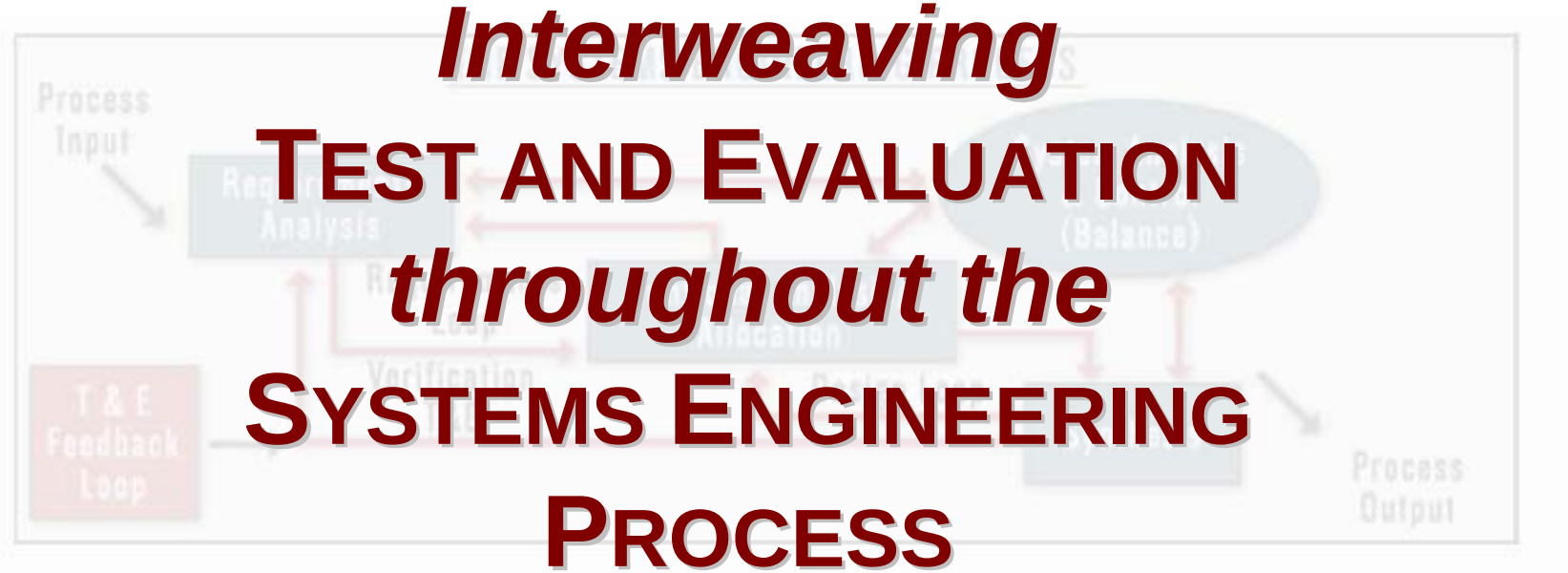
8th Annual NDIA Systems Engineering Conference
October 24-27, 2005, San Diego, CA

Track 3: Involving Test & Evaluation in Systems Engineering

Interweaving TEST AND EVALUATION *throughout the* SYSTEMS ENGINEERING PROCESS



Josh Tribble
MILITARY ANALYST, AVW TECHNOLOGIES

Phone: 757-361-9587
E-mail: tribble@avwtech.com
860 Greenbrier Circle, Suite 305
Chesapeake, VA 23320
http://www.avwtech.com

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

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Agenda

- Corporate and personal background
- The problem-- state of systems acquisition
  - Impact of JCIDS, systems complexity, acquisition reform, push for integrated T&E, and the impact of PPBE and CAIV
- Integrated T&E within systems engineering tasks
  - T&E activities and support for and from each of the tasks in the engineering process
- Integrated T&E interwoven throughout the acquisition life cycle
  - T&E activities in context of major acquisition milestones and impact on systems engineering
- Conclusion & recommendations
- Q&A

AVW TECHNOLOGIES

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
30 military analysts and IT/admin support
Small veteran owned business since 2002
Headquartered in Chesapeake, VA

Author Bio

- Former active duty Naval Officer
  - Surface Warfare qualified /ship driver
  - Tomahawk, AEGIS combat system, Anti-submarine warfare, gas turbine engineering management
  - COMOPTEVFOR Operational Test Director, Level II DAWIA Cert in T&E
  - USNA '96, BS Aerospace Engineering
- Serving in Navy Reserve as officer in charge of embarked security detachment
- AVW experience
  - LPD-17 air defense (P_{RA}) M&S management.
  - Amphibious ship combat systems T&E
  - Sea Base-to-Shore connector JCIDS assessment & ICD development
  - OT&E management (EOA, IOT&E planning, M&S and total ship test management) for DD(X) + CVN, LHA-6, LPD 17
  - 5+ years T&E management supporting/involved in OT&E, DT/CT, Program Management/Systems Analysis, LFT&E

Josh Tribble
Military Analyst
Phone: 757-361-9587
E-mail: tribble@avwtech.com
860 Greenbrier Circle, Suite 305
Chesapeake, VA 23320
http://www.avwtech.com

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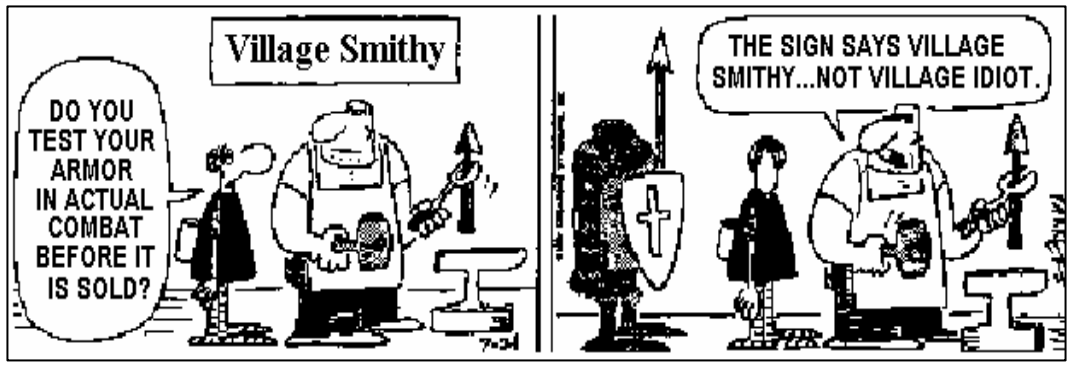
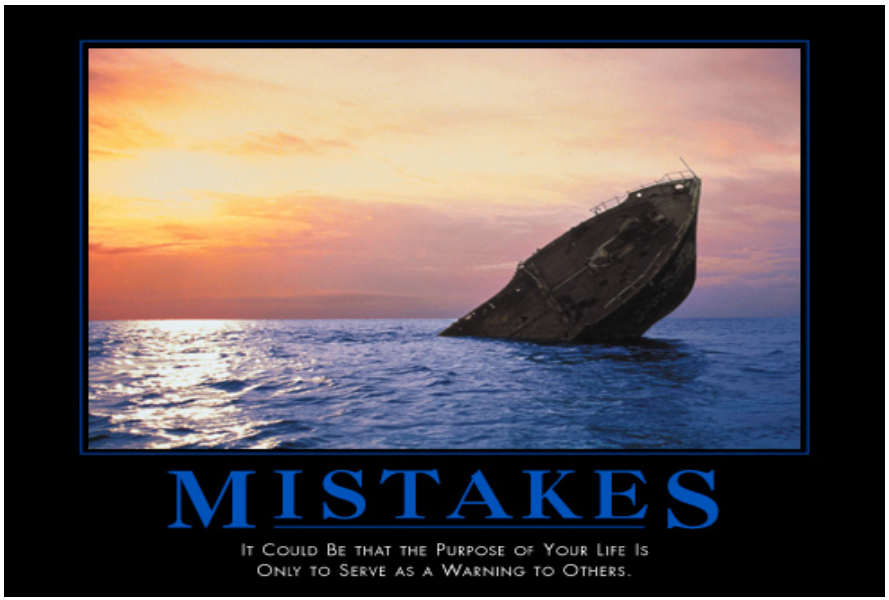
Acquisition Culture?





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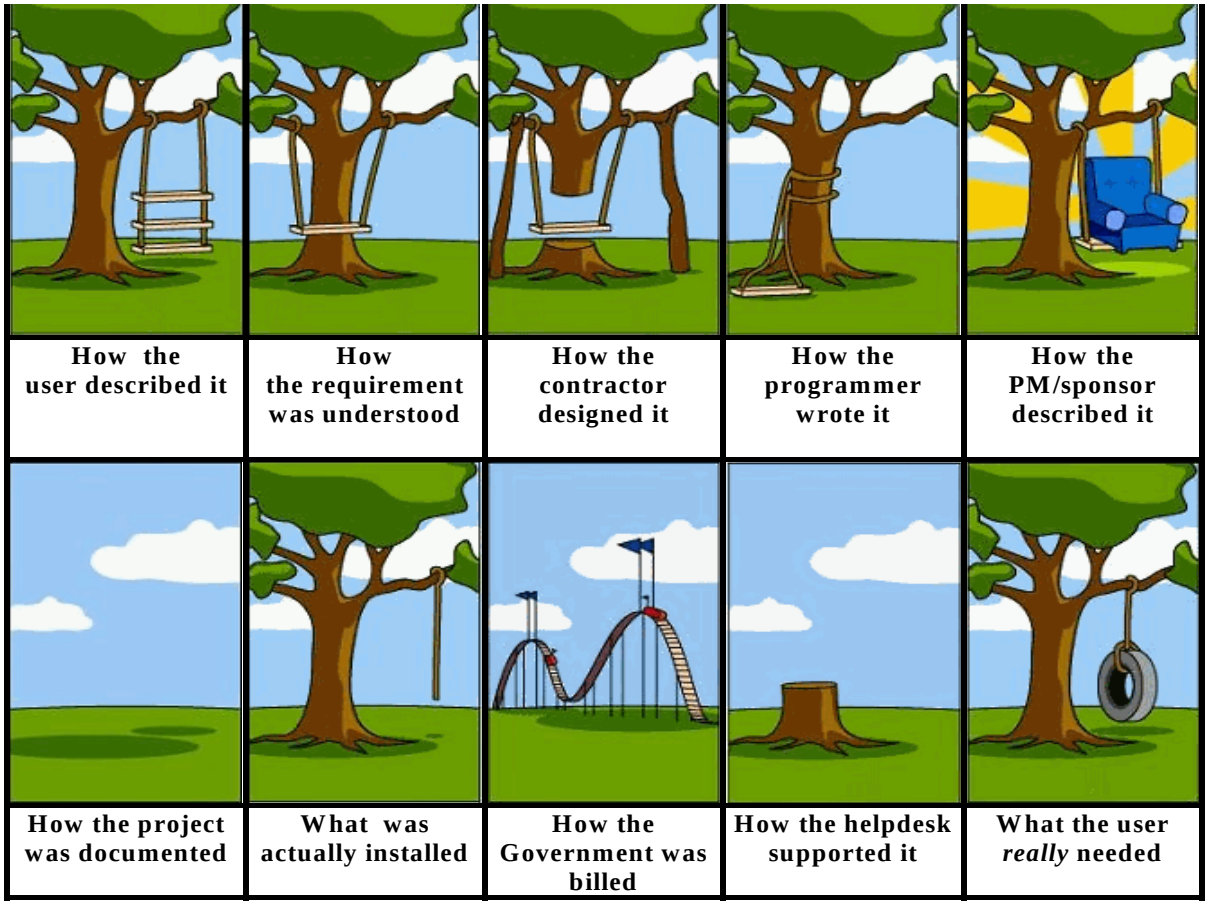
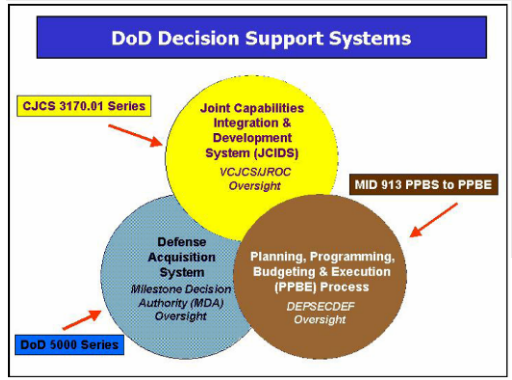
The Problem—State of Systems Acquisition

Acquisition Conundrum



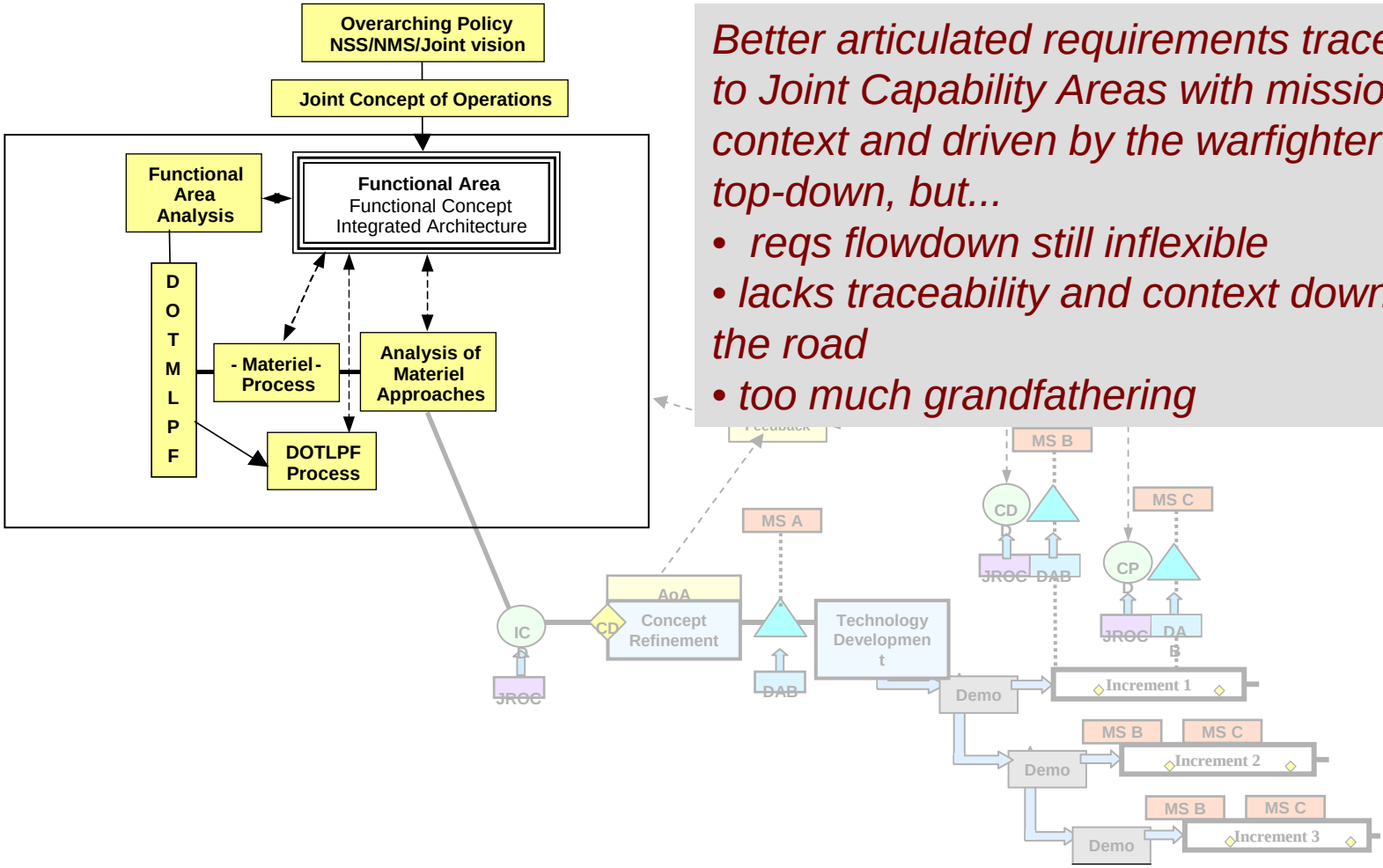
Although a humorous exaggeration –

How can T&E & systems engineering help fix this in a Joint, FoS/SoS, CAIV environment?



We must transform to deliver the right product, that is on time, that works, and that is affordable and sustainable

JCIDS Capabilities and Requirements input to the Acquisition Process



Better articulated requirements traced to Joint Capability Areas with mission context and driven by the warfighter top-down, but...

- *reqs flowdown still inflexible*
- *lacks traceability and context down the road*
- *too much grandfathering*

Requirements **Acquisition**

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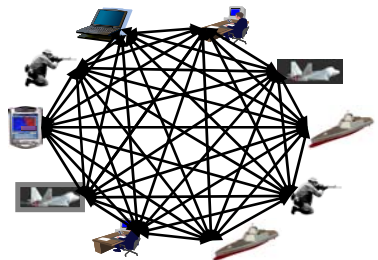
Complexity Challenge

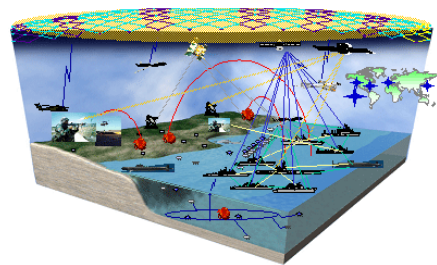
?

INCREASING RISK

- Open Architecture/Systems
- Complex C4I—FORCEnet/GiG
- Joint Interoperability
- Emerging Technology & Materials

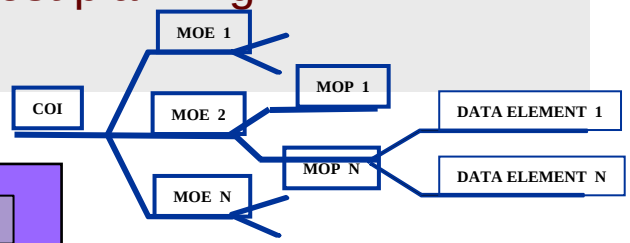
- More difficult to develop
- More difficult to test
- Compressed timelines
- Compressed budgets
- ***MORE RISK…& HIGHER COSTS***

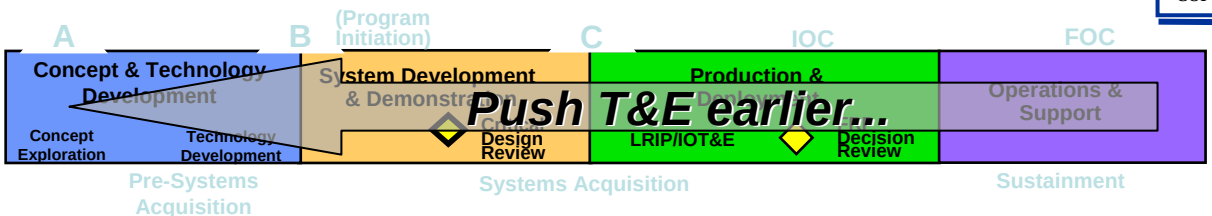




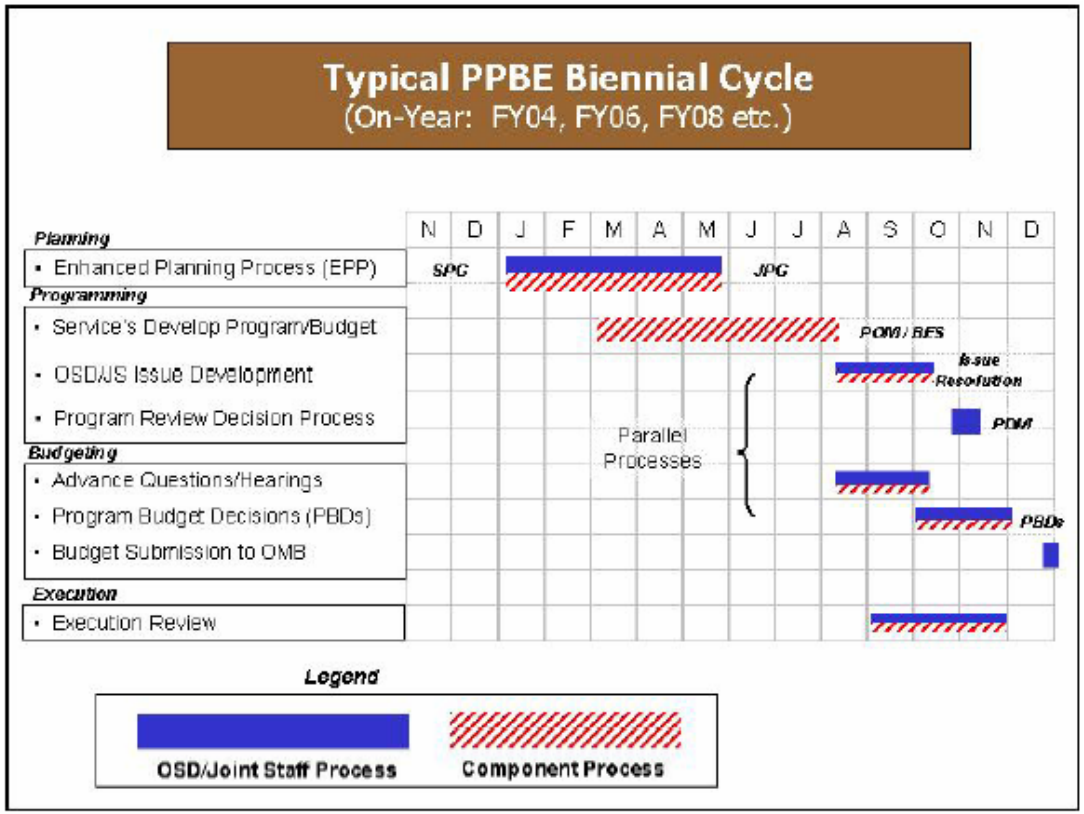
Status of T&E

- **Integrated T&E required by new DoD 5000 series**
- **Need to change focus on program success, delivery of capabilities – not mere oversight & reporting on pass/fail**
- **Push for early tester & engineer involvement during JCIDS**
- **Push T&E to the left in the cycle**
- **Numerous other areas to reduce costs and effectiveness of T&E support for programs:**
  - political and business climate
  - combined use of test resources, M&S, etc.
  - advanced analytical methods including design of experiments
  - proper understanding of requirements, context, intent
  - process maturity and improvement (CMMI, Six Sigma, etc.)
  - more systems engineering methodology in test planning
  - testing to support risk management





Harsh Reality of PPBE



- Programs including systems engineering and T&E are driven by CAIV.
- Calendar driven process can conflict with event driven engineering/tests
- Design issues found in systems engineering can be downplayed due to perceived need to shield program from scrutiny during POM cycle
- T&E can be seen as place to rob funding to pay for overruns

T & E Funding vs. RDT&E / Total Program Costs

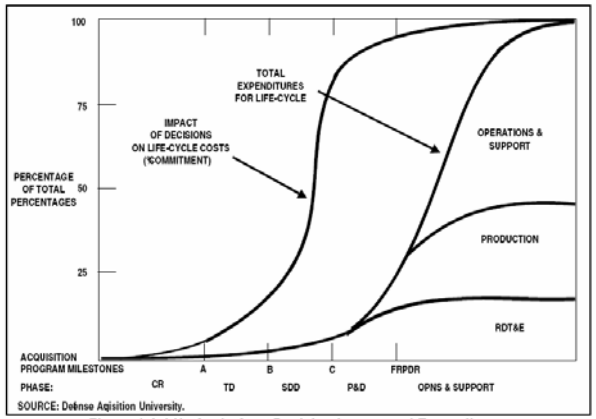
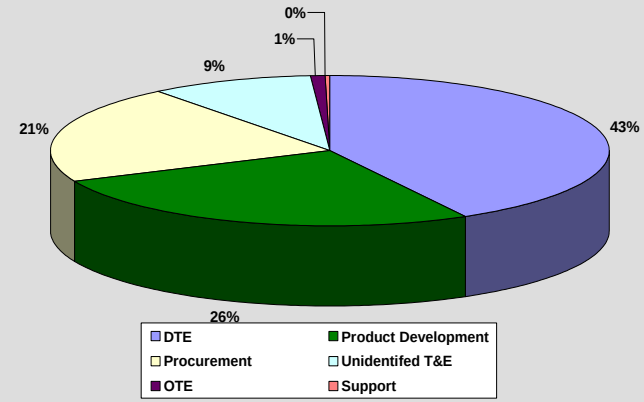
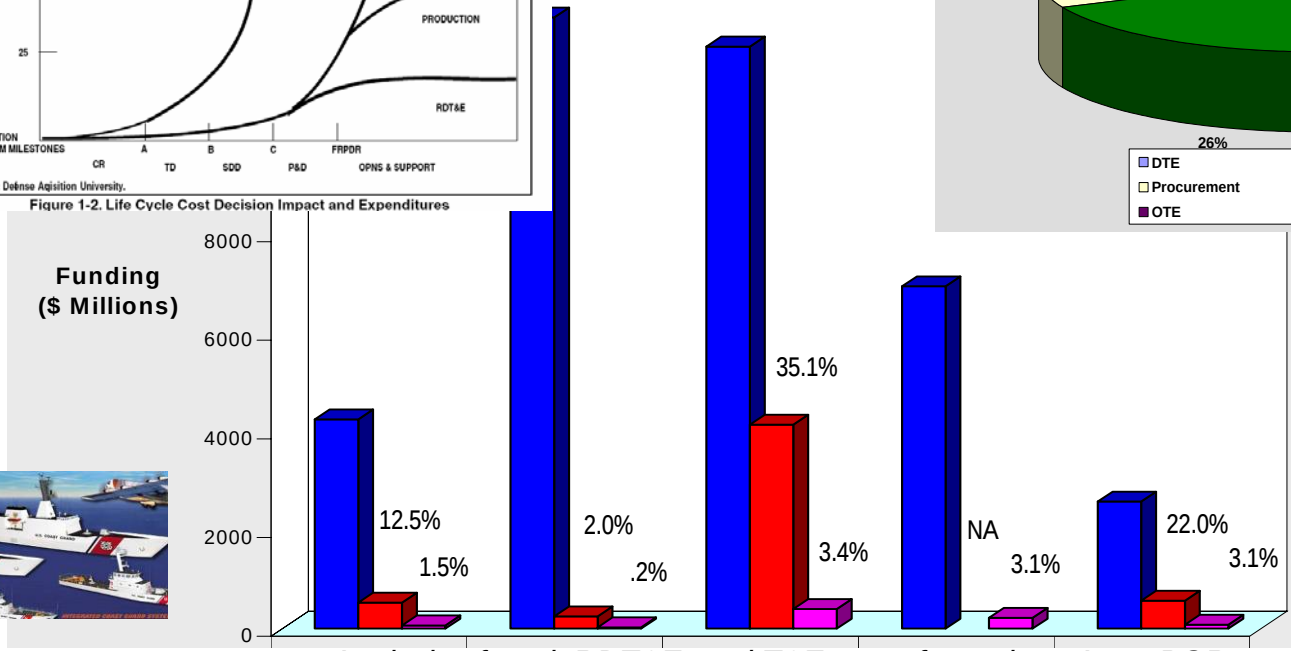


Figure 1-2. Life Cycle Cost Decision Impact and Expenditures

Survey of cost breakdown for 18 major Navy programs





Analysis of total, RDT&E, and T&E costs for various Army PORs

T&E is a *much* smaller fraction of RDT&E than development costs both of which are far overshadowed by life-cycle costs – thus, **T&E reduces program risk while adding little to overall program cost**

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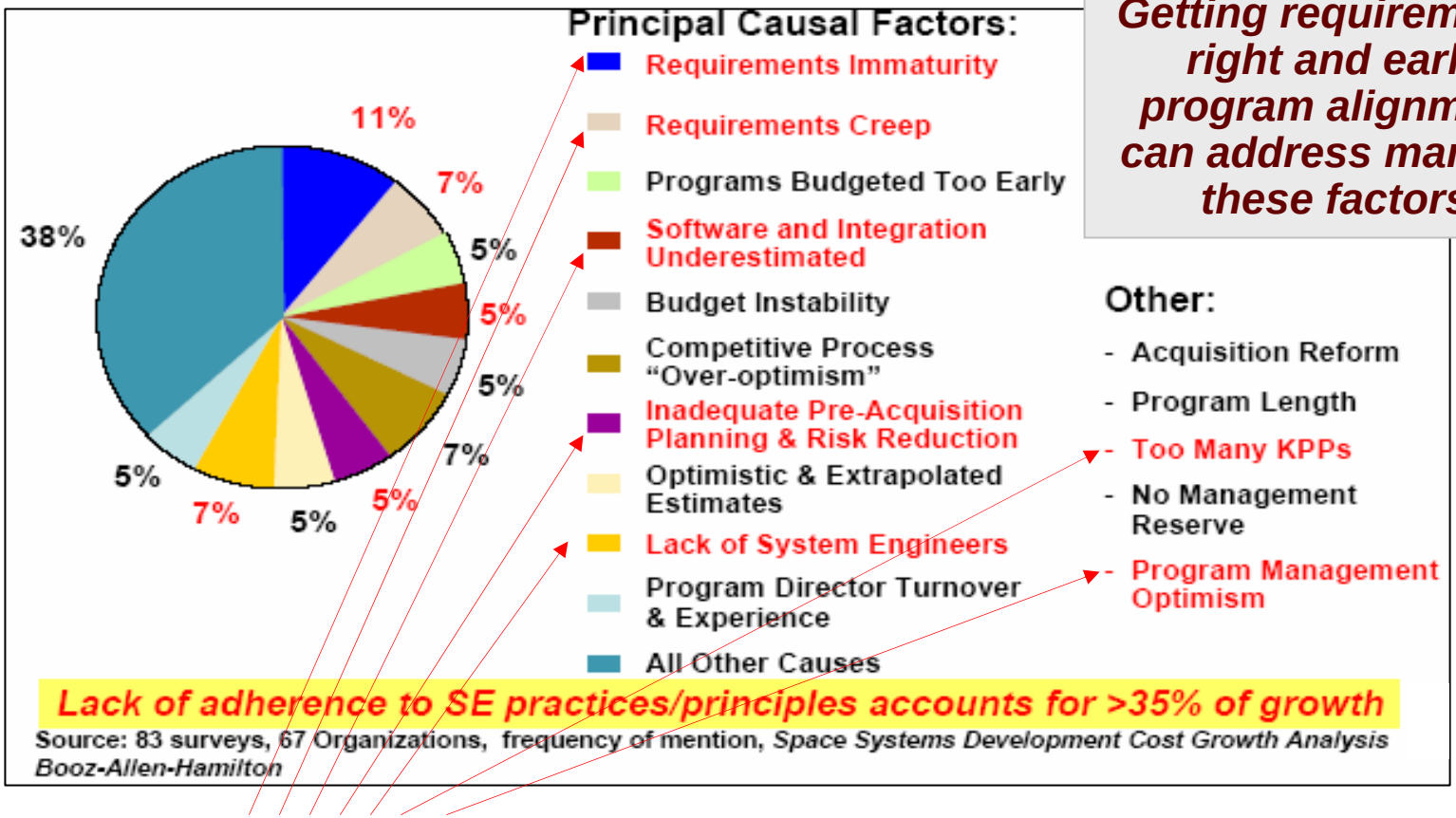
Causes of Development Growth



Getting requirements right and early program alignment can address many of these factors

Testers and systems engineers can influence many of these tasks to reduce risk and total program cost growth

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Integrated T&E Within Systems Engineering Tasks

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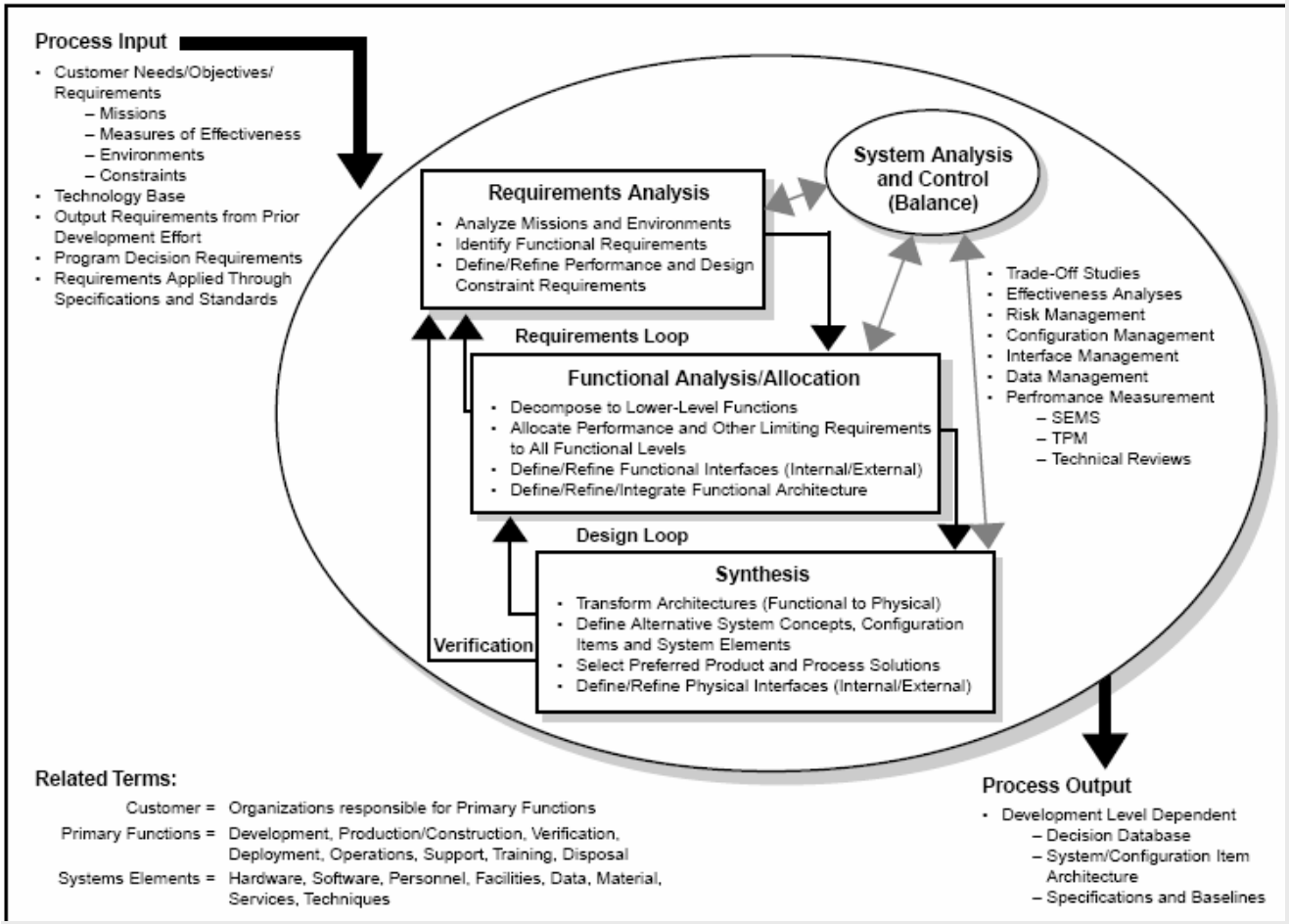
T&E During Sys Eng Tasks



Involves testers, engineers, & managers from PMO, Design Agent, Subcontractors, OTAs, gov't certification agencies, SYSCOM, etc.

- Testers can support each of the tasks, not just validation
- T&E is supported by each process task and by sys engineers

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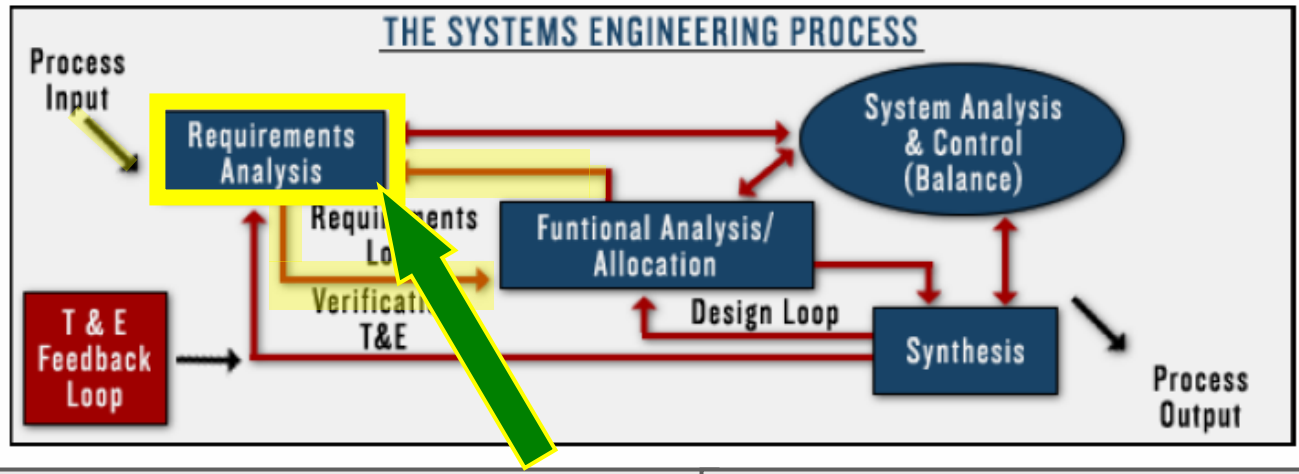
T&E During Sys Eng Tasks (Cont')



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

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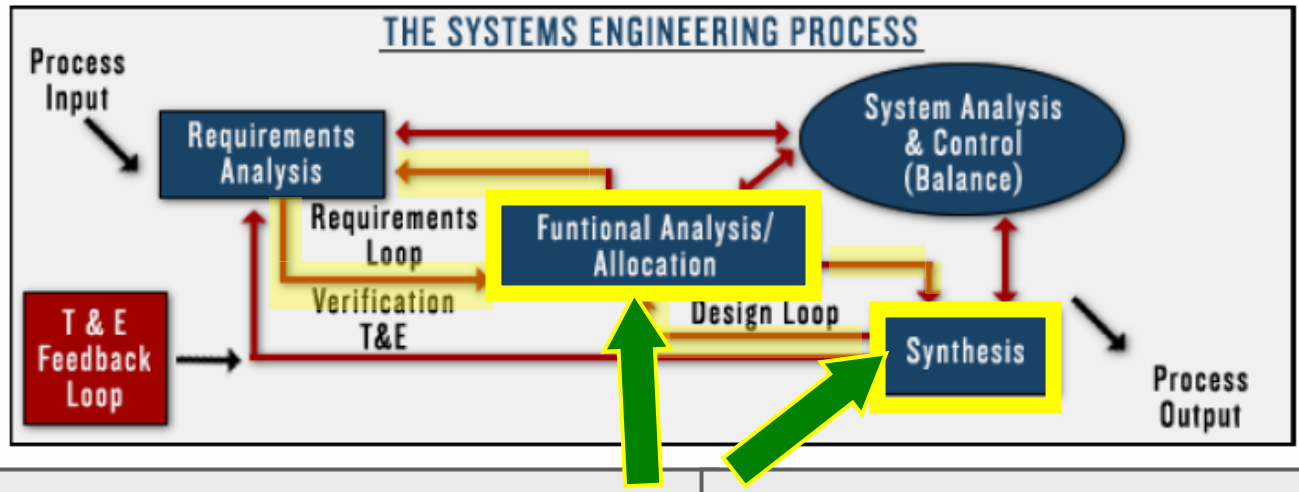
T&E During Sys Eng Tasks (Cont')



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

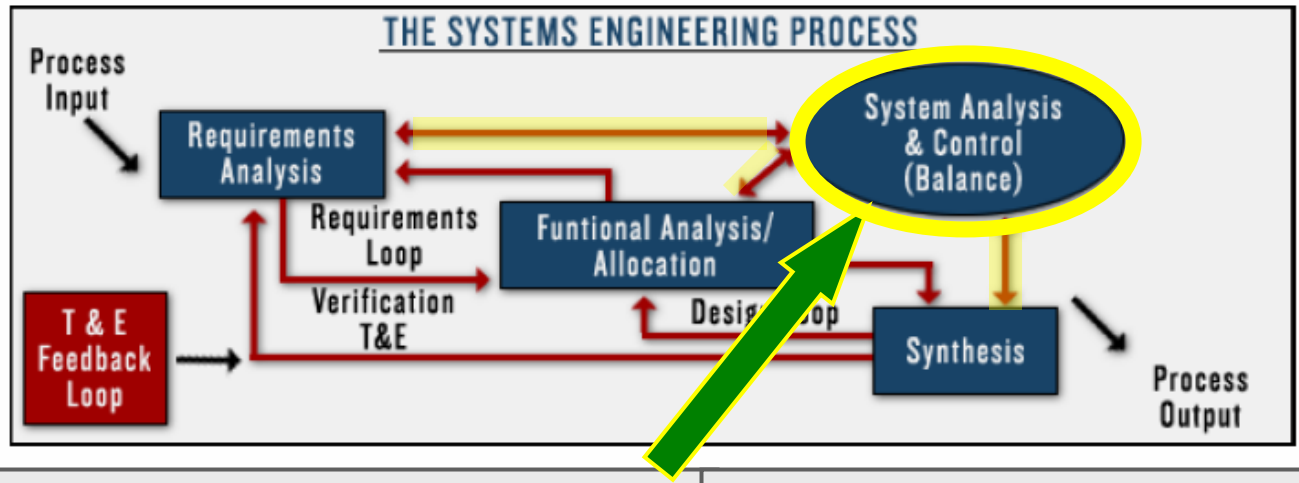
T&E supported by insight (which improves test planning efficiency) into:

- 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

T&E During Sys Eng Tasks (Cont')



Testers support by influencing:

- 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)

T&E is supported by insight into:

- 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

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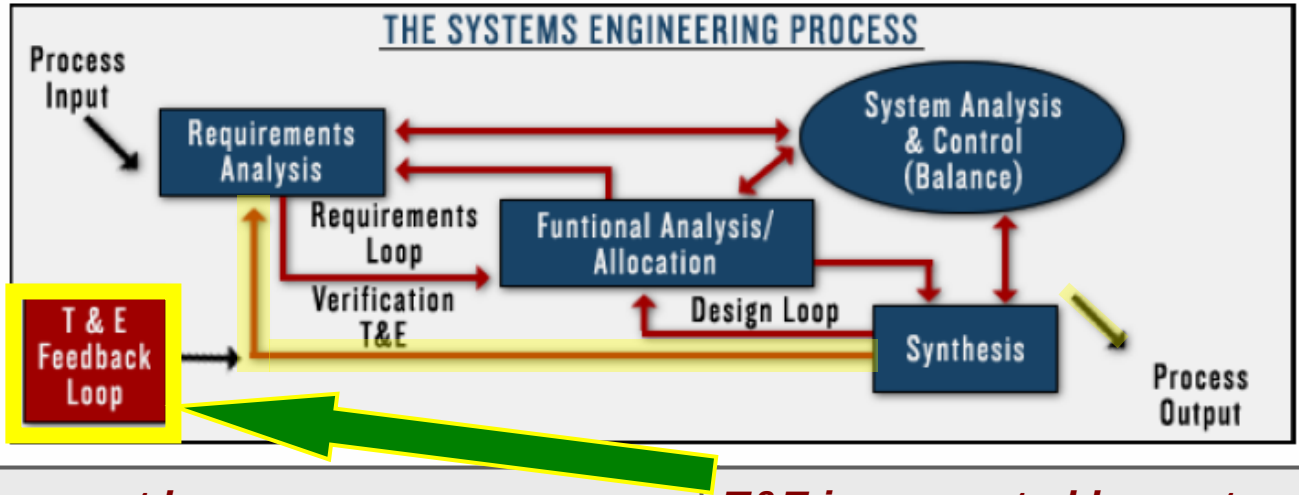
T&E During Sys Eng Tasks (Cont')



Testers support by:

- Planning and executing tests to verify requirements and validate functions and mission capabilities (+ M&S V&V)
- 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

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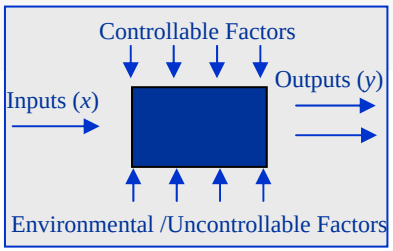
~~DT vs. OT~~ ➡ IT

DT:

- Test to specs.
- Limited test environment often done in laboratory.
- Focused on a specific set of criteria.
- Test threshold values not capability.
- Integration testing designed around minimum performance criteria and interface spec.
- May not address all threats or missions.



OT:

- Operational environment & threat
- Operated by users
- End – to end mission & support
- Production representative; system of systems
- Test overall capability of an item to meet mission needs.
- Test value added for mission accomplishment.
- Test the limitations and capabilities of an item so that:
- Employ and assess doctrine/TTP
- Title X mandated independent IOT&E

THIS MUST TRANSFORM INTO A CONTINUUM OF INTEGRATED TESTING

- **DT can address some OT objectives for risk reduction**
- **OT is much more than IOT&E**
- **Fit in CT, LFT&E, Experimentation, M&S, logistics audits**

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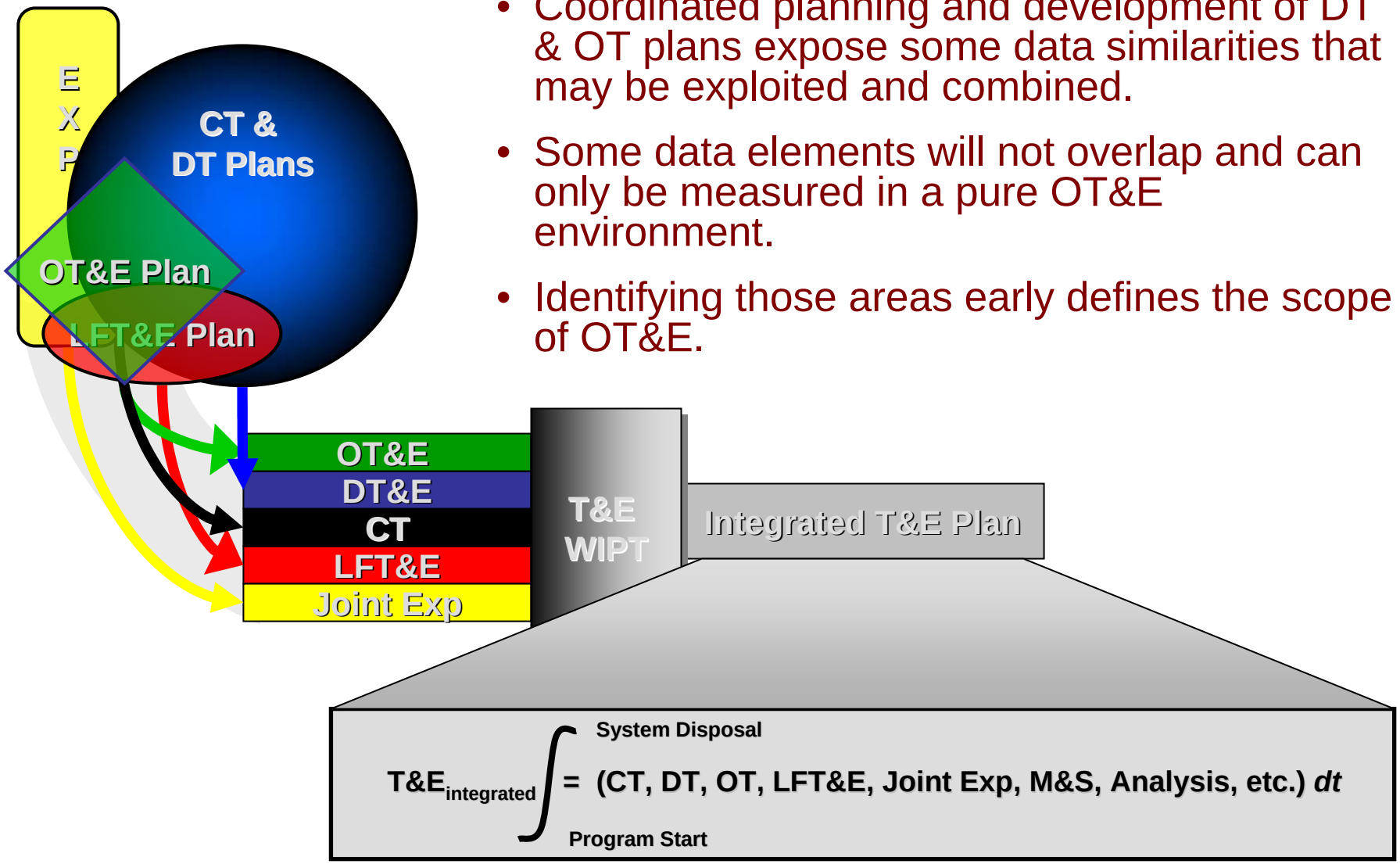
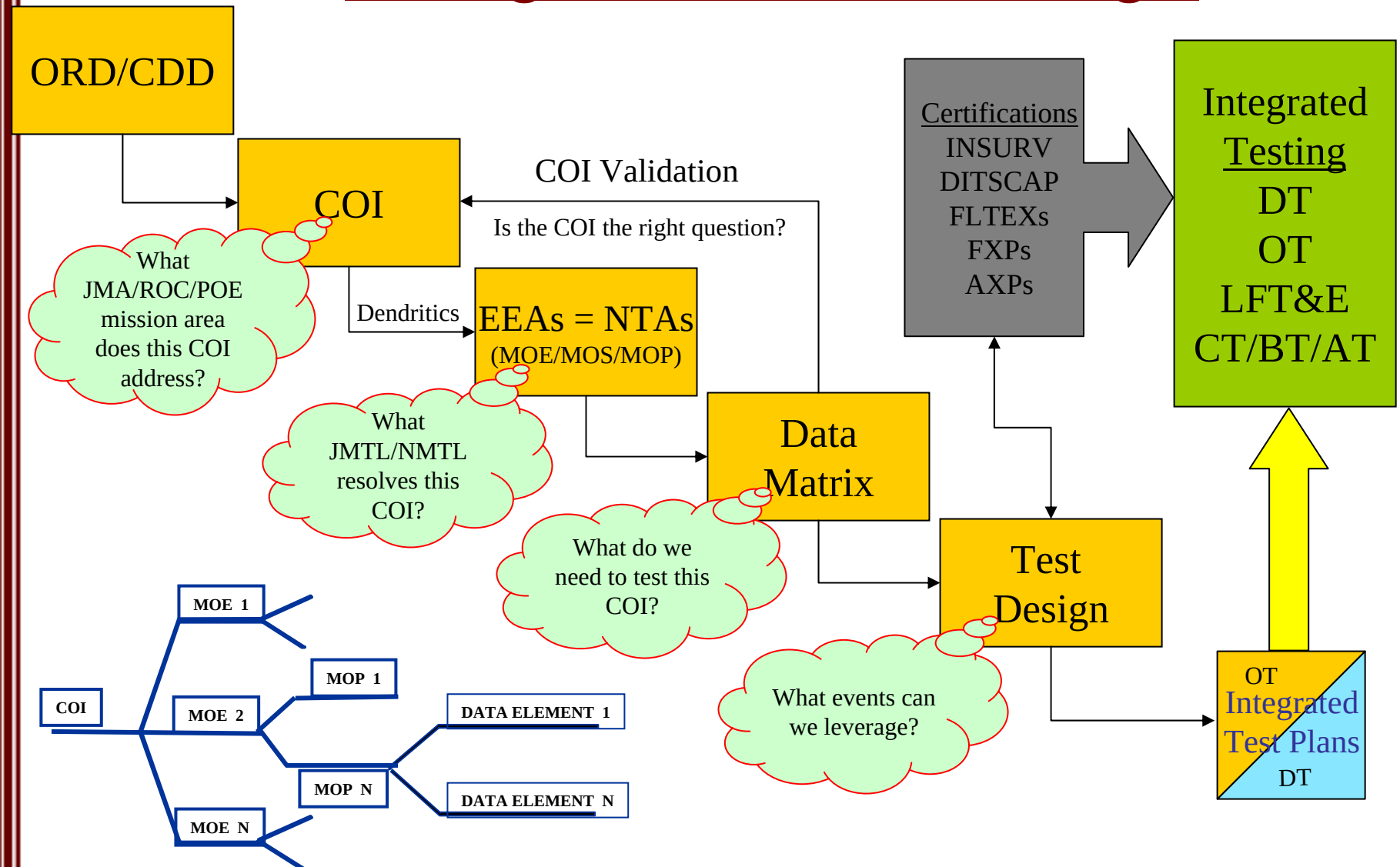
Integrated T&E

- Coordinated planning and development of DT & OT plans expose some data similarities that may be exploited and combined.
- Some data elements will not overlap and can only be measured in a pure OT&E environment.
- Identifying those areas early defines the scope of OT&E.



Total Ship Integrated Test Design



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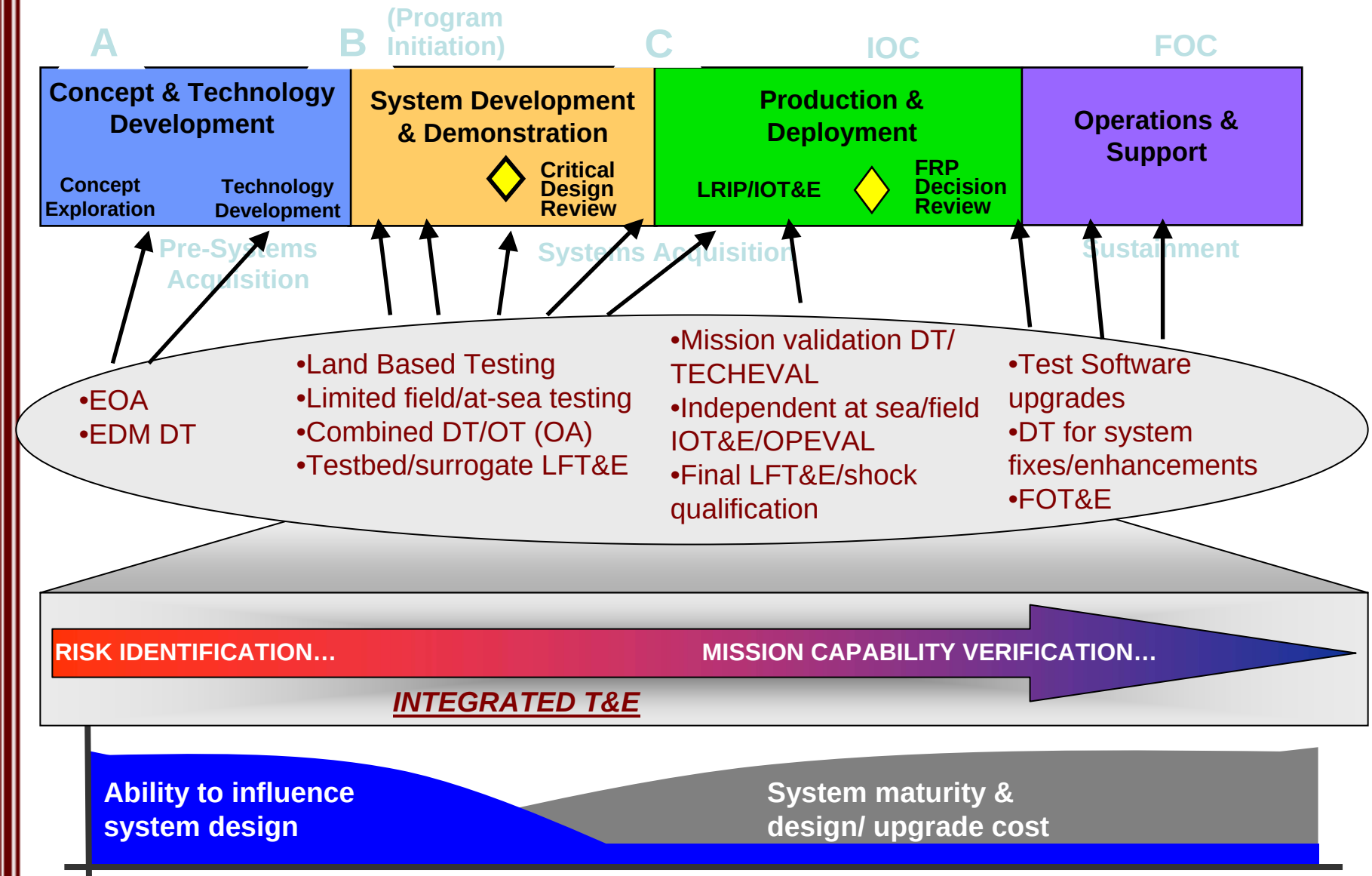
Integrated T&E Interwoven Throughout the Acquisition Life Cycle

T&E within the Acquisition Life Cycle

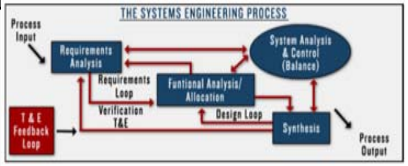
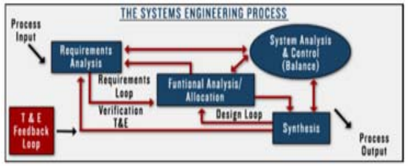
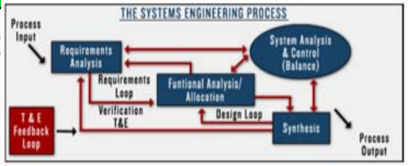
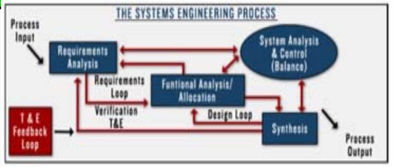


Systems Engineering + T&E
within the Acquisition Cycle

AVW TECHNOLOGIES

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	

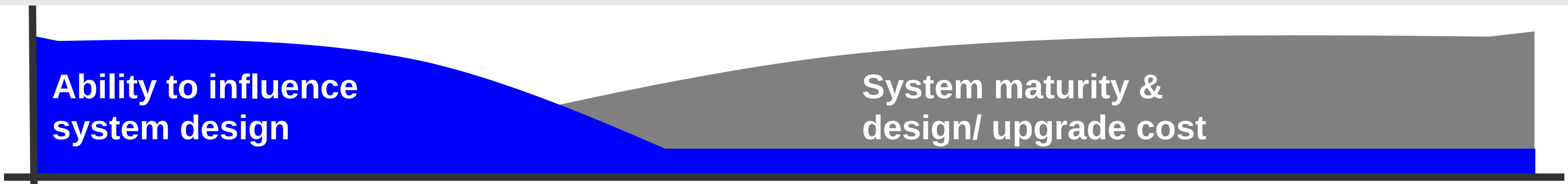





•Requirements te •Concept studies •CONOPS devel •Mission/Functio •Joint Experimentation/	•Technology Feasibility •EDM DT •Design Review •EOA •M&S	•Detailed Desig •Design OA •Detailed CON •User reviews •TTP developm •Trade studies	•Lab/Land Based Te •Limited field/at-sea •Testbed/surrogate L •Supportability 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 •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



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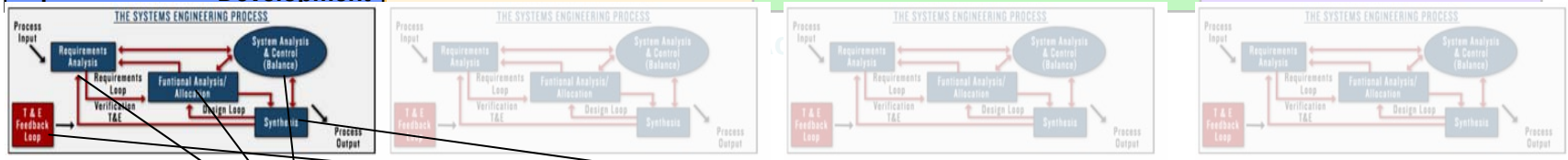
Systems Engineering + T&E
within the Acquisition Cycle

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

RISK MANAGEMENT… MISSION CAPABILITY DELIVERY…

INTEGRATED T&E & SYSTEMS ENGINEERING

Ability to influence system design

System maturity & design/ upgrade cost

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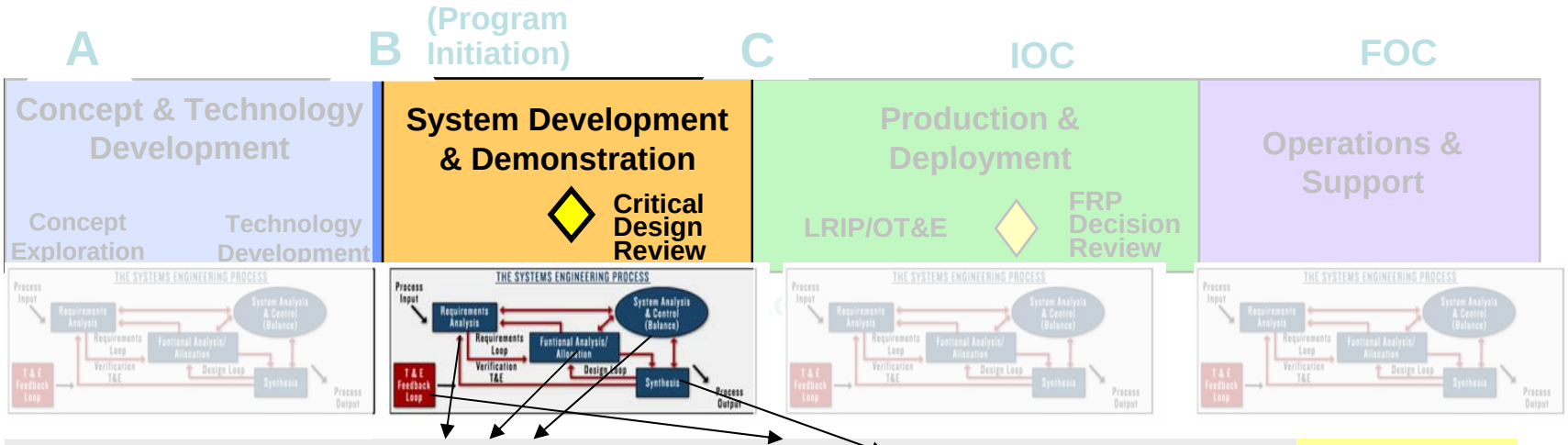
Systems Engineering + T&E within the Acquisition Cycle



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

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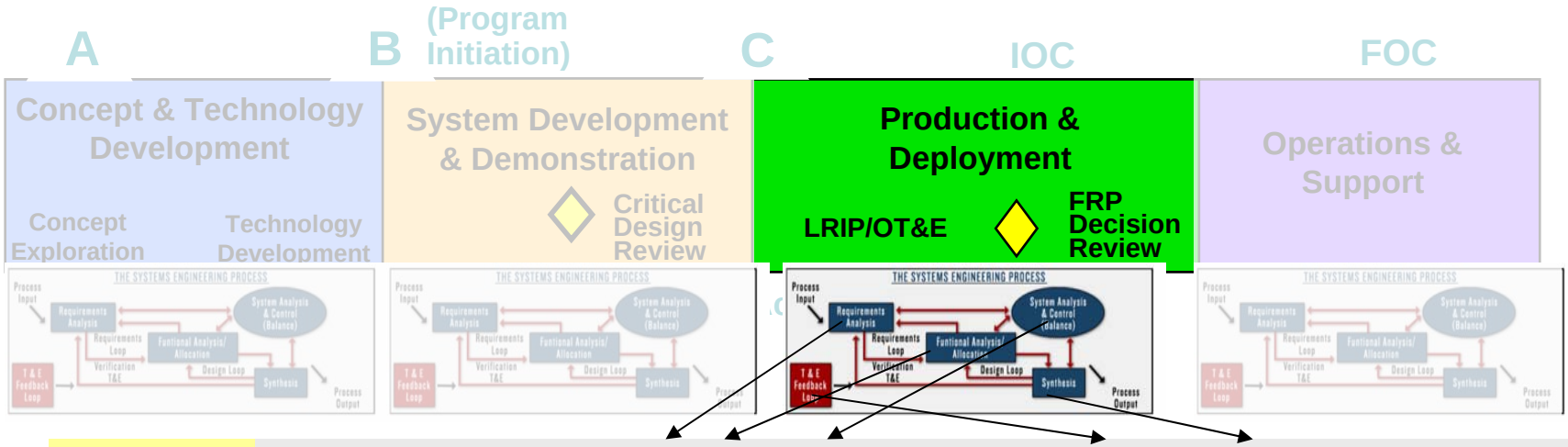
Systems Engineering + T&E
within the Acquisition Cycle



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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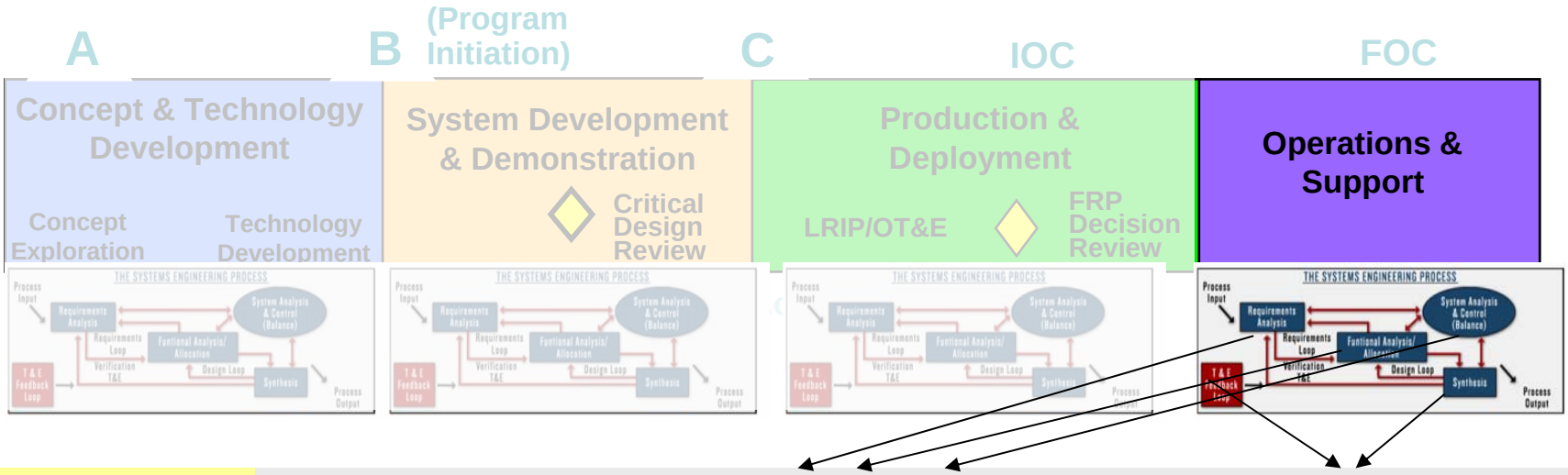
Systems Engineering + T&E
within the Acquisition Cycle



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

Conclusions & Recommendations (cont')

Systems engineering and T&E recommendations:

- *Implement IT&E top down from DOT&E and OSD-SE*
- *Pull testing to the left*
- Align TEMP, Systems Engineering Plan, Acquisition Strategy for Systems Engineering and IT&E and reformat TEMP for IT&E
- Show more clear requirements traceability in TEMP from JCIDS to MOE/MOS to CTP with mission context
- Consolidate service T&E effort under single organization to coordinate T&E among OTA, PEO, SYSCOM
- Do the same for Joint T&E
- Consider 6-Sigma/CMMI process improvement – *and implement recommendations*
- Require 1 EOA before MS B and 1 OA before MS C for ACAT I programs
- Change culture from pass-fail IOT&E to exploration of capes and lims

Conclusions & Recommendations (cont')

Systems engineering and T&E recommendations (cont'):

- Expand education for T&E planning using systems engineering methodology
- Increase priority for T&E in DAWIA courses
- Expand M&S/VV&A education and training
- Encourage use of distributed test tools
- Increase early T&E focus on suitability
- Standardize statistical methodology including Design of Experiments
- Certify organizations for T&E process
- Insert operational and environmental realism as early as possible
- Use risk management in test planning and report results to influence risk management
- *Clearly show IT&E VALUE ADDED to Program Managers*

Conclusions & Recommendations (cont')

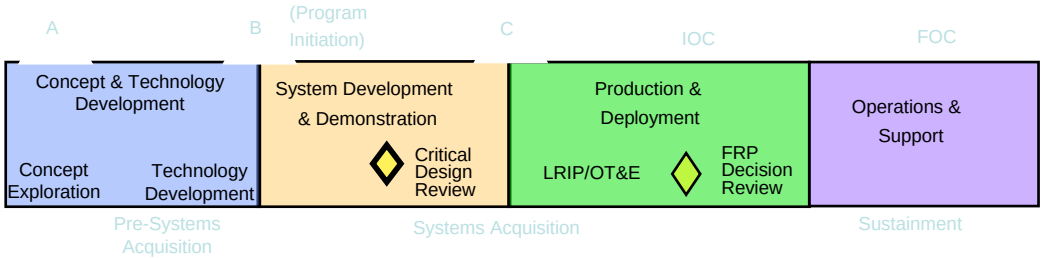
Systems engineering and T&E recommendations (cont'):

- **Most importantly, don't analyze and talk about transformation – *implement it!***

Additional recommendation for future papers...

- *Acquisition reform is happening...*
- *We've discussed transforming T&E within systems engineering*
- *Now...how do we **transform PPBE** (which is necessary to change the negative aspects of acquisition culture and business practices.)*

AVW TECHNOLOGIES



Questions?

AVW TECHNOLOGIES

Backups

AVW T&E
Database Structure