Robust Integrated T&E Framework

Raytheon IDS

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Overview
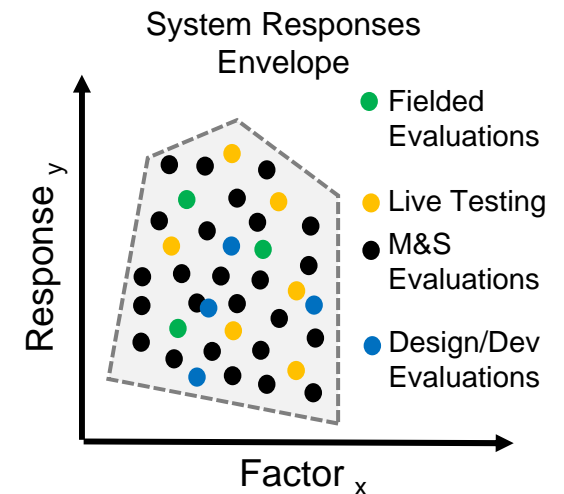
- Test & Evaluation Climate

- T&E Framework

- Communicating through the Framework

- A Holistic Point of View

- Summary

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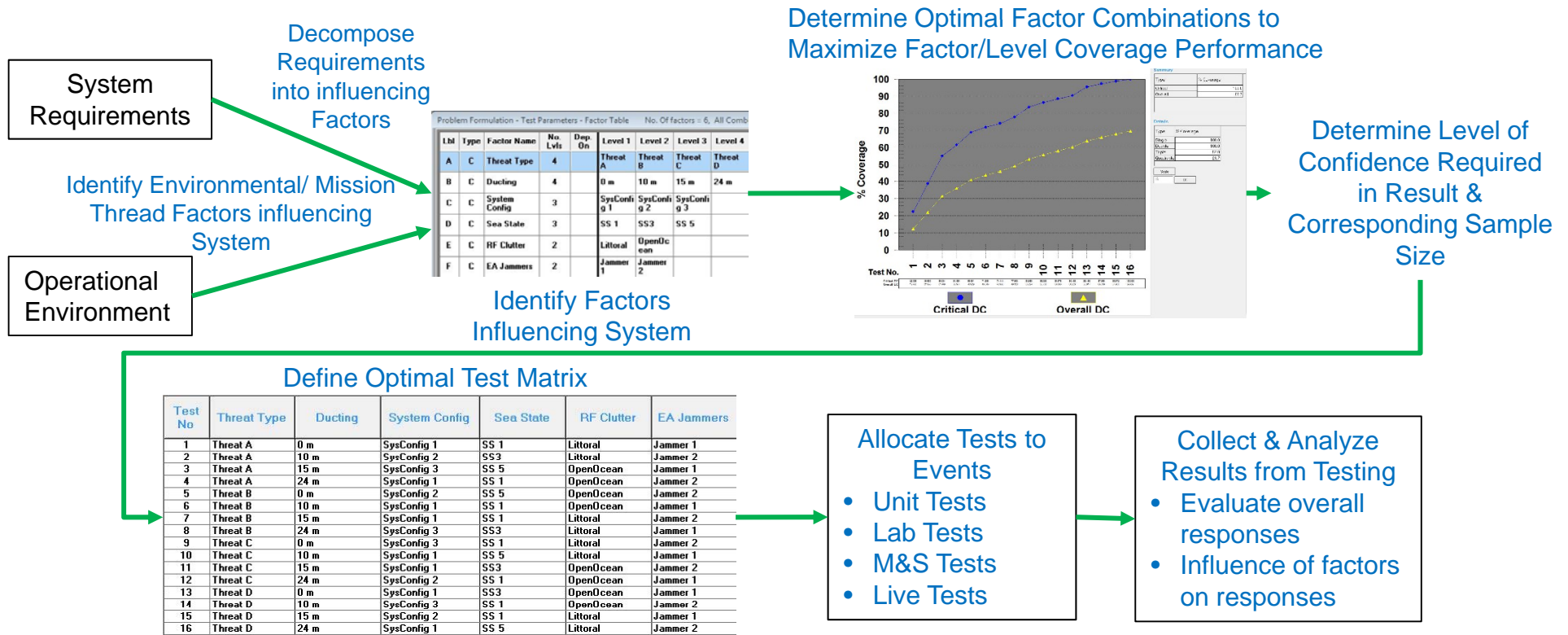
Test & Evaluation Climate is Changing

- In todays challenging budget environment while system complexity is increasing the T&E community is faced with:
  - Need to find defects early in the development process with shorter release cycle times
    - Defects found later can result in significant costs to the program if found during system level testing or later
  - Fewer opportunities for performing live testing
    - Conducted events must have a high probability of success (provide data required)
    - Greater need for multiple levels of Modeling and Simulation (M&S) environments
  - Verification and Validation of M&S more important
    - Specific Intended Uses must be defined early in program
    - Verification & Validation evidence needs to be generated incrementally
    - Accurate understanding of capabilities and limitation of M&S needs to be communicated

- Comprehensive Characterization of System Envelope Required
  - Invest in collection & analysis of data from all viable program venues
  - M&S needs to be leveraged through out System Engineering program

- Benefits of Test Optimization needs to be applied across the board
  - Need to look at how to get biggest benefit out of each stage of integration and testing
    - Understand how information from lower level activities support top level objects
    - Understand what activities provide the greatest understanding

System Responses Envelope

- ● Fielded Evaluations
- ● Live Testing
- ● M&S Evaluations
- ● Design/Dev Evaluations

Response $_y$ / Factor $_x$

Holistic T&E Approach -> Comprehensive Understanding of System

Application of Statically Test Optimization to T&E Framework

System Requirements

Decompose Requirements into influencing Factors

Determine Optimal Factor Combinations to Maximize Factor/Level Coverage Performance

Identify Environmental/ Mission Thread Factors influencing System

Operational Environment

Identify Factors Influencing System

Determine Level of Confidence Required in Result & Corresponding Sample Size

Define Optimal Test Matrix

Allocate Tests to Events
- Unit Tests
- Lab Tests
- M&S Tests
- Live Tests

Collect & Analyze Results from Testing
- Evaluate overall responses
- Influence of factors on responses

A Structured Framework Minimizes Testing & Builds Measurable Confidence

Test Cases Generated with rdExpert

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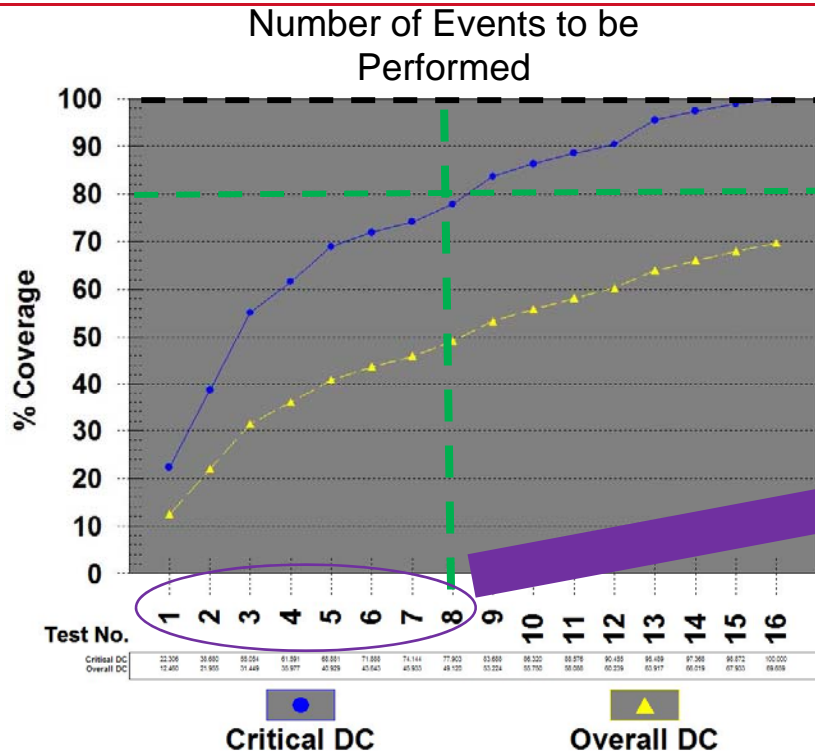# Importance of Selecting Factors & Communication

- The importance of selecting factors and corresponding levels can not be overstated
  - Must Leverage SMEs in determining correct factors
  - May need to perform screening experiments to determine driving factors
  - Need to fully understand the factors that drive the requirements being evaluated
  - Must understand the range of environments in which system will be employed

- Documenting factor design space provides powerful mechanism for engaging customer and stakeholder community
  - Vehicle for communicating and achieving agreement on what influences the design
  - Helps to scope the number of tests/event required to build confidence in the system
  - Helps to quantitatively negotiate the level of evaluation required
  - Used to allocate evaluations to the appropriate T&E venues

- Experiences in development of integrated developmental & operational testing
  - Developers teamed with government T&E Stakeholders to identify & refine required factors
  - Employed SMEs in areas such as combat system, radars, threats, and general live testing
  - Members focused on identifying factors supporting a diverse set of objectives achieved through a minimal number of test venues
  - T&E community takes perspective of "how the system is expected to be employed" to determine importance of factors.

> ## A Fully Engaged Team Plays Key Role in Defining Factors Driving Scenarios

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Using Coverage Charts to Communicate

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Number of Events to be Performed

Raytheon experience - Statistical Test Optimization -> average 30% reduction in required test cases while maintaining/improving existing coverage

Trade Space not Evaluated "Test Debt"

% of Factor Combinations Covered by Defined # of Test Cases (Domain Coverage (DC))

Test No	Threat Type	Ducting	System Config	Sea State	RF Clutter	EA Jammers
1	Threat A	0 m	SysConfig 1	SS 1	Littoral	Jammer 1
2	Threat A	10 m	SysConfig 2	SS3	Littoral	Jammer 2
3	Threat A	15 m	SysConfig 3	SS 5	OpenOcean	Jammer 1
4	Threat A	24 m	SysConfig 1	SS 1	OpenOcean	Jammer 2
5	Threat B	0 m	SysConfig 2	SS 5	OpenOcean	Jammer 2
6	Threat B	10 m	SysConfig 1	SS 1	OpenOcean	Jammer 1
7	Threat B	15 m	SysConfig 1	SS 1	Littoral	Jammer 2
8	Threat B	24 m	SysConfig 3	SS3	Littoral	Jammer 1
9	Threat C	0 m	SysConfig 3	SS 1	Littoral	Jammer 2
10	Threat C	10 m	SysConfig 1	SS 5	Littoral	Jammer 1
11	Threat C	15 m	SysConfig 1	SS3	OpenOcean	Jammer 2
12	Threat C	24 m	SysConfig 2	SS 1	OpenOcean	Jammer 1
13	Threat D	0 m	SysConfig 1	SS3	OpenOcean	Jammer 1
14	Threat D	10 m	SysConfig 3	SS 1	OpenOcean	Jammer 2
15	Threat D	15 m	SysConfig 2	SS 1	Littoral	Jammer 1
16	Threat D	24 m	SysConfig 1	SS 5	Littoral	Jammer 2

Critical DC

Overall DC

- Quantitatively Communicate Amount of System Evaluated
- Communicate the Test Cases Providing Largest Coverage of the System

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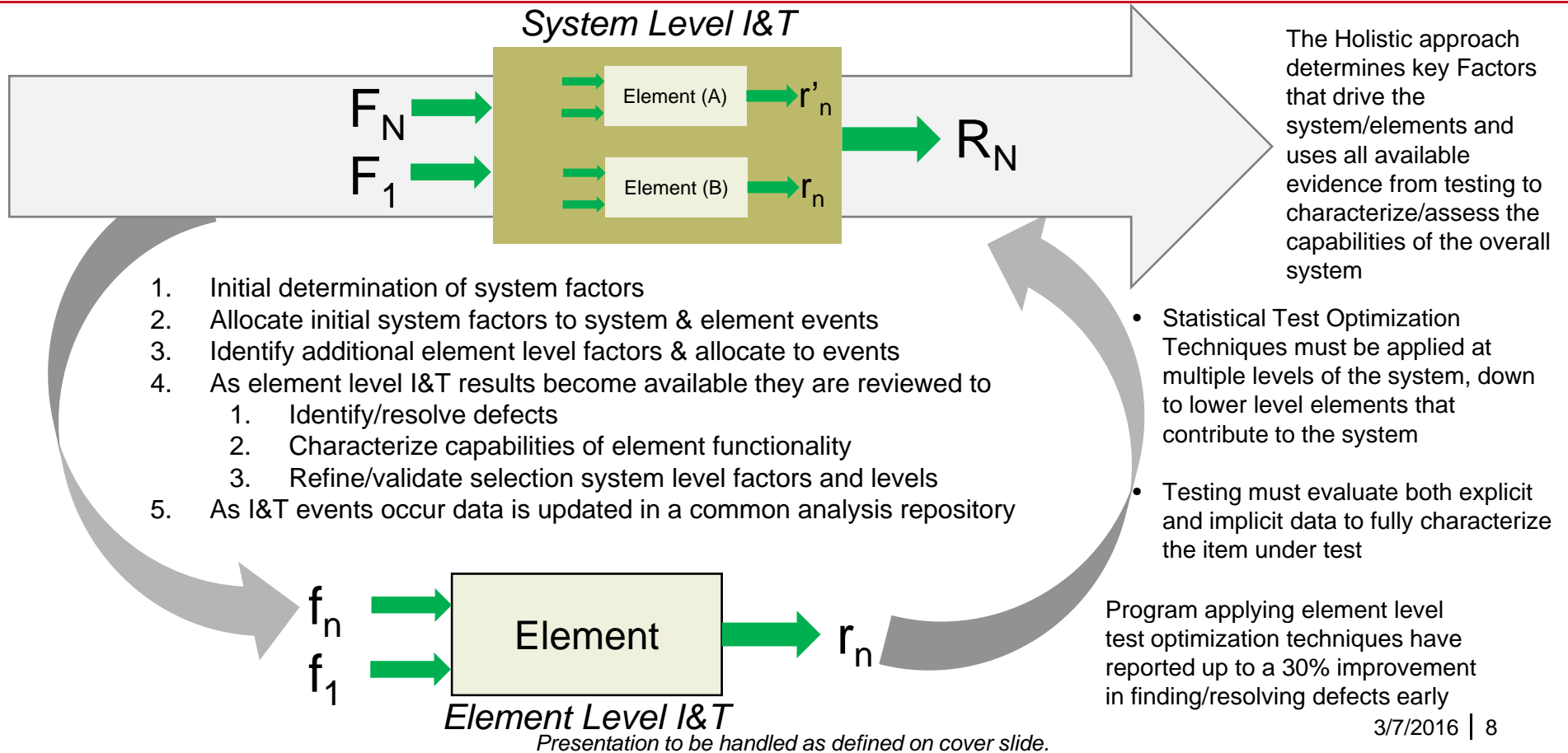3/7/2016 | 6

Creating Holistic T&E Approach

- A Holistic approach does not just look at T&E at a single phase of a program but looks at how all phases work together to characterize the capabilities of the system
  - Understand how results from low level events can support greater understanding of the capabilities of the element and overall system
  - Understand how leveraging results from early evaluations (e.g. unit testing) can provide earlier resolution of critical defects

- Holistic approach looks at new element functionality and the factors that influence, to determine what T&E is required
  - Team based approach brings together all aspects of System Engineering to determine appropriate factors and T&E venues
  - Teams determine the proper levels and variations for each factor to accurately stimulate needed responses
  - Teams look at all T&E venues to improve understanding of system (e.g. Lab Testing, M&S, Developmental Testing, Operational Testing)

- The impact of the new functionality on the overall system is then reviewed to determine its impact on the system level factors and what from the lower level testing can be leveraged.

- All data from evaluations and assessments are shared with the team to form an integrated picture of the system and assess progress through out the programs evolution
  - Evaluating results from lower level testing in the context of the overall system helps to improve the understanding of the capabilities and limitations of the system incrementally
  - Output from one phase is the input of the next phase of testing
  - Requires a data repository for test data that can be leveraged and added to throughout the evolution of the program

> **A Holistic Approach to T&E Provides**
> 1. Increased Understanding of System Capabilities & Limitations
> 2. Earlier Resolution of Costly Defects

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Understanding Through Compounding Evaluation

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System Level I&T

Element (A) r'_n

F_N

F_1

Element (B) r_n

R_N

The Holistic approach determines key Factors that drive the system/elements and uses all available evidence from testing to characterize/assess the capabilities of the overall system

1. Initial determination of system factors
2. Allocate initial system factors to system & element events
3. Identify additional element level factors & allocate to events
4. As element level I&T results become available they are reviewed to
   1. Identify/resolve defects
   2. Characterize capabilities of element functionality
   3. Refine/validate selection system level factors and levels
5. As I&T events occur data is updated in a common analysis repository

- Statistical Test Optimization Techniques must be applied at multiple levels of the system, down to lower level elements that contribute to the system

- Testing must evaluate both explicit and implicit data to fully characterize the item under test

f_n

f_1

Element r_n

Element Level I&T

Program applying element level test optimization techniques have reported up to a 30% improvement in finding/resolving defects early

Summary

- Meeting the demands of the current customer environment requires
  - Greater application of statistical test optimization on programs
  - Combining and leveraging data generated from all levels of testing to properly characterize the system

- Improve qualitative & quantitative knowledge of system
  - Measureable understanding of how much of the system has been evaluated
  - Understanding of the program risks due to testing not performed

- Reduce program cost though identification of defects earlier in program life cycle
  - Mitigate cost and schedule risk during later phases of system integration and testing
  - Provide program management with more accurate picture of system capabilities throughout development

- Improve confidence in capabilities/performance
  - Better understanding of lower level element functionality
  - Better understanding of how elements support system behavior/performance

- Improvement in characterization of capabilities and limitations through SME participation
  - Understanding of how system is expected to be employed in the field
  - Understanding of how the designers envisioned the system to work

Holistic Approach Builds Measureable Confidence Incrementally

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Bibliography

- Douglas Moshier
  - 18 Years with Raytheon Company
  - Engineering Fellow in System Verification, Test, and Analysis Directorate
  - Supported all phases of System Engineering on various programs
    - Requirements, Design, Analysis, Verification/Validation, Integration & Testing
  - Worked Development and Analysis of Various M&S environments
  - Key member of Missile Defense Agency National Team I&T and Advanced Concept Teams.
  - Currently Supporting Zumwalt Integration & Test Organization
    - Development lead for Zumwalt Test Bed Hardware-in-the-Loop Facility
    - Zumwalt Advanced Program Lead
  - Masters in Mechanical Engineering from University of Connecticut
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