Cost Efficient Risk Management
through
Integrated T&E
throughout
the Systems Engineering Life-Cycle

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NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

STRENGTH THROUGH INDUSTRY & TECHNOLOGY
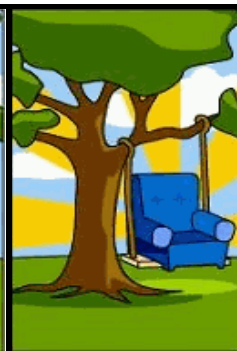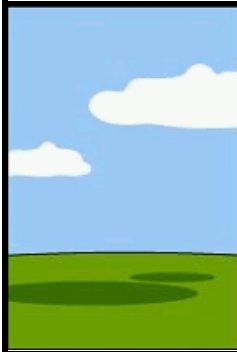
Agenda

- Introduction
  - Acquisition humor
  - Complexity challenge = increasing risk
  - Intro to Integrated T&E
- Integrated T&E within systems engineering to manage risk
  - Alignment of T&E processes within systems engineering process to identify risks early and often
  - Integration of T&E organizations/processes within iterative systems engineering throughout acquisition life cycle as a key component of risk mitigation
- Enablers to implement IT&E within a program
  - Risk based T&E planning and reporting
  - AVW IT&E Database Toolset
  - Other recommendations for implementing IT&E
- Conclusion/ Q&A

Acquisition 101?

How the user described it	How the requirement was understood	How the contractor designed it	How the programmer wrote it	How the PM/sponsor described it
How the project was documented	What was actually installed	How the Government was billed	How the helpdesk supported it	What the user *really* needed

How do we avoid this?

Complexity Challenge

?

- **Open Architecture/Systems**
- **Complex C4I—GIG/FORCEnet**
- **Joint Interoperability**
- **Emerging Technology & Materials**
- **Capabilities Based Requirements**
- **CAIV**

- **More difficult to develop**
- **More difficult to test**
- **Compressed timelines**
- **Compressed budgets**
- ***MORE RISK…& HIGHER COSTS***

AVW TECHNOLOGIES
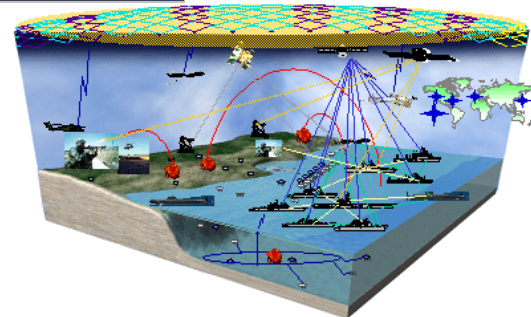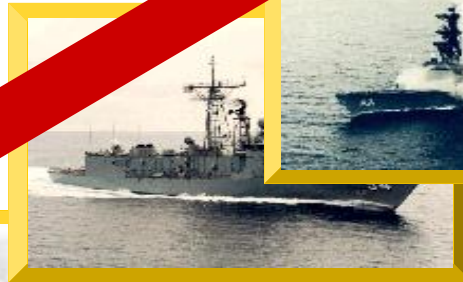
DT vs. OT (vs. LFTE, etc...) → IT

DT

- Test to specs.
- Limited test environment perhaps in lab
- Focused on a specific set of criteria.
- Test threshold values not capability
- Critical technical parameters
- Integration testing designed around minimum performance criteria and interface spec.
- May not address all threats or missions.
- CT adds contractual issues

Controllable Factors

Inputs (*x*) → [ ] → Outputs (*y*)

Environmental /Uncontrollable Factors
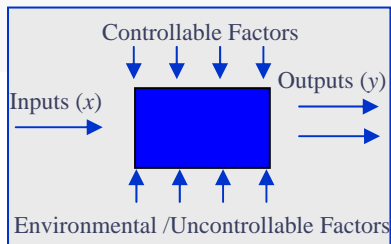
OT

- Operational environment & threat with end users & support
- End-to-end mission perf. & support
- Production representative; system/ family of systems
- Test overall capability of an item to meet user's mission needs and value added for mission accomplishment.
- Test the limitations and capabilities of an item so that:
- Employ and assess doctrine/TTP
- Independent IOT&E & LFT&E mandates (Title X)

THIS MUST TRANSFORM INTO A CONTINUUM OF TESTING
- **Increasing fidelity of technical and operational assessments**
- **Cooperating organizations**
- **Reduced budget and timeline ?**
- **Team/IPT structure not competitive**

Integrated T&E

- Key component of risk management for a program
- Coordinated planning and development of individual test objectives
- Some data elements will not overlap and can only be measured in a technical, operational, or live fire environment but there can be potential for significant cost savings and earlier risk reduction
- Requires buy-in from all orgs + strong T&E WIPT

EXP

CT & DT Plans

OT&E Plan

LFT&E Plan

OT&E
DT&E
CT
LFT&E
Joint Exp, ACTDs

T&E WIPT

Integrated T&E Plan

$$\text{T\&E}_{integrated} \int = (\text{CT, DT, OT, LFT\&E, Joint Exp, M\&S, Analysis, etc.})\ dt$$

System Disposal

Program Start

T&E During Sys Eng Tasks
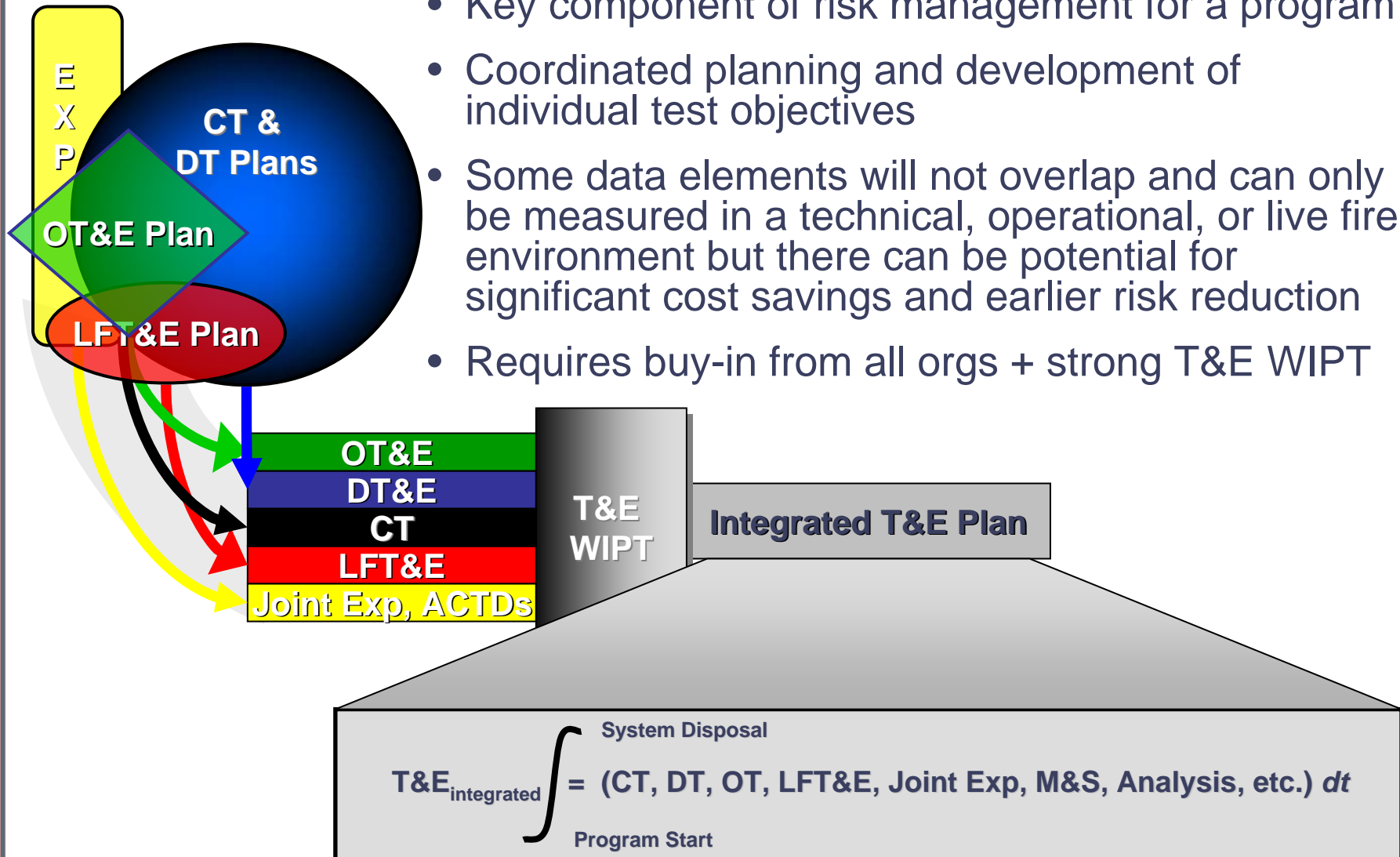
THE SYSTEMS ENGINEERING PROCESS
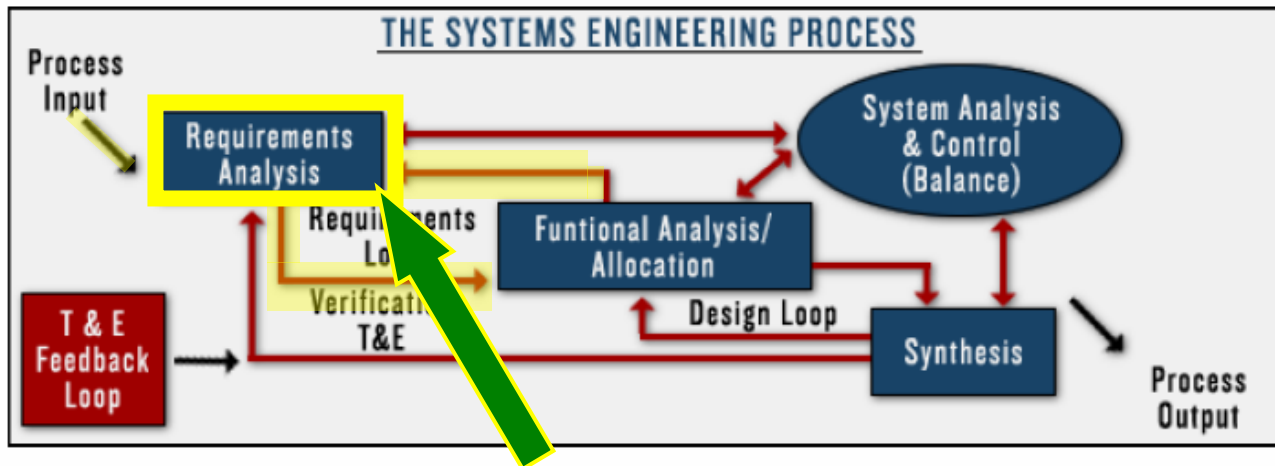
Testers support by influencing:
- Measurable, objective, meaningful reqs
- Reqs context & op scenarios
- Bounding system (technical/operational)
- Assisting mission / functional breakdown
- TPM selection
- Influencing HSI
- Prioritization of reqs (critical / need / want)
- IV&V of reqs flowdown + delivered technical and operational capabilities

T&E is supported by insight into various aspects of project to facilitate efficient test planning:
- Customer expectations
- Project & external constraints (CAIV…) Reqs context and intentions
- Life cycle support planning
- HSI planning/design
- Physical / logical architecture drivers
- Prioritization of requirements

THE SYSTEMS ENGINEERING PROCESS

Process Input

Requirements Analysis

Requirements Loop

Verification T&E

T&E Feedback Loop

Funtional Analysis/ Allocation

System Analysis & Control (Balance)

Design Loop

Synthesis

Process Output
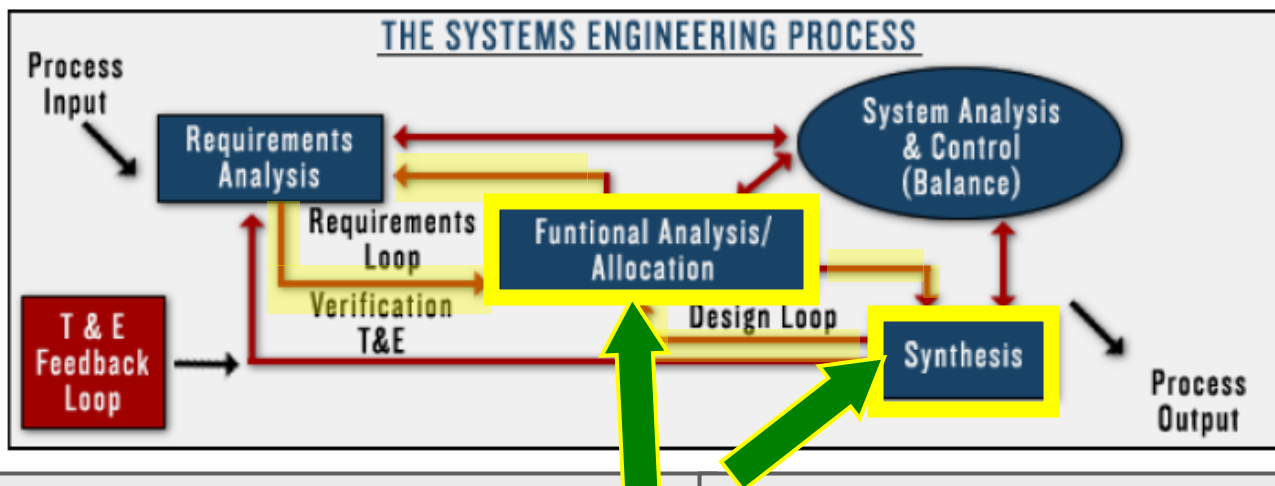
Testers support by influencing:
- Consistency in reqs/functional flowdown based on original intentions and op context
- Influencing HSI in detailed design including user reviews of HCI & functionality
- Verification of requirements implementation through limited component level tests
- Interface definition
- Prioritization of lower level requirements
- IV&V of reqs flowdown + delivered technical and operational capabilities
- M&S planning/development

T&E supported by insight (which improves test planning efficiency) into:
- Detailed reqs flowdown and prioritization
- Detailed life cycle support planning
- HSI planning/design
- Detailed architecture drivers
  & early collection of evaluation data:
- Life cycle planning
- HSI design implementation
- Software eng. process assessment
- M&S V&V
- SCI/Component & interface test data

THE SYSTEMS ENGINEERING PROCESS

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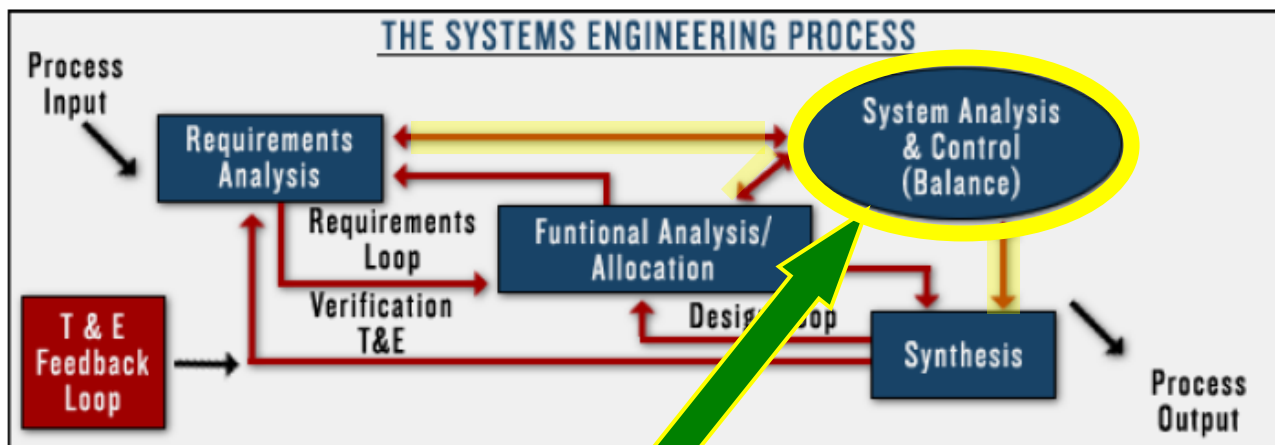
Testers support by influencing:	*T&E is supported by insight into:*
• M&S analysis planning • Monitoring M&S development • Assisting in M&S analysis execution • Independent evaluation of analysis results • Evaluation of systems and software engineering process/process improvement • Independent review of risk management and input of T&E issues as new/updated risks • Objective TPM tracking • Design for safety, life-cycle, interoperability, & survivability (instead of merely testing)	• Capabilities and limitations from analysis that points to need for live testing • Pre and post-test predictions • Test design and noise factors selection (design of experiments), sensitivity studies • System & component trade-offs *& collection of evaluation data:* • Analytical and M&S based evaluation of system performance • M&S V&V

T&E During Sys Eng Tasks (Cont')

THE SYSTEMS ENGINEERING PROCESS

Process Input → Requirements Analysis

Requirements Loop

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Process Output
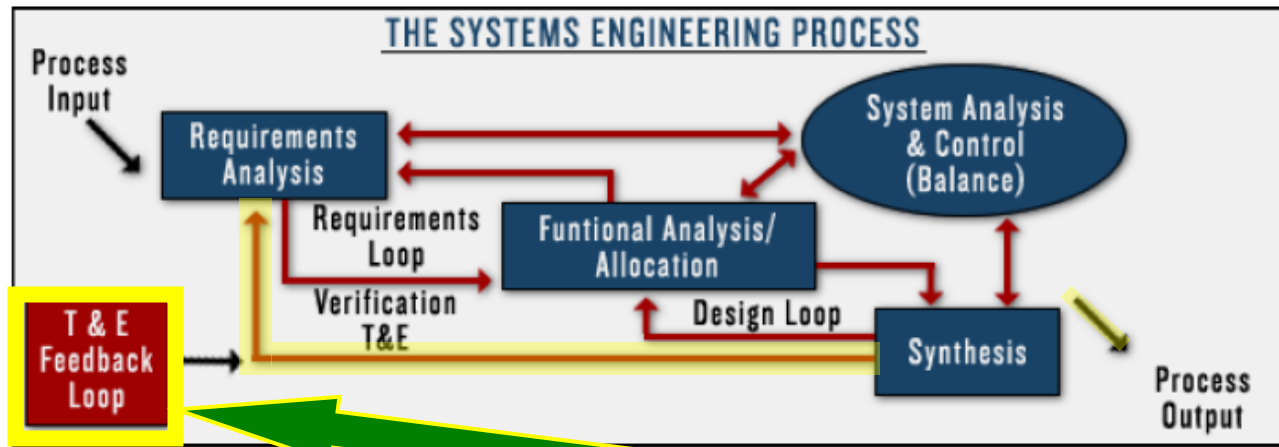
Testers support by:
- Planning and executing tests to verify requirements and validate functions and mission capabilities
- Giving engineers insight into performance of system
- Independent internal and external agencies evaluation of the system

[traditional T&E – with greater participation from systems engineers & increased use of standard engineering methodology for planning efficient tests

T&E is supported by systems engineers:
- Interpretation of technical results
- Determining impacts on HSI, life-cycle planning, IA, etc.
- Categorization of issues and problems

T&E supports accurate decision making:
- Proceeding with output to next acquisition phase, or
- Proceeding to next phase of testing, or
- Repeat of previous tasks while holding at this point in the acquisition cycle

Systems Engineering + T&E
within the Acquisition Cycle

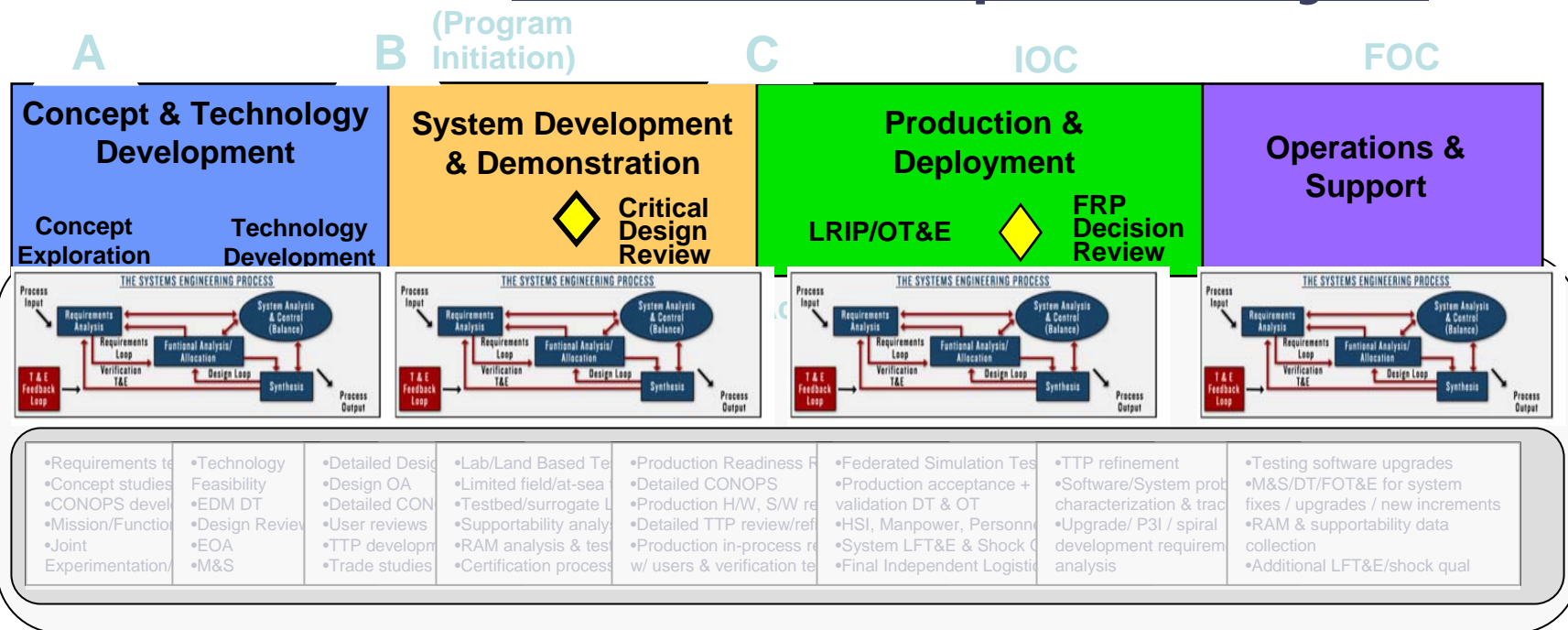A   B **(Program Initiation)**   C   IOC   FOC

Concept & Technology Development	System Development & Demonstration	Production & Deployment	Operations & Support
Concept Exploration **Technology Development**	◆ **Critical Design Review**	**LRIP/OT&E** ◆ **FRP Decision Review**	

THE SYSTEMS ENGINEERING PROCESS

Process Input → Requirements Analysis → Requirements Loop → Funtional Analysis/ Allocation → Design Loop → Synthesis → Process Output; Verification T&E; System Analysis & Control (Balance); T&E Feedback Loop

- •Requirements te
- •Concept studies
- •CONOPS devel
- •Mission/Function
- •Joint Experimentation/

- •Technology Feasibility
- •EDM DT
- •Design Review
- •EOA
- •M&S

- •Detailed Desig
- •Design OA
- •Detailed CON
- •User reviews
- •TTP developm
- •Trade studies

- •Lab/Land Based Te
- •Limited field/at-sea
- •Testbed/surrogate L
- •Supportability analy
- •RAM analysis & test
- •Certification process

- •Production Readiness R
- •Detailed CONOPS
- •Production H/W, S/W re
- •Detailed TTP review/ref
- •Production in-process re w/ users & verification te

- •Federated Simulation Tes
- •Production acceptance + validation DT & OT
- •HSI, Manpower, Personne
- •System LFT&E & Shock Q
- •Final Independent Logistic

- •TTP refinement
- •Software/System prob characterization & trac
- •Upgrade/ P3I / spiral development requirem analysis

- •Testing software upgrades
- •M&S/DT/FOT&E for system fixes / upgrades / new increments
- •RAM & supportability data collection
- •Additional LFT&E/shock qual

MORE THAN TESTING ... CONTINUOUS EVALUATION
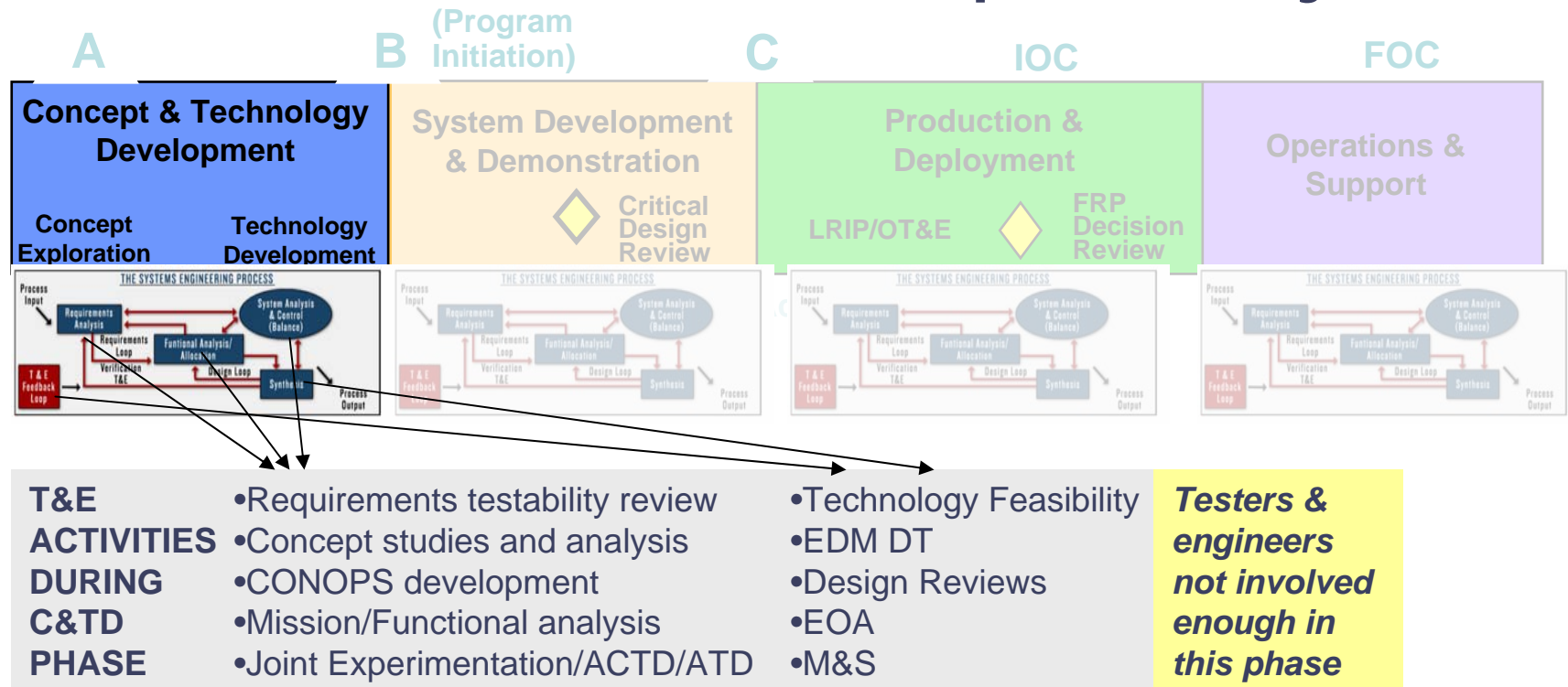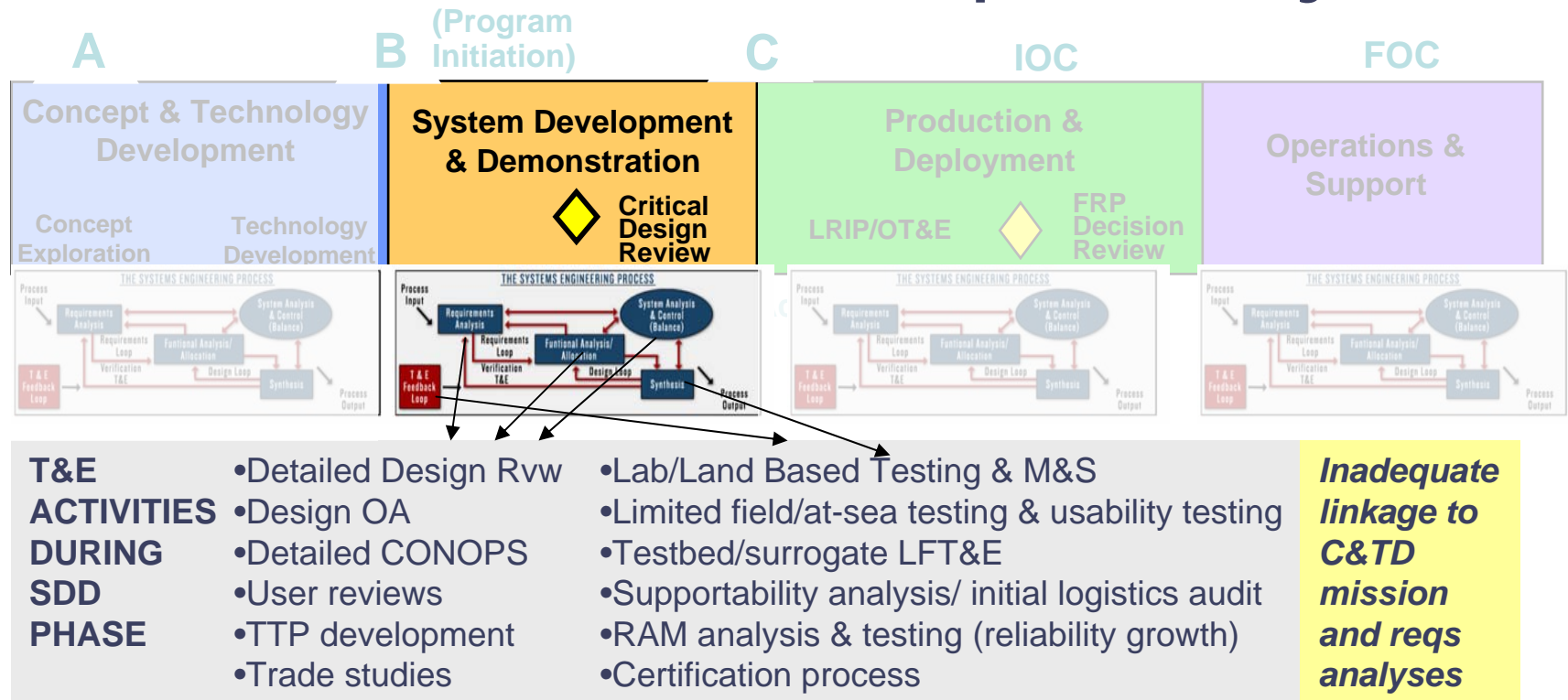
RISK MANAGEMENT…   **MISSION CAPABILITY DELIVERY…**

INTEGRATED T&E & SYSTEMS ENGINEERING

Ability to influence system design

System maturity & design/ upgrade cost

AVW TECHNOLOGIES

Systems Engineering + T&E
within the Acquisition Cycle

A	B (Program Initiation)	C	IOC	FOC
Concept & Technology Development	**System Development & Demonstration**	**Production & Deployment**	**Operations & Support**	

| Concept Exploration | Technology Development | Critical Design Review | LRIP/OT&E | FRP Decision Review |

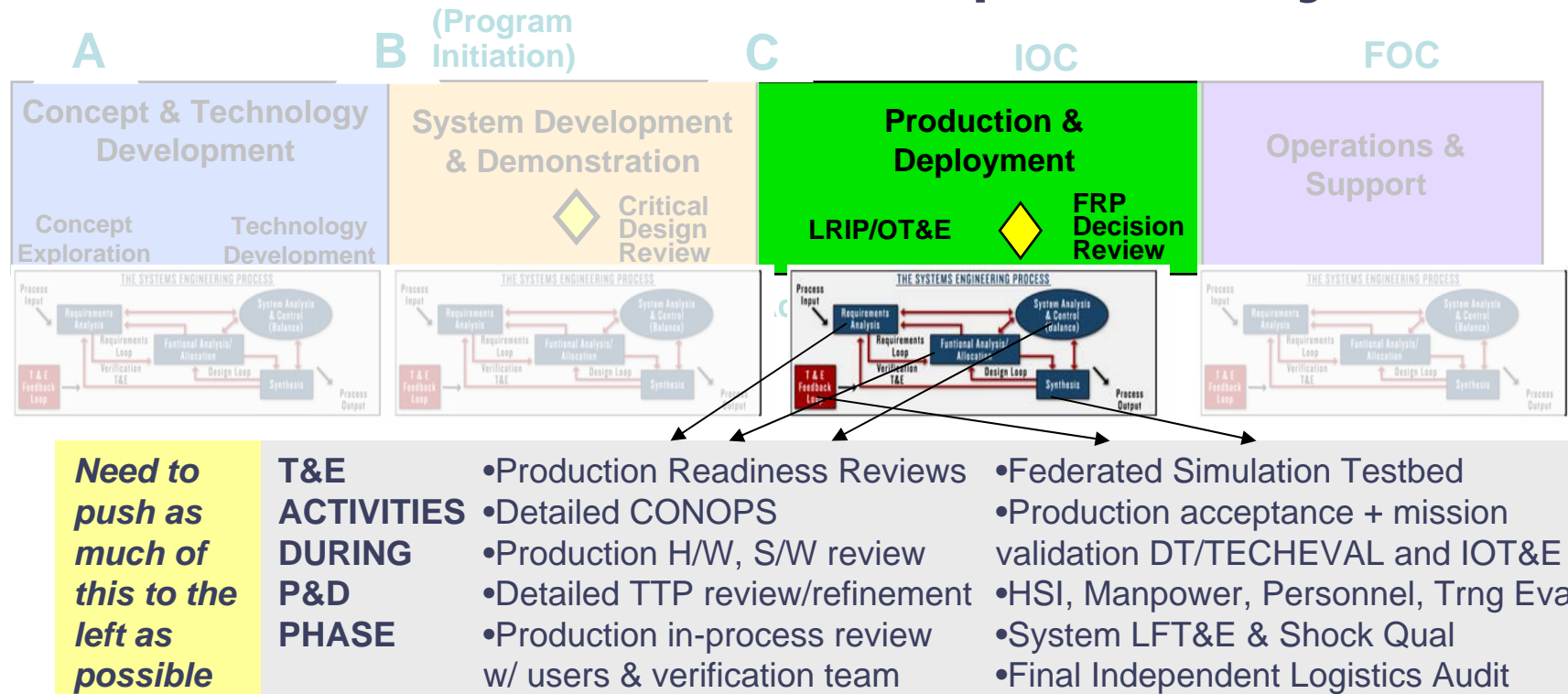|	T&E	•Requirements testability review	•Technology Feasibility	*Testers & engineers not involved enough in this phase*
	ACTIVITIES	•Concept studies and analysis	•EDM DT	
	DURING	•CONOPS development	•Design Reviews	
	C&TD	•Mission/Functional analysis	•EOA	
	PHASE	•Joint Experimentation/ACTD/ATD	•M&S	

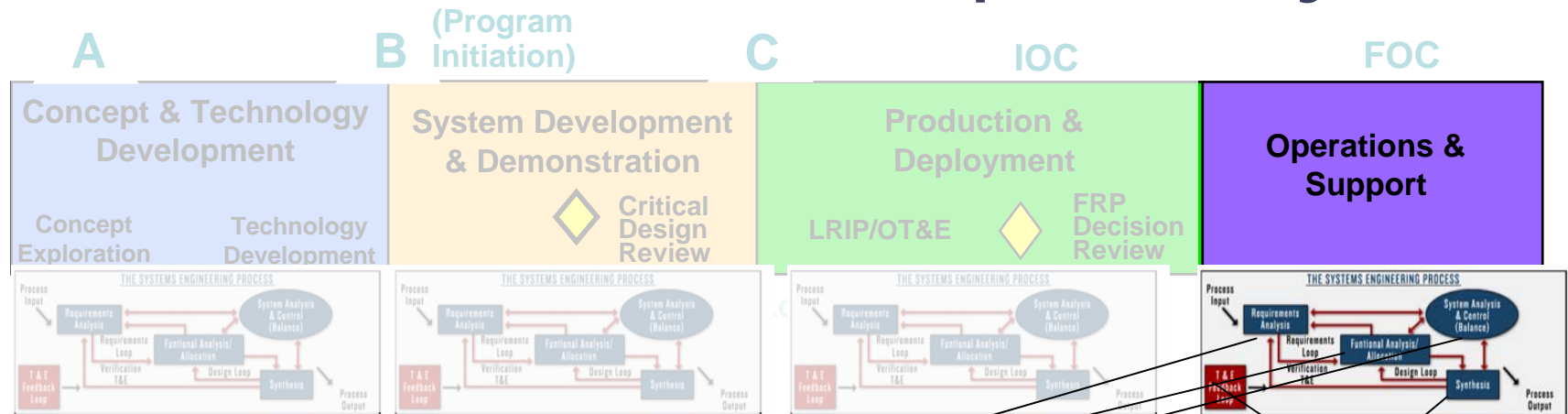**RISK MANAGEMENT…**   **MISSION CAPABILITY DELIVERY…**

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Concept Exploration Technology Development	◆ Critical Design Review	LRIP/OT&E ◇ FRP Decision Review		

T&E ACTIVITIES DURING SDD PHASE

- Detailed Design Rvw
- Design OA
- Detailed CONOPS
- User reviews
- TTP development
- Trade studies

- Lab/Land Based Testing & M&S
- Limited field/at-sea testing & usability testing
- Testbed/surrogate LFT&E
- Supportability analysis/ initial logistics audit
- RAM analysis & testing (reliability growth)
- Certification process

Inadequate linkage to C&TD mission and reqs analyses

RISK MANAGEMENT…   **MISSION CAPABILITY DELIVERY…**

INTEGRATED T&E & SYSTEMS ENGINEERING

Ability to influence system design
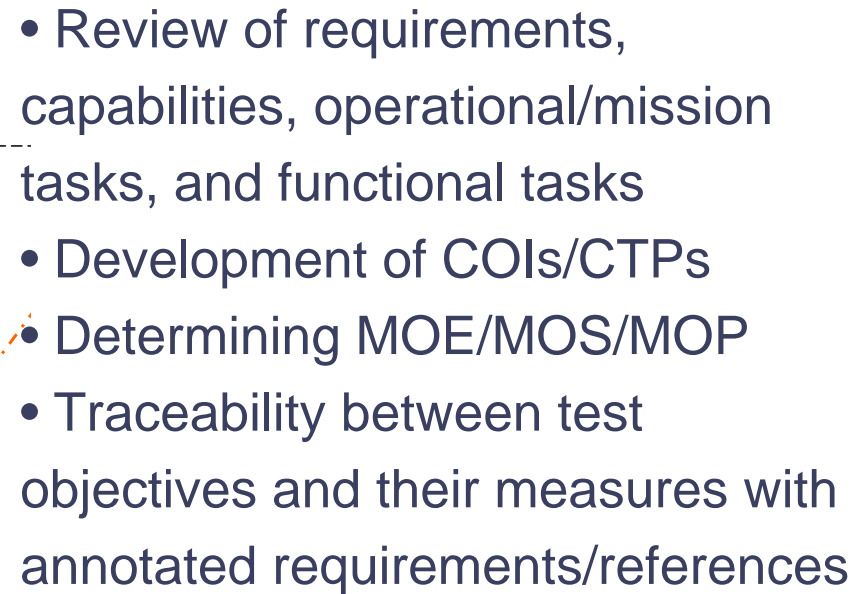
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Concept & Technology Development	System Development & Demonstration	Production & Deployment	Operations & Support
Concept Exploration Technology Development	◇ Critical Design Review	LRIP/OT&E ◇ FRP Decision Review	

Need to push as much of this to the left as possible

T&E ACTIVITIES DURING P&D PHASE

- Production Readiness Reviews
- Detailed CONOPS
- Production H/W, S/W review
- Detailed TTP review/refinement
- Production in-process review w/ users & verification team

- Federated Simulation Testbed
- Production acceptance + mission validation DT/TECHEVAL and IOT&E
- HSI, Manpower, Personnel, Trng Eval
- System LFT&E & Shock Qual
- Final Independent Logistics Audit

RISK MANAGEMENT…   MISSION CAPABILITY DELIVERY…

INTEGRATED T&E & SYSTEMS ENGINEERING

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Systems Engineering + T&E
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Concept & Technology Development	System Development & Demonstration	Production & Deployment	Operations & Support

Concept Exploration | Technology Development

Critical Design Review

LRIP/OT&E | FRP Decision Review

Upgrades/ increments need better tie to req capability & tech maturity

T&E ACTIVITIES DURING O&S PHASE

- TTP refinement
- Software/System problem characterization & tracking
- Upgrade/ P3I / spiral development requirements analysis

- Testing software upgrades
- M&S/DT/FOT&E for system fixes / upgrades / new increments
- RAM & supportability data collection
- Additional LFT&E/shock qual

RISK MANAGEMENT…   MISSION CAPABILITY DELIVERY…

INTEGRATED T&E & SYSTEMS ENGINEERING

Ability to influence system design

System maturity & design/ upgrade cost

Enablers to implement
in IT&E for risk-management

- Actually implementing a process for IT&E with adequate buy-in is the first step
- Use software tools to step through planning and reporting processes and document IT&E
- Implement risk based test planning and reporting
- Other recommendations to follow…

AVW IT&E Database Toolset Architecture

AVW TECHNOLOGIES

Test Objective Mapping, Test Event Planning, Resource Planning, Event Tracking

Progammatic & Design Issues Tracking & Risk Categorization

Test Event Lessons Learned

- MNS
- ORD/CDD
- EVAL Strategy
- M&S Strategy
- Requirement
- TEMP
- Page/para
- KPPs
- EEAs

- Test Phase (OT-A)
- Test Phase (OT-B)
- Test Phase (OT-C)
- Test Phase (OT-D)

- Test Event
- Test Event
- Test Event
- Reports

- Test Report
- Lessons Learned

- MOE
- MOP
- Objective
- Threshold

- Lessons Learned Report
  - Discussion
  - Observation
  - Recommended Action
  - Program/TEIN
  - Lesson Title
  - Lesson Learned

- Category
  - Policy
  - Test Procedure
  - Doctrine
  - Training
  - Resources
  - Organization
  - Technique
  - Other

- Name
- Phone
- Organization
- E-mail
- Rank

Issue
- Working Group
- Affected COI
- Reference(s)
- Test Event
- Issue Title
- Technical Ref
- Description
- Affected System(s)
- Priority
- Date Opened
- Risk Level
- Last Updated
- Resolution
- Issue POC
  - Name
  - E-mail
  - Command
  - Phone
- Action Due Date
- Action Date
- Action POC
  - Name
  - E-mail
  - Organization
  - Phone
- Status
  - Open
  - Closed
    - Date Closed
    - Closed by
    - Justification

Welcome to the AVW Database Utility
Where would you like to go?

Requirements | Issues | Lessons Learned
Search | Reports | Checklists

~ You are currently attached to the DD(X) db ~

AVW

AVW IT&E Database Capabilities

- Review of requirements, capabilities, operational/mission tasks, and functional tasks
- Development of COIs/CTPs
- Determining MOE/MOS/MOP
- Traceability between test objectives and their measures with annotated requirements/references

AVW IT&E Database Capabilities

- Identification of conditions for development of test matrices in a logical experimental design
- Identification of discrete data elements and requirements for a given test objective linked to various test events/scenarios
- Resource and cost estimation to support TEMP, budget programming, test planning, and other efforts including ties for each resource to test objectives.

AVW IT&E Database Capabilities

- Rapid test reporting
- Lessons learned tracking in standard Joint/Service Lessons Learned formats
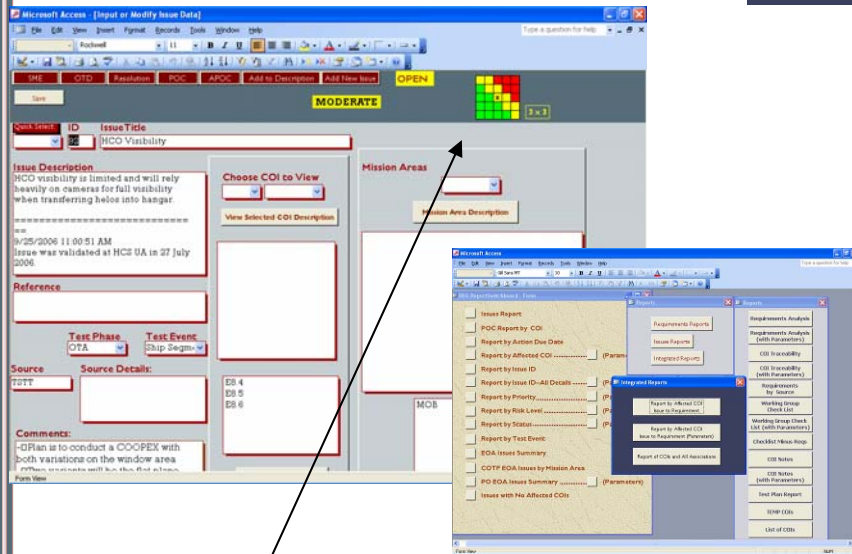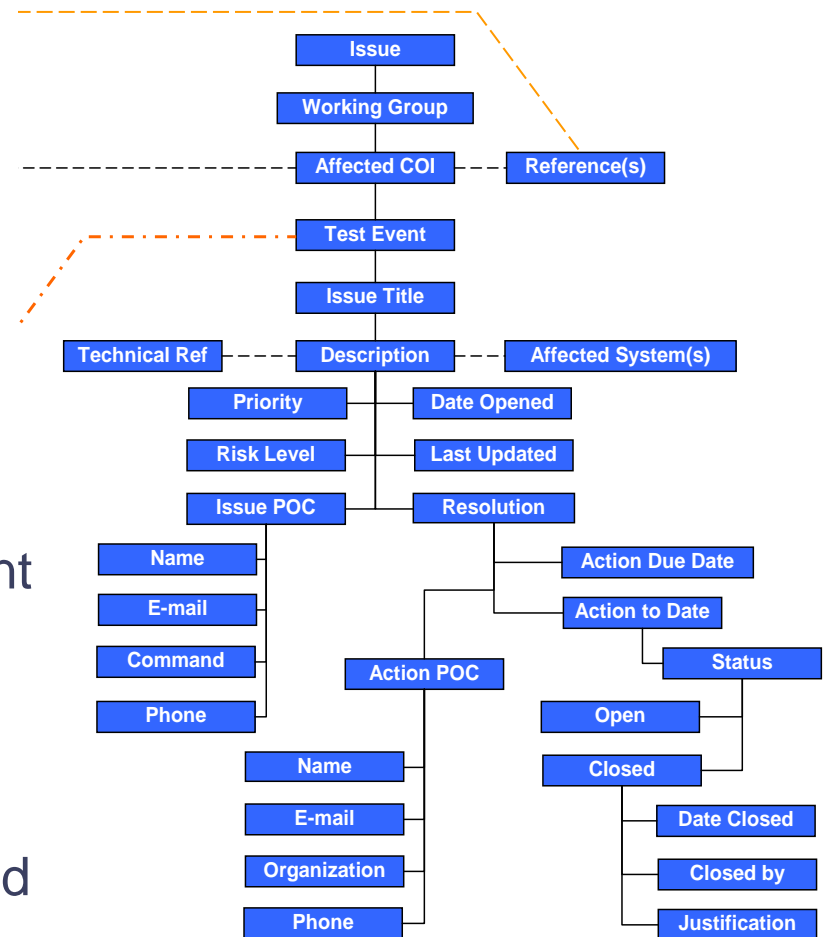- Long term archiving of test results and program status

AVW IT&E Database Capabilities

- Traceability of test results to test event to objectives to parent requirements
- Risk based issue assessment
- Rapid reporting of issues
- Long term archiving of test results and program status
- User tailored reports to assess risks by function, mission area, system, req., etc.

Risk Based
Test *Planning & Resourcing*

Probability of Occurrence	Consequence	5	4	3	2	1
A – Frequently occurs during tests/operations (prob ~ 1.0)		II	II	I	I	I
B – Probably will occur during tests/operations		II	II	II	I	I
C – Occasionally may occur during tests/operations (prob ~ 0.5)		III	II	II	II	I
D – Remote chance to occur during tests/operations		III	III	II	II	II
E – Not likely to occur during tests/operations (prob ~ 0)		III	III	III	II	II

Consequence Levels:
1: prevents accomplishment of primary mission or presents a serious safety hazard
2: sig pri mission degradation w/o a work-around, secondary mission failure, or mod safety hazard
3: major secondary mission degradation w/o work-around; pri mission degradation w/ work-around
4: minor degradation/impact to primary and secondary missions
5: no impact to mission but operator annoyance or recommended enhancement

Risk Levels:
I: High Risk – The spec/req/capability req significant CT, some independent DT and OT; highest pri for resource allocation; more test runs/ conditions permutations than other tests; most scrutiny required before integrating tests
II: Moderate Risk – Requires some dedicated DT and OT; medium resource priority; less scrutiny before integrated tests completely
III: Low/Manageable Risk – Little to no independence between CT, DT, OT, and LFT&E req; strong candidate for fully leveraging a small set of integrated tests for all data; lowest priority for resource allocation.

This supports TEMP test event and resource allocation + detailed test planning; removes much of subjectivity surrounding allocation of scarce testing funding.

Risk Based Test *Reporting*

AVW TECHNOLOGIES

Probability of Occurrence	Consequence	5	4	3	2	1
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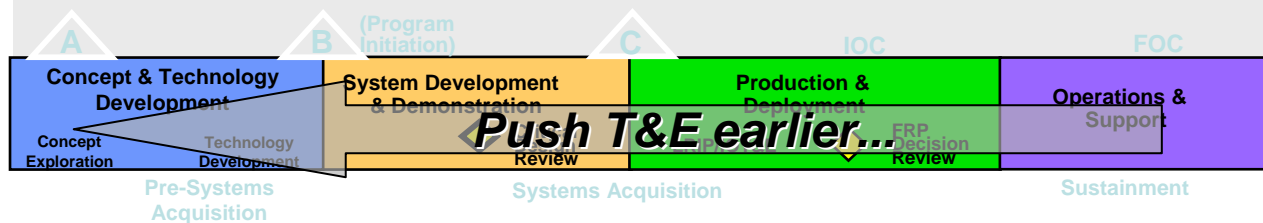5: no impact to mission but operator annoyance or recommended enhancement

Risk Levels:

I: High Risk – resolve prior to fielding & conduct major re-test of mission area prior to fielding with the most resources applied

II: Moderate Risk – resolve prior to fielding and re-test the specific requirement as soon as possible (depending on the requirement, re-test may be allowed to be conducted during follow-on T&E after fielding); apply moderate amount of resources to re-test

III: Low/Manageable Risk – resolve when possible but does not impact fielding; re-test at next available previously planned test event; lowest prioritization for test resources

This could be tied directly to risk register and supports reporting of CT, DT, OT, LFT&E, M&S Runs, or any other analysis or test

Additional Recommendations

- Fully implement IT&E top-down and institutionalize with PEO/PM orgs
- closer align T&E Strategy/TEMP, Systems Engineering Management Plan, and Acquisition Strategy
- Maximize test data and usage of that data across test programs and fully align results to the program's risk registry
- Conduct assessment and testing as early as possible and with all organizations to support risk mitigation
- More test objective to requirements traceability in the TEMP
- Service T&E reorganize to Enterprise business model to drive IT&E plus alignment with JT&E, DOT&E

A   B (Program Initiation)   C   IOC   FOC

| Concept & Technology Development | System Development & Demonstration | Production & Deployment | Operations & Support |

Concept Exploration   Technology Development

Push T&E earlier...

Review   FRP Decision Review

Pre-Systems Acquisition   Systems Acquisition   Sustainment

Additional Recommendations (cont')

- Implement more systems engineering rigor across T&E
- Collect metrics on early risk mitigation efforts of T&E
- Develop and field in consolidated baselines to reduce testing, integrate across programs not just within
- Stress to threats and operating environments early and often
- Change T&E score-card to a risk assessment vs. capabilities; continuous feedback throughout tests; foster more cooperation including leveraging JT&E, Experimentation, Training Exercises
- Increase PM focus on life cycle, HSI, other factors beyond technical mission performance
- Coordinate use of standard statistical methodology for T&E including DOE, Lean 6 Sigma, etc.

(See paper from 2005 conference for discussion)
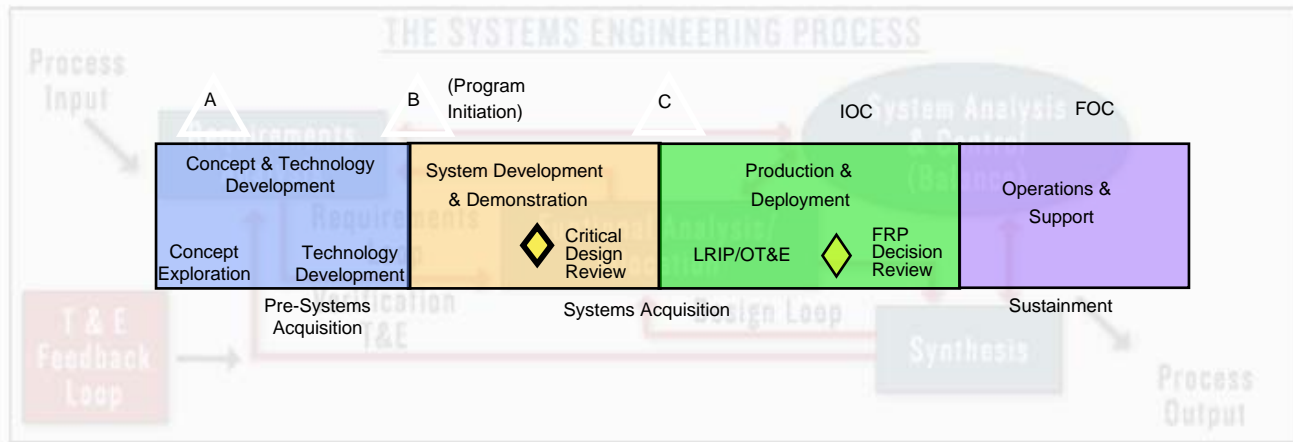
Backups

Author Bio

- **Former Naval office**
  - Active Duty: Surface Warfare Officer
    - Tomahawk, Aegis warfare experience + HM&E
    - COMOPTEVFOR Operational Test Director for land attack warfare systems
  - Reserve: OIC of Navy Reserve Embarked Security Det
- **Current AVW experience**
  - LPD-17 air defense (P_{RA}) M&S management
  - Amphibious ship combat systems T&E
  - Joint Maritime Assault Connector JCIDS analysis
  - Current project: DD(X) OT&E support focusing on IOT&E planning, OA execution, M&S, and total ship test management

~6 years acquisition experience focusing on T&E and systems engineering

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Company Profile

Professional Engineering Services
ORD, ICD, CDD, TEMP, Systems Engineering, Systems Integration, M&S Management

Test and Evaluation Support
TEMP, DT/OT, Test Management, Test Plans, Execution, Data Collection, Analysis

Shipbuilder Engineering Management Consulting
Systems Engineering, Systems Integration, M&S Management

Contract Vehicles:
Obtained GSA PES schedule CY04
NAVSEA MAC member thru JJMA and CSC
NAVSEA Seaport

Corporate Highlights:
Total Ship / System of Systems Focus
Expeditionary Warfare Expertise
Mission Focused Systems Engineering and Analysis
Matrix support leverage full corporate capabilities
35 military analysts and IT/admin support
Small veteran owned business since 2002
Headquarters in Chesapeake, VA

INNOVATIVE SOLUTIONS TO THE CHALLENGES OF THE FUTURE