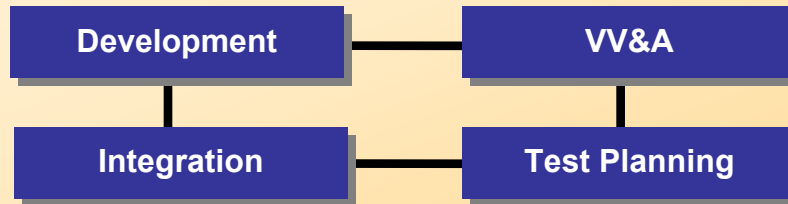
SIMULATION CONTROL PANELS (SCP)

Threat	Softkill	Radars
Natural Environment	Hardkill	CEC
Scenario	Test Bed	SSDS

CS Element PMs →

← M&S Developers

TESTBED MEETINGS

SCP MEMBERS, DEVELOPERS, EXPERTS	WORKING IPT MEMBERS	MANAGEMENT IPT MEMBERS

Semi-Annual Reviews

Testbed Demonstrations

Monthly Testbed Meetings

Periodic Meetings – Specific Issues

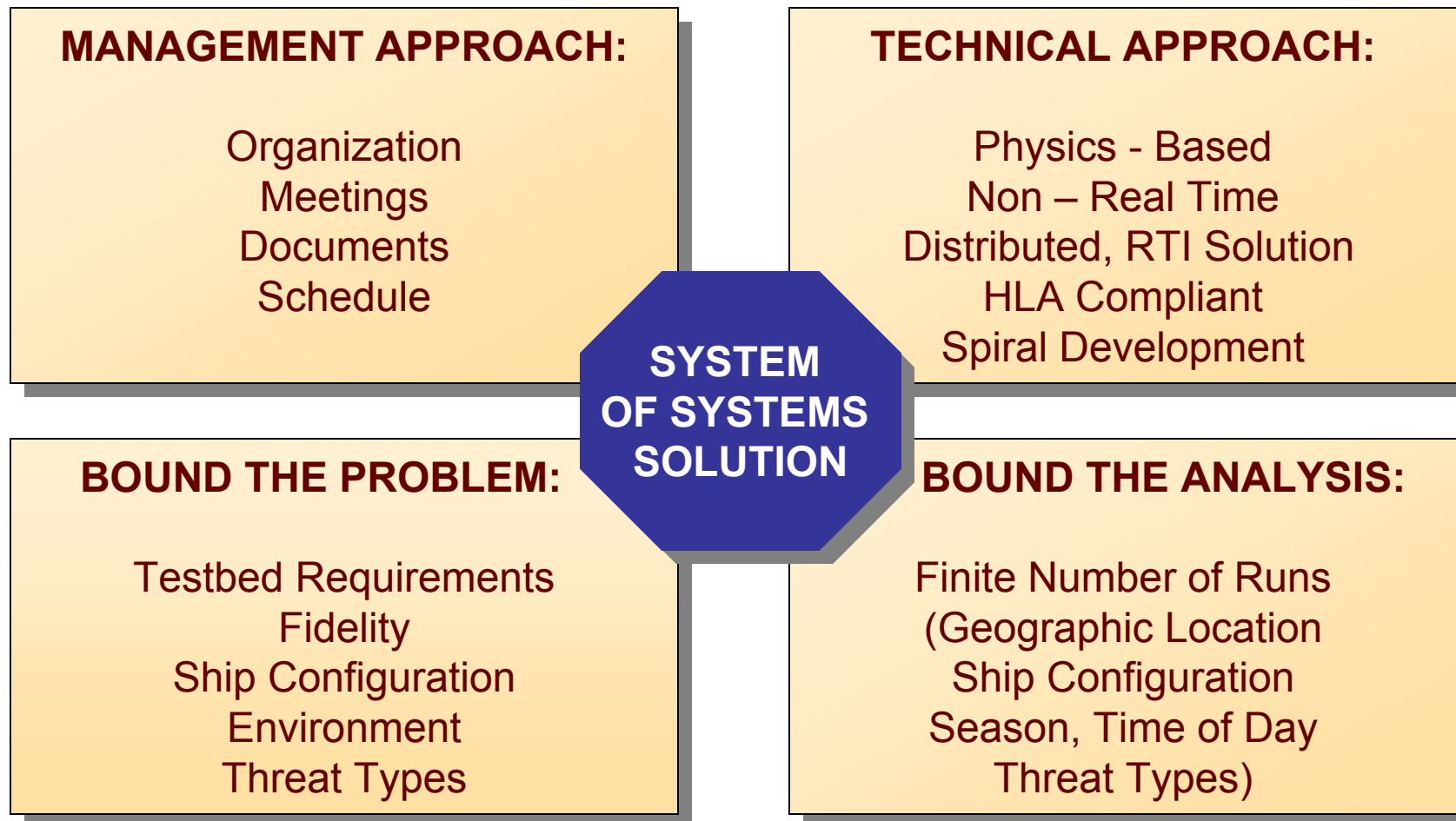**Federation Object Model Meetings**

Phenomena Meetings

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TESTBED DOCUMENTS

REQUIREMENTS DOCUMENT

Testbed and Model Requirements

Defined at the Beginning

**TESTBED AND MODEL
BUILD PLAN & REPORT**
Technical Approach
Functionality Per Build
Configuration Management
Integration Plan and Report

SECM

System Engineering
Conceptual Model

Illustrates Model Relationships
(Links to Supporting Documents)

**VERIFICATION & VALIDATION
PLAN AND REPORT**

Derived from the Requirements
Generated from
Relational Database

AVW Process developed the Approach, Requirements and Build Plan
AVW Database Produced the Requirements and VV&A Documents

TESTBED SCHEDULE

ID	Task Name	Start	Finish
1	Model Build 1	Mon 10/25/04	Mon 10/25/04
2	Testbed Build 1	Tue 10/26/04	Wed 12/15/04
3	Model Build 2	Fri 9/30/05	Fri 9/30/05
4	Testbed Build 2	Mon 10/3/05	Wed 11/16/05
5	Model Build 3	Thu 8/3/06	Thu 8/3/06
6	Testbed Build 3	Fri 8/4/06	Thu 8/24/06
7	Model Build 4	Fri 4/13/07	Fri 4/13/07
8	Testbed Build 4/Final	Mon 4/16/07	Thu 5/31/07
9			
10	SSDS TE #1	Thu 12/8/05	Sat 12/10/05
11	SPS-48E Characterization Testing	Mon 12/12/05	Tue 12/13/05
12	SSDS TE #2	Mon 4/10/06	Fri 4/14/06
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15	CSSQT U/W	Tue 6/27/06	Wed 7/12/06
16	A/C Trackex	Mon 6/26/06	Mon 6/26/06
17	DT/DTE	Tue 6/27/06	Tue 6/27/06
18	MSLEX (BQM 34)	Wed 7/5/06	Thu 7/6/06
19	RCSR Measurement	Thu 7/6/06	Sat 7/8/06
20	SSDS TE #4	Mon 10/2/06	Thu 10/5/06
21	A/C Trackex	Mon 10/2/06	Tue 10/3/06
22	DTE	Wed 10/4/06	Thu 10/5/06
23	DT/OT Firings	Mon 10/9/06	Thu 10/12/06
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Timeline callouts:
- 4 Builds
- Live Test Events
- Analysis Runs
- Final VV&A Documentation

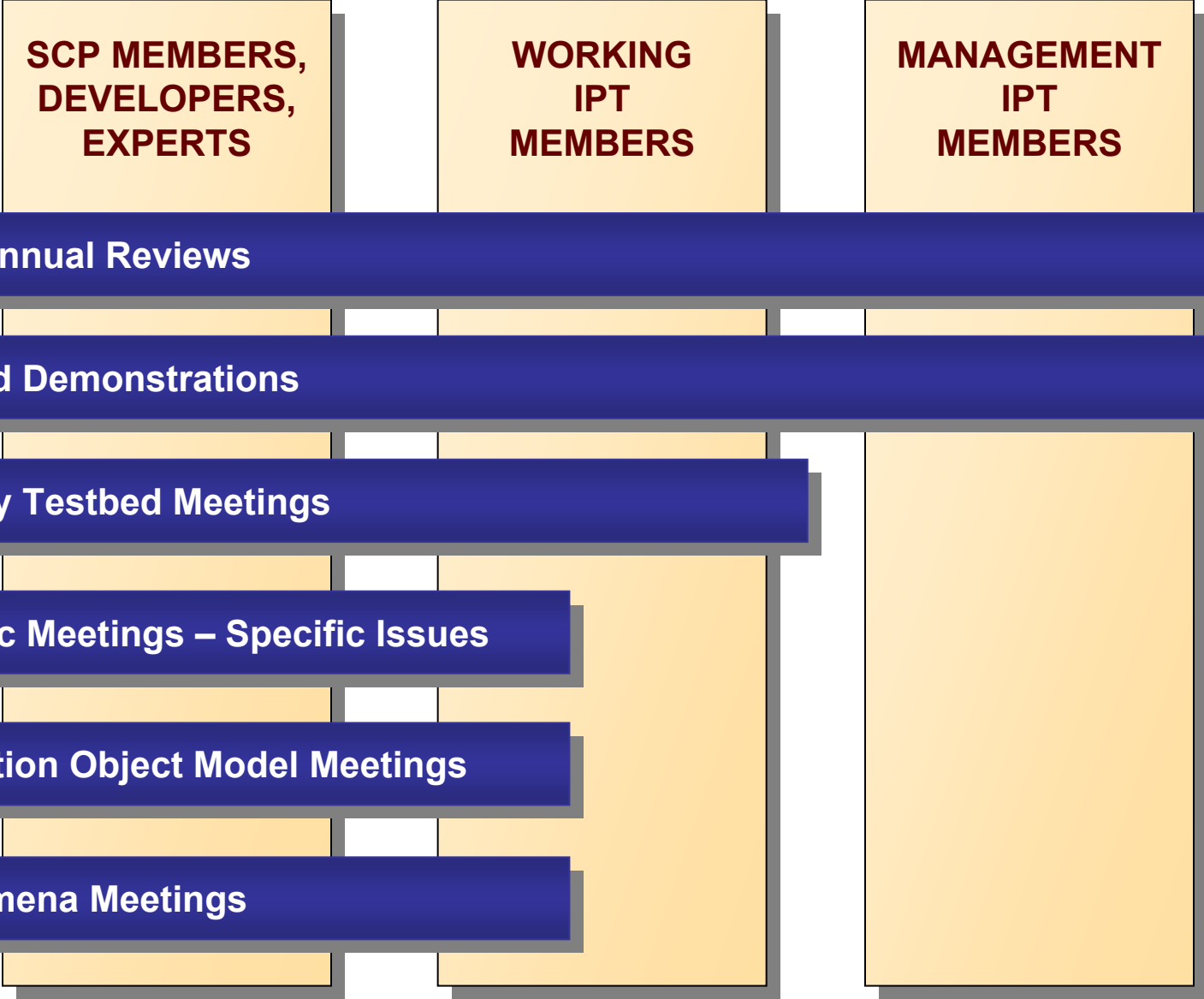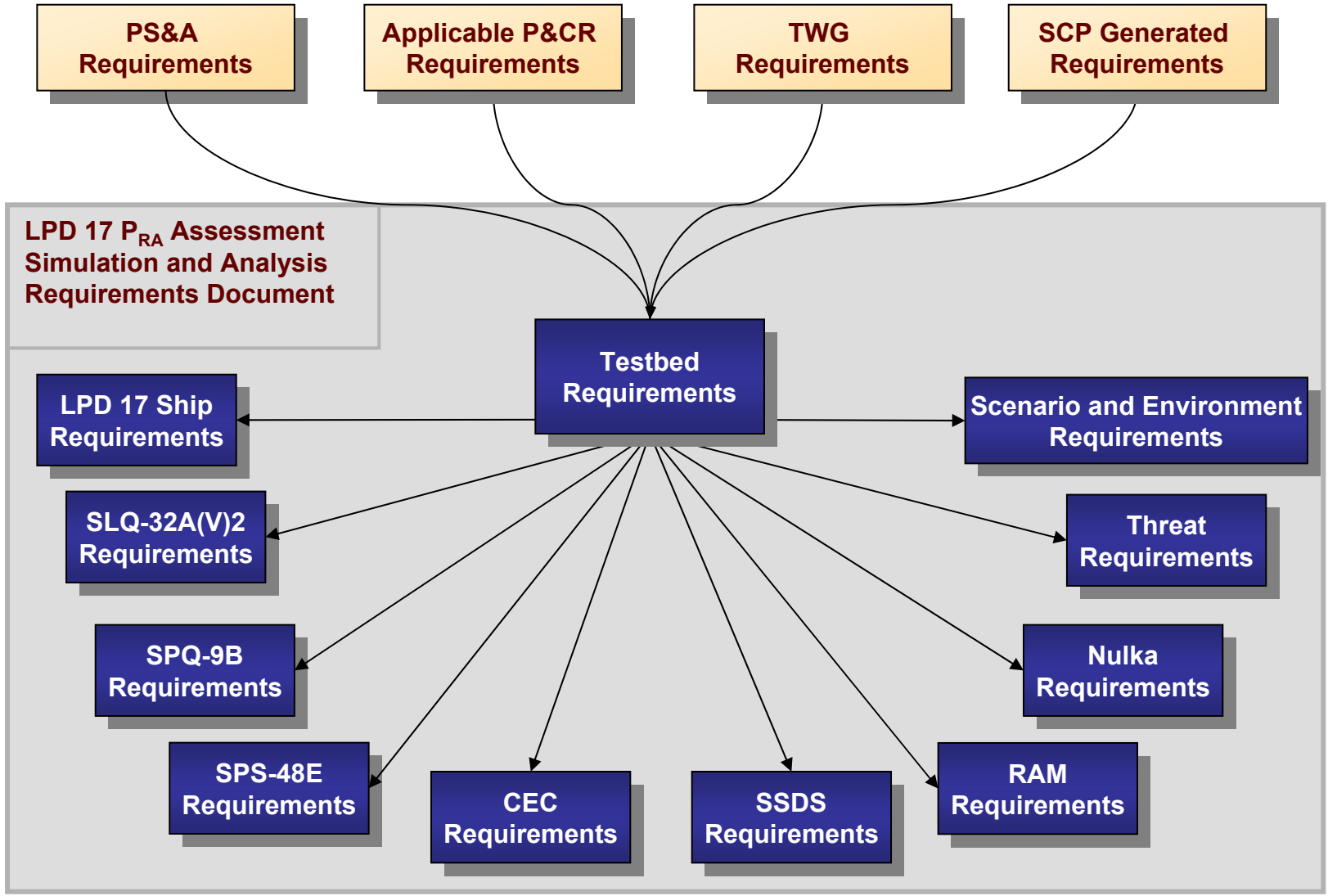Milestone markers: 10/25, 9/30, 8/3, 4/13, 11/9, 11/9, 8/22, 9/19, 10/17

AVW TECHNOLOGIES

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TESTBED REQUIREMENTS FLOW

PS&A Requirements

Applicable P&CR Requirements

TWG Requirements

SCP Generated Requirements

LPD 17 P$_{RA}$ Assessment Simulation and Analysis Requirements Document

Testbed Requirements

LPD 17 Ship Requirements

Scenario and Environment Requirements

SLQ-32A(V)2 Requirements

Threat Requirements

SPQ-9B Requirements

Nulka Requirements

SPS-48E Requirements

CEC Requirements

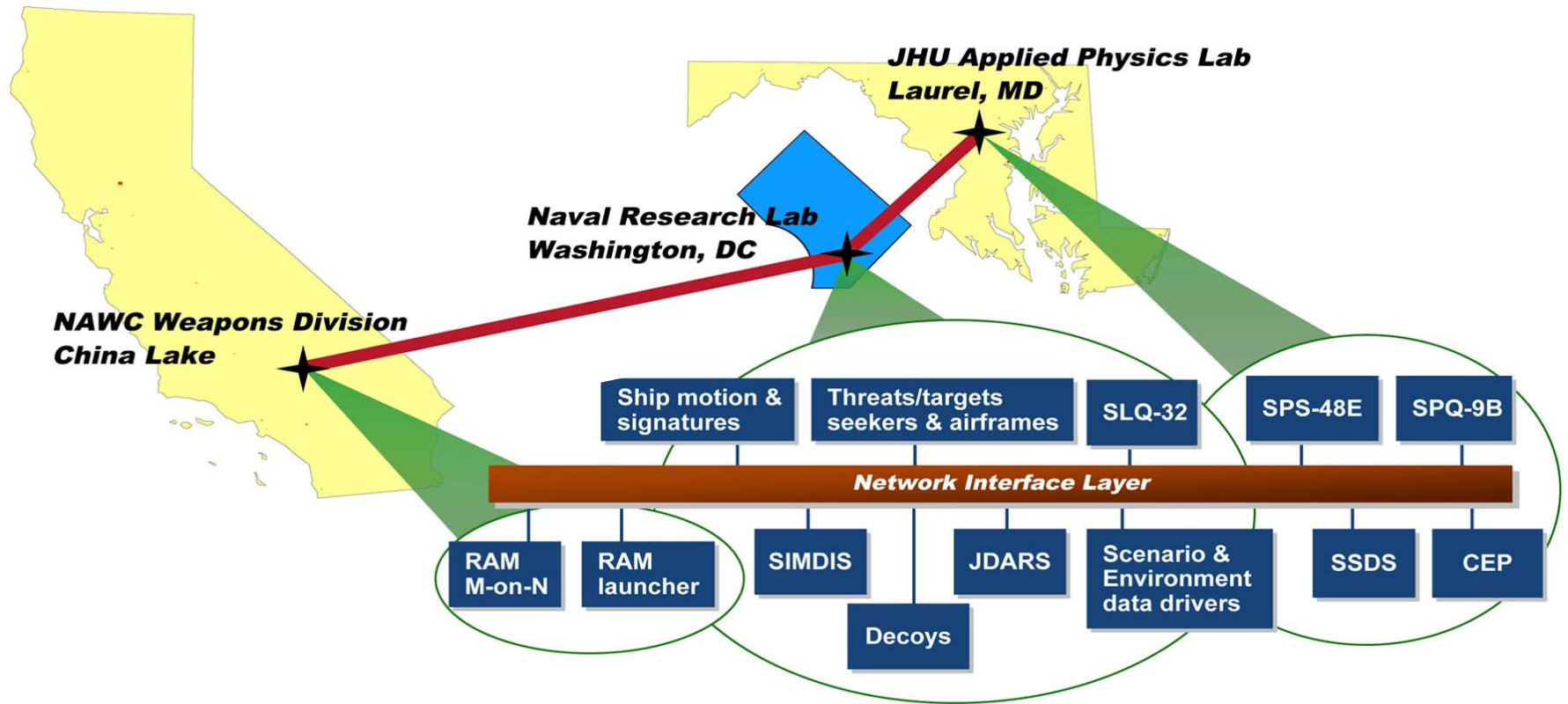**SSDS Requirements**

RAM Requirements

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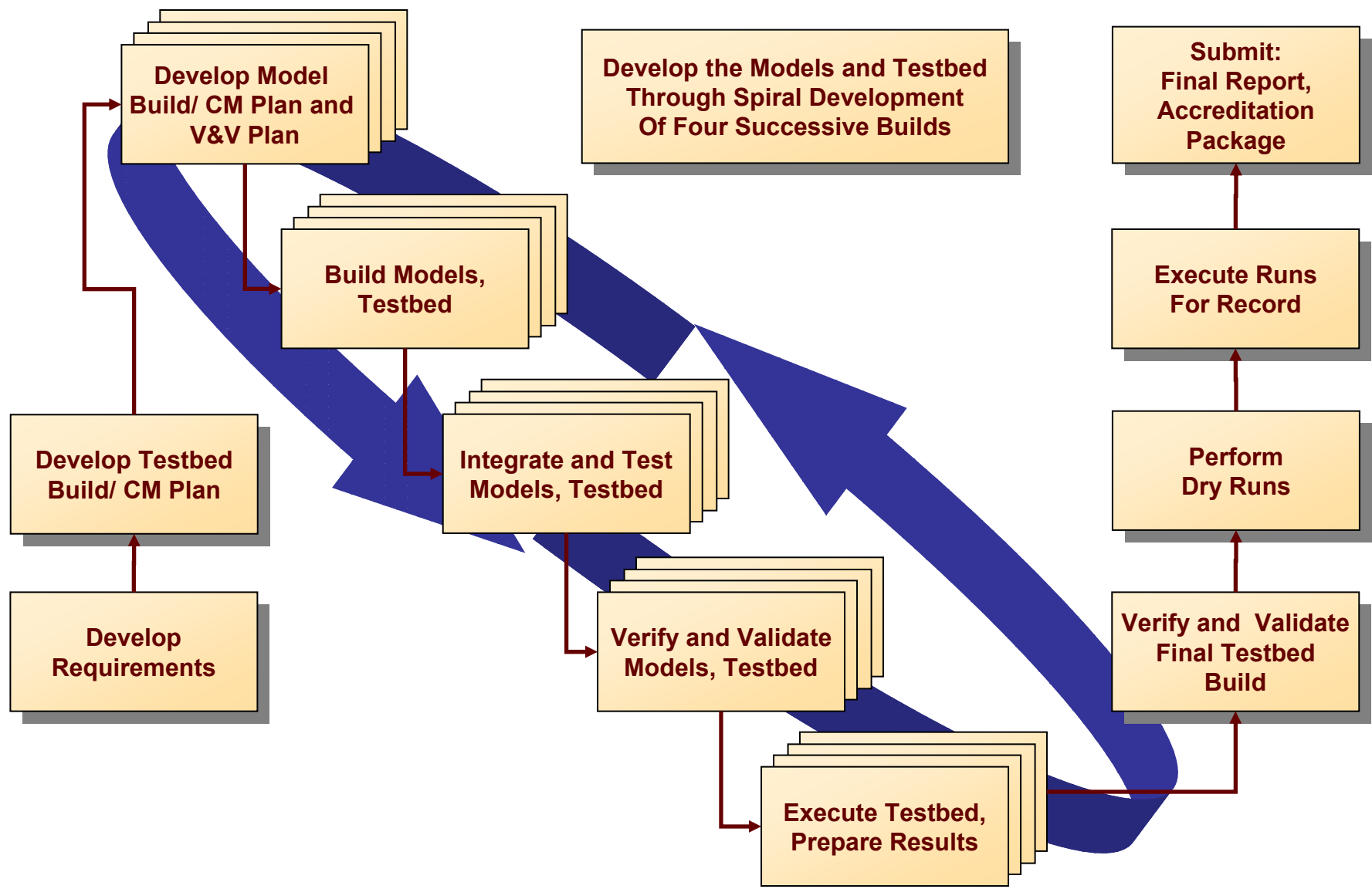- **Testbed Analysis and Scenario Development**

LPD 17 PRA TESTBED

Geographically Distributed Federation of Tactical HWIL,
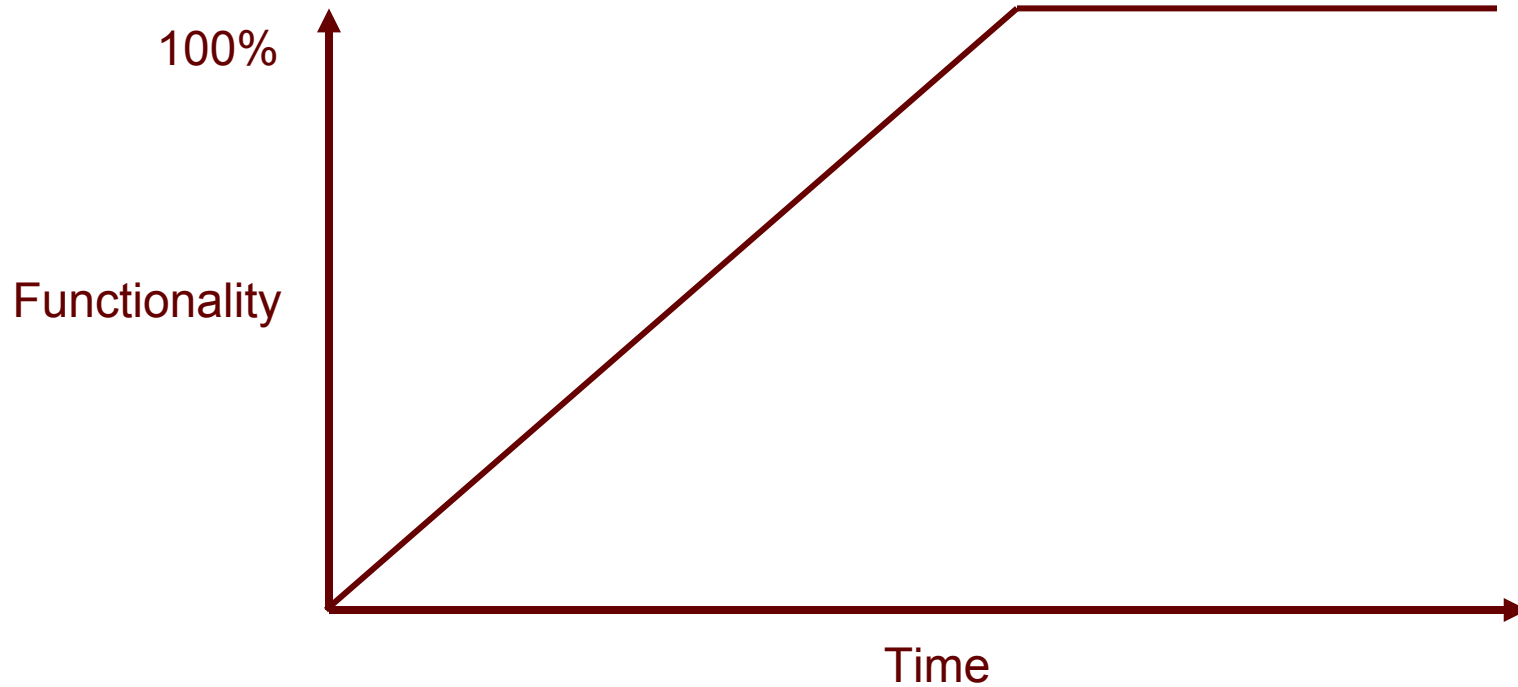Tactical SWIL and Digital Physics Based Models

![AVW TECHNOLOGIES]

TESTBED SPIRAL DEVELOPMENT

Develop Model Build/ CM Plan and V&V Plan

Develop the Models and Testbed Through Spiral Development Of Four Successive Builds

Submit: Final Report, Accreditation Package

Build Models, Testbed

Execute Runs For Record

Develop Testbed Build/ CM Plan

Integrate and Test Models, Testbed

Perform Dry Runs

Develop Requirements

Verify and Validate Models, Testbed

Verify and Validate Final Testbed Build

Execute Testbed, Prepare Results

DEVELOPMENT TIMELINE

Build 1	Build 2	Build 3	Build 4	Dry Runs	→	Analysis Runs

100%

Functionality

Time

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ANALYSIS OVERVIEW

- Objective – to bound a problem having infinite possibilities.
- Number of variables limited by time to perform analysis runs
- Make analysis space finite and within a reasonable operational context.
- Not skewed in any one point of view.
- Scientifically supported; no need spending money on physics excursions.
- Approach should be consistent across ship classes.
- The scenarios are scripted to prevent other ships, LCACs, and aircraft from interfering with the engagement sequence.
- The threat should not be distracted from its target by these other units in the scenario.

SCENARIO OVERVIEW

- **Background**
  - **LPD 17 is part of an Expeditionary Strike Group (ESG).**
  - **Early detection and engagement of the launching platform is not in the context of the P<small>RA</small> Assessment since its focus is ASCM self defense.**
  - **Battle force networking, force link tracking and force cooperative engagements standpoint are not supported by the LPD 17 P<small>RA</small> self defense context; therefore, the ship will be in a worst case situation with no data links active, requiring it to perform the entire detect-to-engage sequence on its own.**

- **Initial Conditions**
  - **Detailed geometries, tactics, and operational situations will be developed to provide boundary/initial conditions for each run as well as to drive the variables during the run to ensure operationally realistic and consistent runs for analysis.**

SCENARIO - THREATS

- **Combat System Setup**
    - **Conducting wartime transit steaming and mission operations with the ship's defensive systems set up to counter ASCM threats automatically.**
    - **No operator actions required except for NULKA launches, which will be treated as a time delay in the automatic engagement sequence based on nominal operator reaction times.**
    - **Surface Warfare Development Group (SWDG) Tactical Memorandums (TACMEMOs) and other tactics and doctrine publications will be used to configure the LPD 17 Combat System representation in the Testbed for execution of each simulated engagement run.**

- **Threats**
    - **Threats will be fired in stream raids of x sec spacing, from eight true bearings (±8°) about the compass rose.**
    - **Intelligence on threats and threat tactics will be used to develop detailed threat engagement scenarios for each run.**
    - **A set of 5 representative threats were selected.**

SCENARIO – SHIP CONFIG

- **Case 1 – "Clean" RCS**
  - **The lowest possible realistic RCS and IR values representative of the ship in transit condition in wartime.**
  - **The flight deck will be as free of aircraft and yellow gear as possible.**
  - **The stern gate will be closed.**

- **Case 2 – "Dirty" RCS**
  - **Near worst possible realistic RCS and IR values representative of the ship in an operational environment conducting well deck and aviation operations.**
  - **SH-60s or MV-22s (whichever has higher RCS value) will be chained on the deck.**
  - **Stern gate will also be open with the well deck empty of LCACs and water.**

SCENARIO - ENVIRONMENT

- **Approach**
  - **Provide representative sample space of environmental and other variables such as water vapor, specific humidity, particulates, temperature, air pressure, ducting, sea state 3 and associated wind direction, wind speed, wave height and wave direction, as well as sun angle.**
- **Season**
  - **Summer Scenario**
  - **Winter Scenario**
- **Time of Day**
  - **Shortly after Sunrise**
  - **Noon**
  - **Afternoon**
  - **Shortly before Sunset**
  - **Midnight**
- **Sea State**
  - **Established as Sea State 3 for All Scenarios**

SCENARIO - GEOGRAPHIES
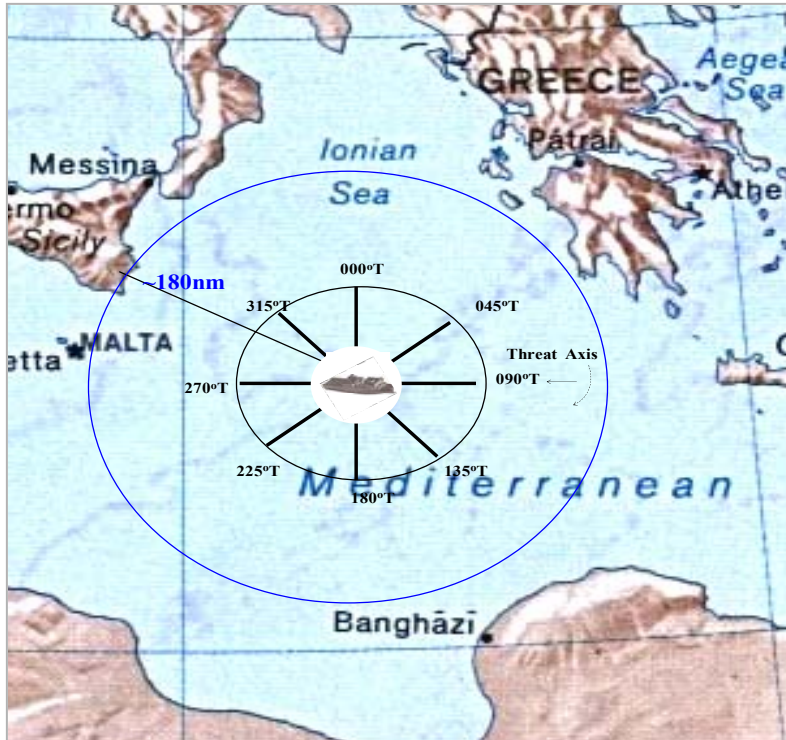
Geography 1
Open Ocean - Mid-Med

Geography 2
Straits of Hormuz

SCENARIO VARIABLES

Threat 1

T 2

T 3

T 4

T 5

Clean RCS   Ship
Dirty RCS   Signature

Med   SOH
Geographic Location

Time:
Sunrise
Noon
Afternoon
Sunset
Midnight

Season:
Winter
Summer

8 Threat
Radials
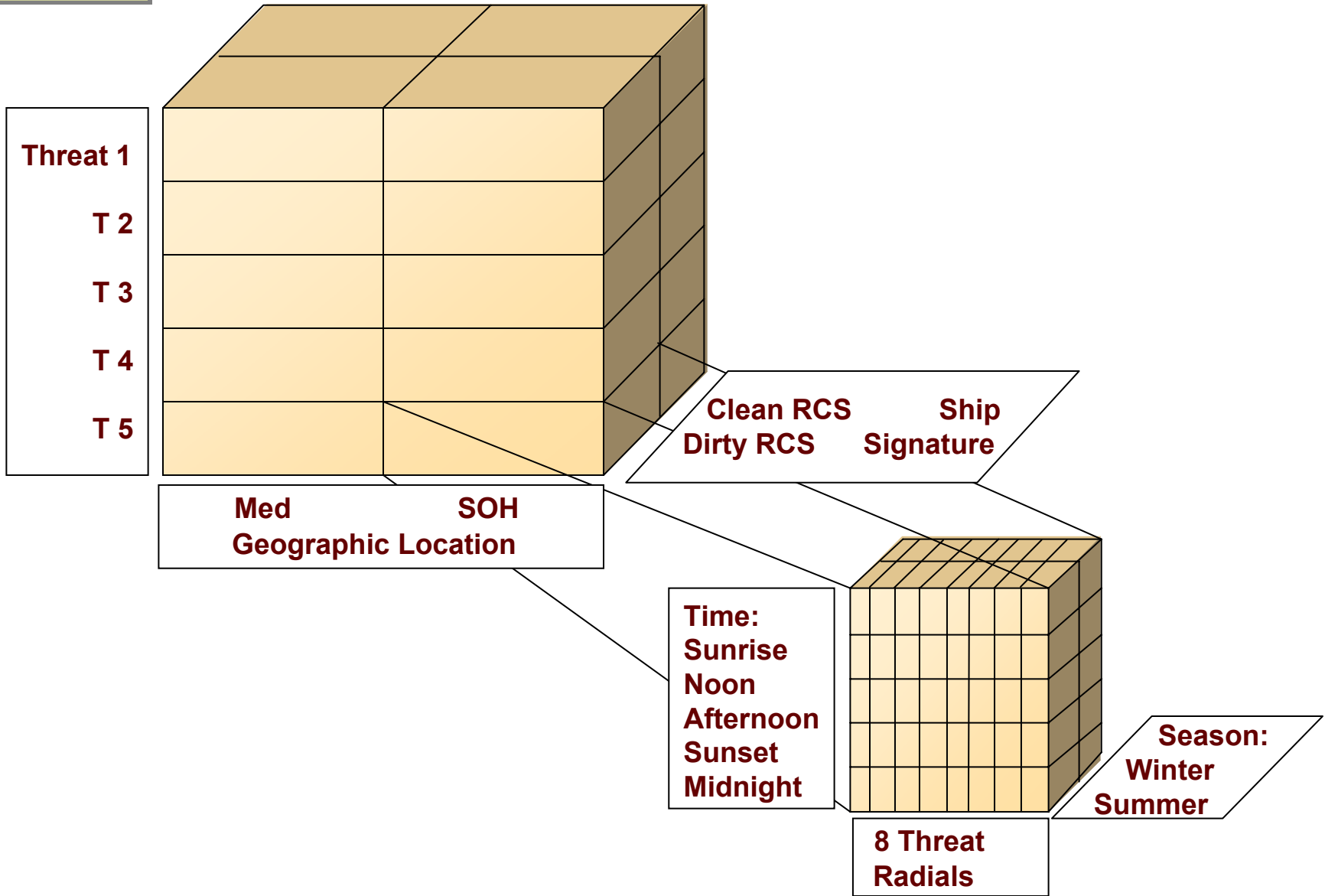
ANALYSIS APPROACH

- **2 Geographies**
  - **Med Open Ocean**
  - **Straits of Hormuz**
  - **Provides Stressing and Non-Stressing Locations**

- **2 Environments**
  - **2 Times of Year**
  - **5 Times of Day**
  - **No Rain**
  - **Provides Nominal Changes in Environment**

- **2 Radar Cross Sections**
  - **Clean, Minimized RCS**
  - **Dirty, Open Well, Helo on Deck**
  - **Provides Large and Small Signatures**

- **5 Threats**
  - **T1R1, T2, T3, T5, T7**
  - **8 Threat Bearings**
  - **45 Deg Intervals**
  - **Provides Combat System Performance from all Directions**

PERFORM ONE RUN FOR EACH COMBINATION OF 6 VARIABLES STATISTICALLY A REPRENTATIVE SAMPLING THROUGH THE SPACE

TESTBED SAMPLE SPACE

PRA Event = 20
(5 Threat x 2 GEO x 2 Signature)

PRA Run = 80
(5 Time x 8 Radials x 2 Seasons)

One Firing for Each Unique Run

Total Number of Runs = 1600

Threat 1

T 2

T 3

T 4

T 5

PRA Event

Clean RCS   Ship
Dirty RCS   Signature

Med   SOH
Geographic Location

PRA Run

PRA Event

Time:
Sunrise
Noon
Afternoon
Sunset
Midnight

Season:
Winter
Summer
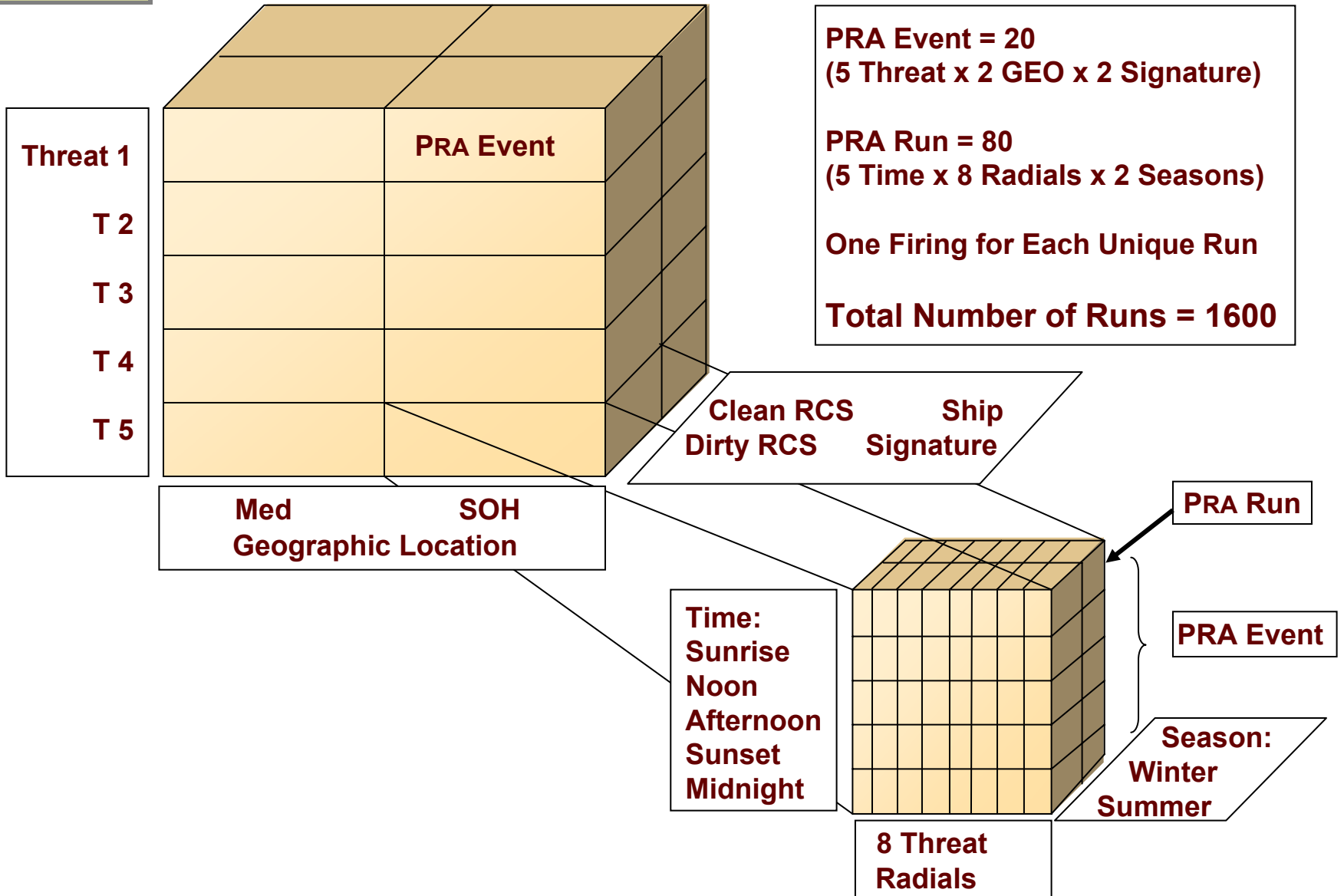
8 Threat
Radials

TESTBED PRA CALCULATIONS
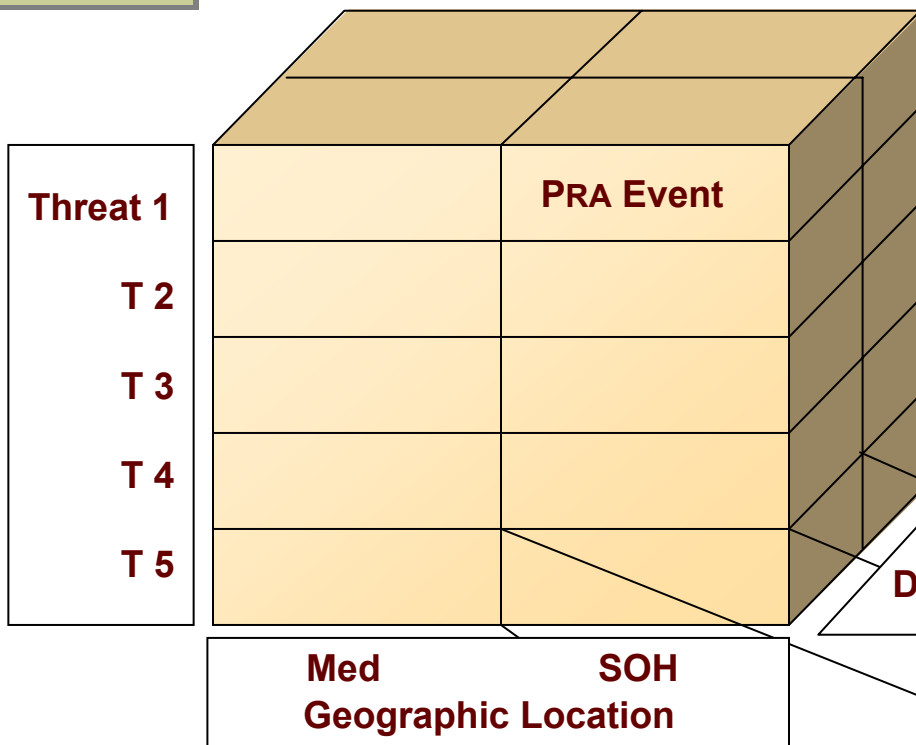
AVW TECHNOLOGIES

PRA Event

Threat 1
T 2
T 3
T 4
T 5

Med   SOH
Geographic Location

Clean RCS   Ship
Dirty RCS   Signature

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PRA Run

PRA Event

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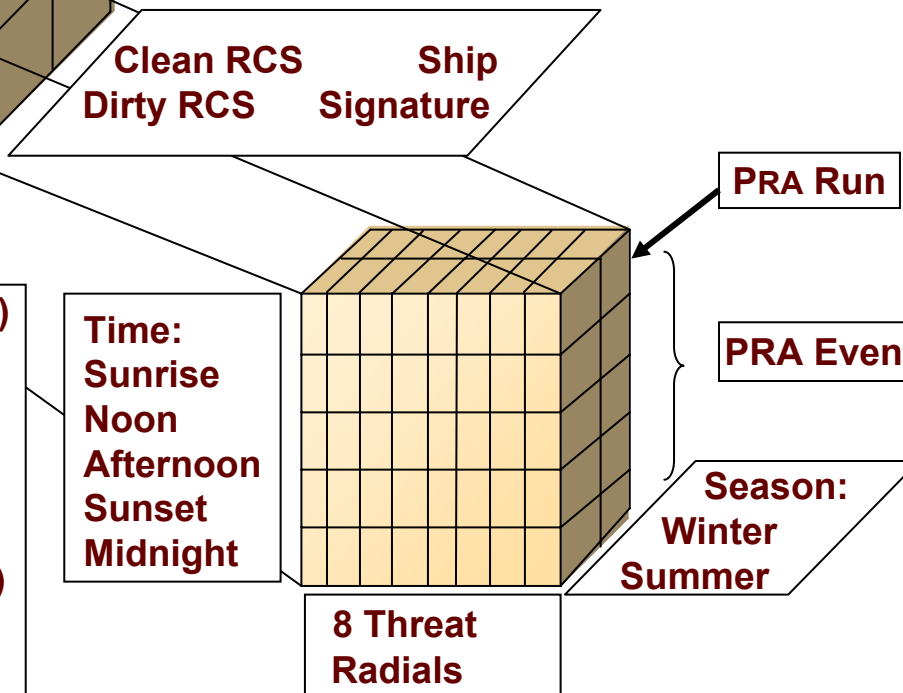
8 Threat
Radials

PRA (Event) = $\dfrac{\text{\# Successes}}{80}$ (20 PRA Values)

PRA (Threat) = $\dfrac{\Sigma \text{ PRA Events}}{4}$ (5 PRA Values)

PRA (Geography) = $\dfrac{\Sigma \text{ PRA Events}}{10}$ (2 PRA Values)

PRA (Ship Sig) = $\dfrac{\Sigma \text{ PRA Events}}{10}$ (2 PRA Values)

PRA Overall = Σ PRA All Event   (1 PRA Value)

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**1600 Runs
2 Hours Per Run
8 Runs Per Day (16 Hour Day)
40 Runs per 5 Day Work Week
40 Weeks for All Runs**

**Working on Automating the Runs
To Minimize Operator Involvement
And Overcome 16 Hour Days**

Analysis Runs

ANALYSIS – KEY EVENTS

- **Identify Key Events During Engagement**
  - **Sensor Performance, Sensor Messages, Weapons Orders, Weapons Performance, Engagement Outcome**
- **Data Collected and Displayed Live During Runs**
- **Used to Verify, Troubleshoot Testbed Performance**
- **Used to Calculate Various PRA Values**

SUMMARY

Success for Testbed Development Based On:

- – **Clearly Defined Requirements**
- – **Testbed Organization and Roles Well Understood**
- – **Documents Contain Necessary Information**
- – **Spiral Development and Schedule**
- – **Execute Phases of Simulation Development**
- – **Pragmatic Scenario Development**
- – **Systematic Analysis Approach**
- – **Collection, Manipulation and Presention of PRA Values**

BACKUP SLIDES