Keeping Legacy Systems Viable: Introducing System Engineering Processes to the O&S Phase

Karen A. Metz
JHU/APL
240.228.0381
Karen.Metz@jhuapl.edu

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Introducing System Engineering Processes to the O&S Phase

- A Changing DoD Acquisition Environment
- System Engineering Approach to Upgrades
  - NAVAIR Style
  - … With a Twist
- Maturity Measures
- Putting It All Together

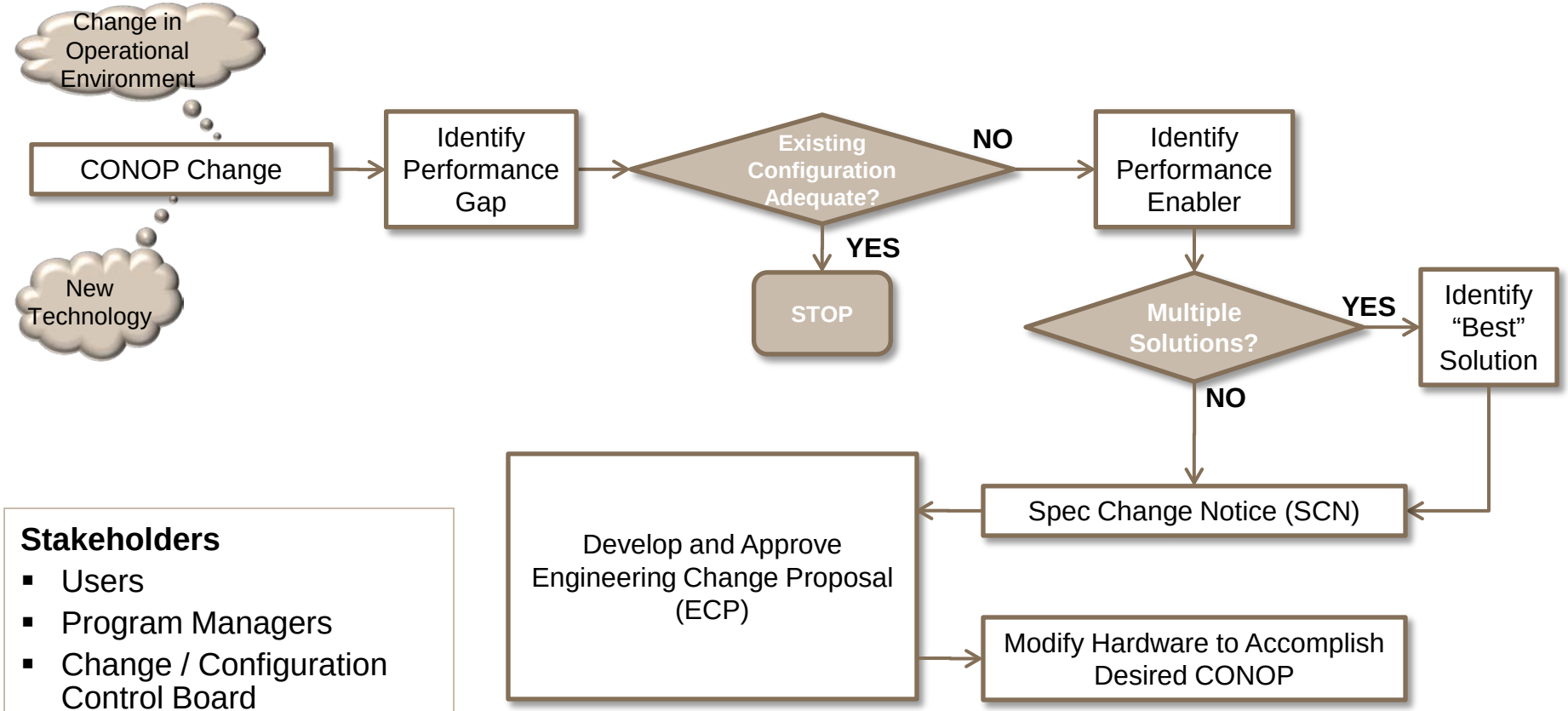
A Changing DoD Acquisition Environment

Assumptions	Realities
Service life is set; platforms will be retired once design service life is reached	Budget constraints force ***equipment life to be extended*** beyond the original service life
Platform upgrades driven by logistics, RMA, obsolescence, and maintenance issues	Platform upgrades are also driven by ***interoperability requirements***, and ***changes to the mission and environment***
Sustainment planning is finalized during production phase	Sustainment planning is often ***inadequate*** beyond the original service life

Systems Engineering Approach to Upgrades

- **Upgrades offer an opportunity to:**
  - Address performance shortfalls
  - Deal with parts obsolescence
  - Improve product reliability / maintainability / availability
- **SE Approach**
  - Identify, refine and validate requirements
  - Determine impact on:
    - Existing design
    - Support equipment,
    - Logistics elements (PHS&T, training, spares, etc.)
  - Assess completeness of existing technical data package
  - Establish maturity of technologies
  - Focus on design and integration challenges

Upgrading …



Stakeholders

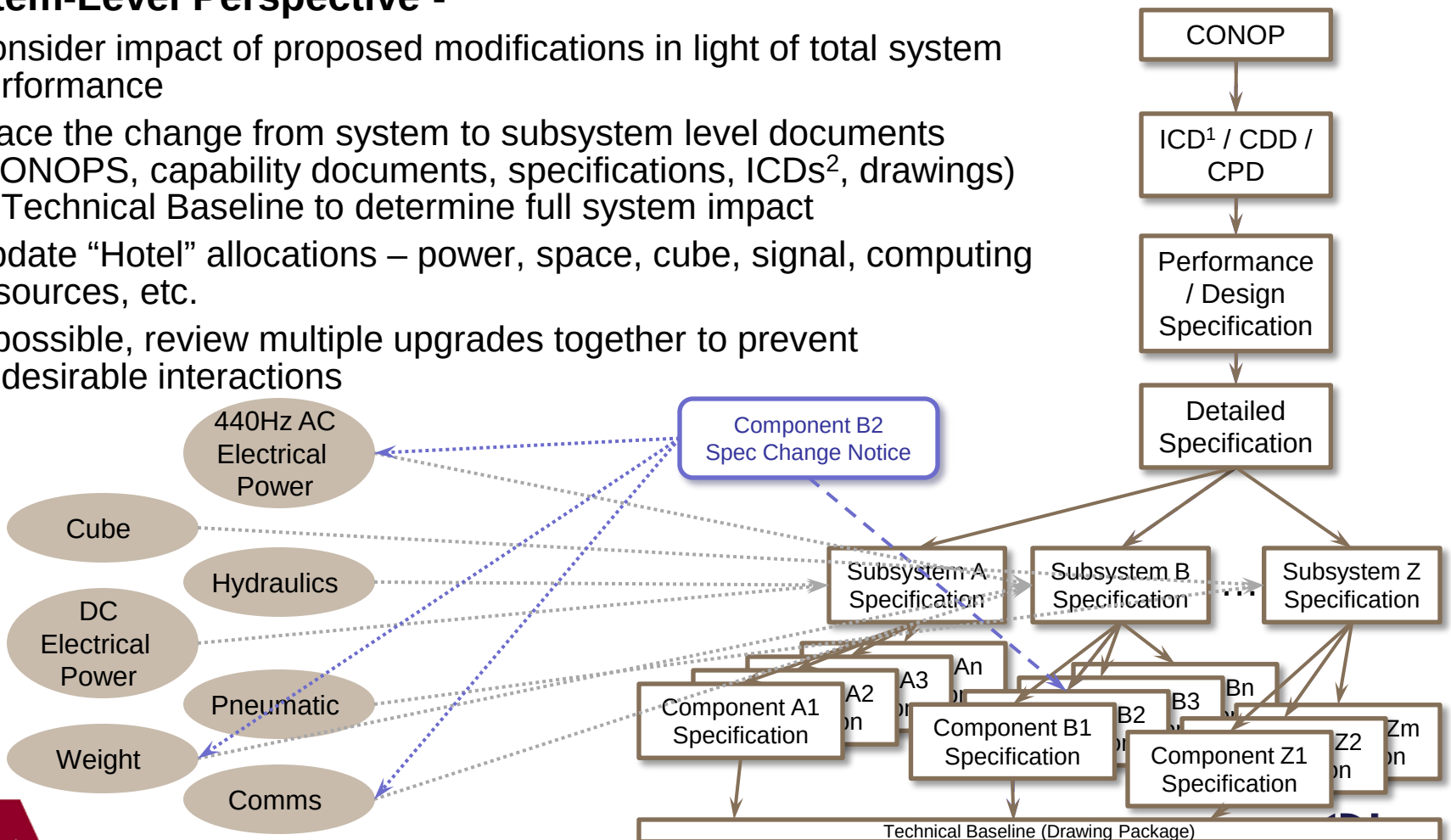
- Users
- Program Managers
- Change / Configuration Control Board
- APMSE / Chief System Engineer

APMSE: Assistant Program Manager, System Engineering
CONOP: Concept of Operations

CDD: Capabilities Development Document
CONOP: Concept of Operations
CPD: Capabilities Production Document
ICD[1]: Initial Capabilities Document
ICD[2]: Interface Control Document

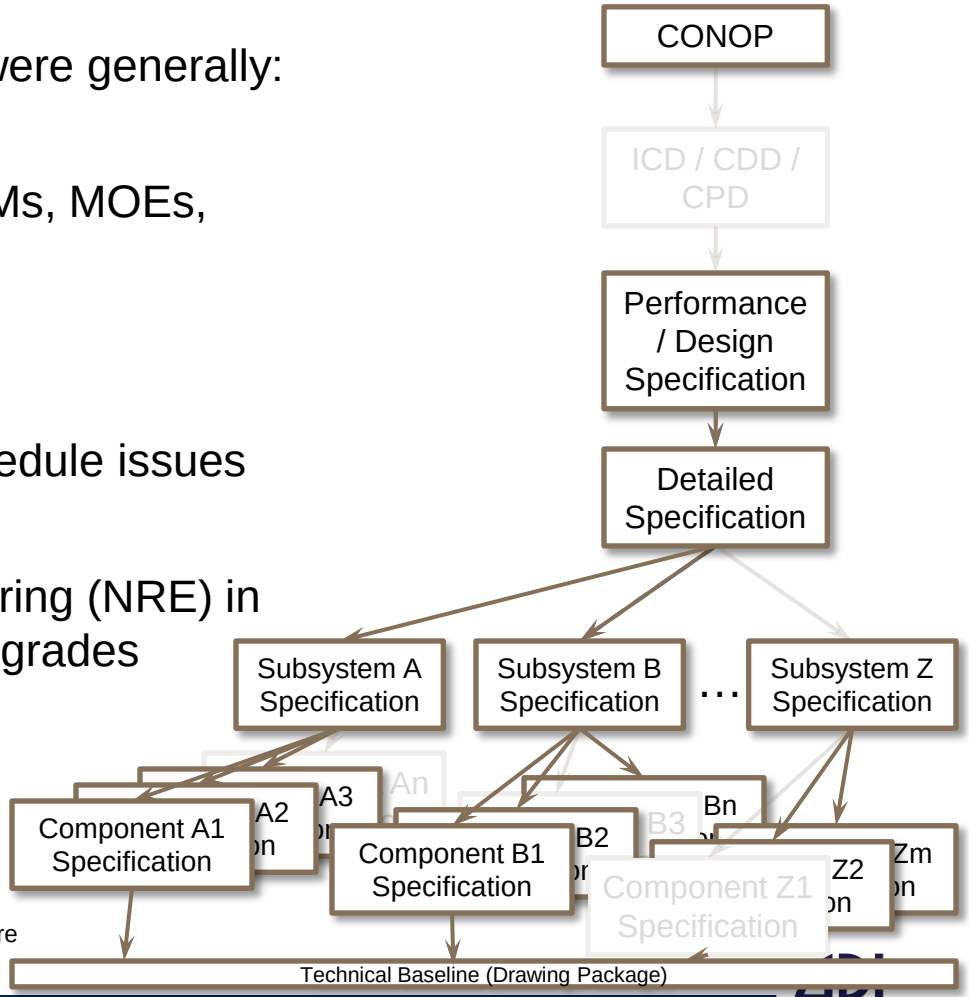
More on Upgrading …

- **System-Level Perspective -**
  - Consider impact of proposed modifications in light of total system performance
  - Trace the change from system to subsystem level documents (CONOPS, capability documents, specifications, ICDs[2], drawings) to Technical Baseline to determine full system impact
  - Update "Hotel" allocations – power, space, cube, signal, computing resources, etc.
  - If possible, review multiple upgrades together to prevent undesirable interactions



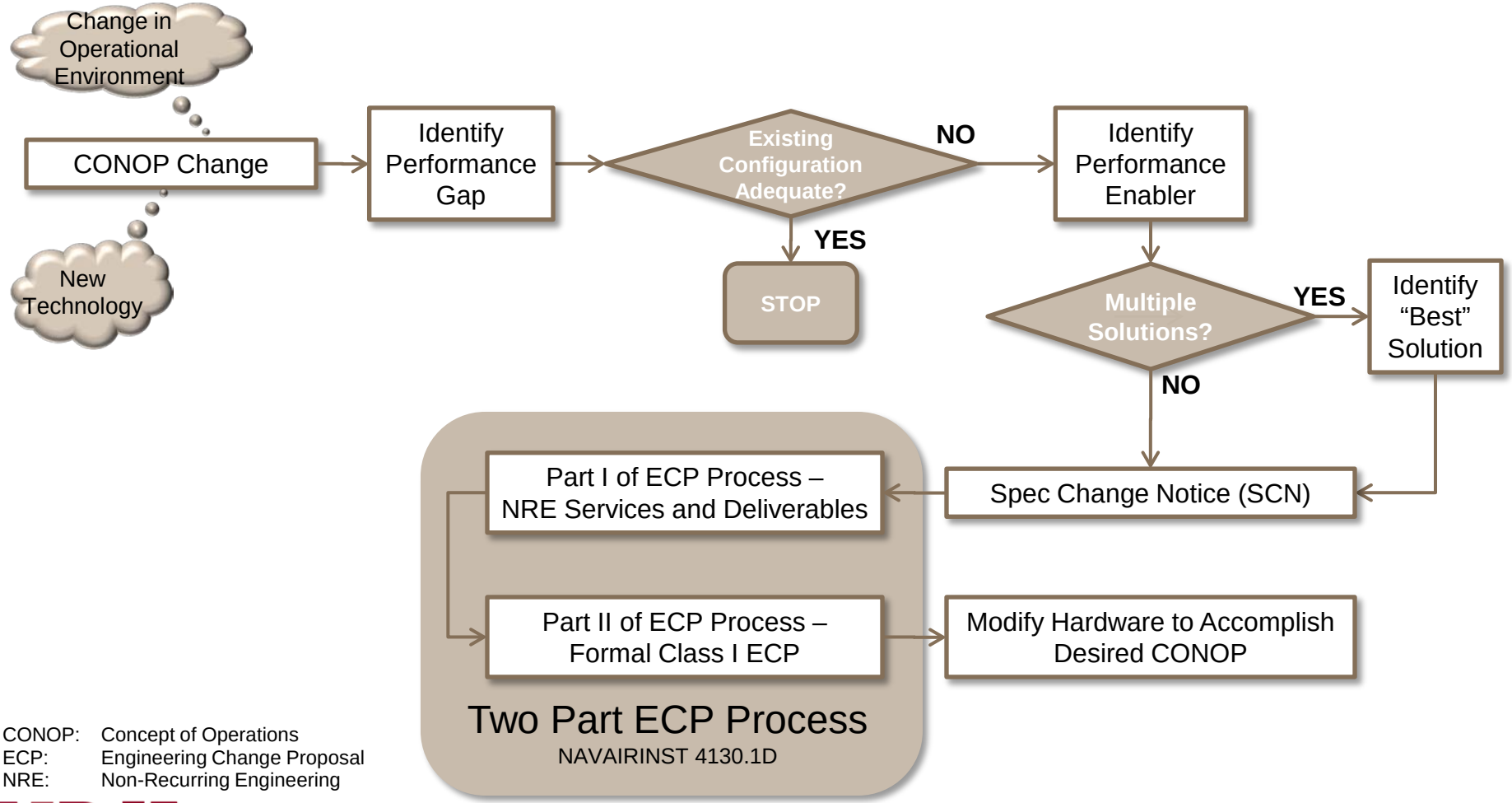
More on Upgrading …

- **Issues**
  - Systems developed before the 1990s were generally:
    - Based on detailed specifications
    - Without defined KPPs, KSAs, TPMs, MOEs, MOPs
  - Updating documentation is often:
    - The last task to be performed
    - Neglected because of budget/schedule issues
- **Solution**
  - Need to perform non-recurring engineering (NRE) in order to reduce risk of implementing upgrades



CDD: Capabilities Development Document
CONOP: Concept of Operations
CPD: Capabilities Production Document
ICD: Initial Capabilities Document
KPP: Key Performance Parameter
KSA: Key System Attribute
MOE: Measure of Effectiveness
MOP: Measure of Performance
TPM: Technical Performance Measure

Upgrading NAVAIR Style …



CONOP: Concept of Operations
ECP: Engineering Change Proposal
NRE: Non-Recurring Engineering

More on the NAVAIR Style …

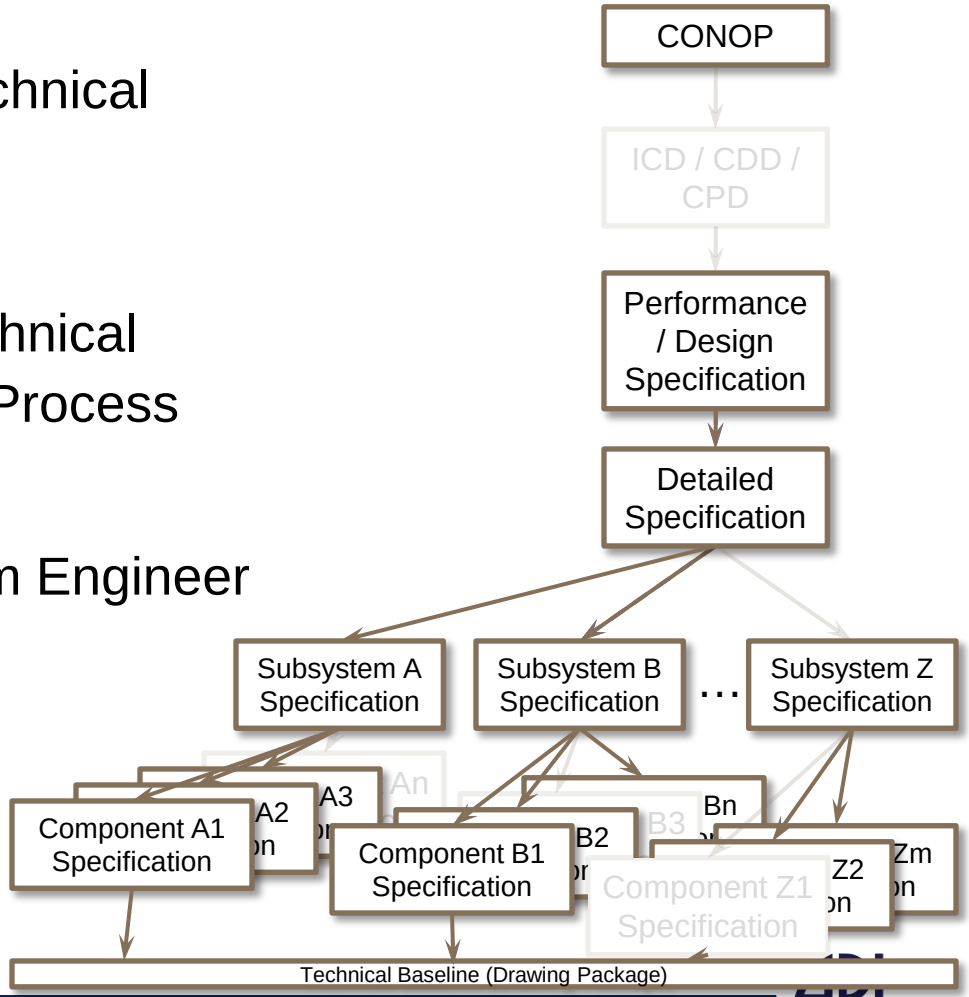
- **Traditional ECPs require a complete technical data package (TDP) to obligate funds**
- **TDP development requires NRE activities, including:**
  - Executing limited trade-offs to identify “better” solution
  - Identifying interface issues
  - Examining weight, balance, footprint, and cube issues
  - Analyzing power budgets, signal timing, etc.
  - Determining necessary wiring, cabling, hydraulic modifications
  - Developing drawings, procedures, tooling to implement modification
  - Determining impact on support equipment and logistics elements
  - Manufacturing, installing, and testing prototype
- **The Two Part ECP process:**
  - Funds NRE activities prior to gaining full ECP approval
  - Leads to a higher quality formal ECP
  - Results in fewer changes and quicker implementation

From NAVAIRINST 4130.1D

ECP: Engineering Change Proposal
NRE: Non-Recurring Engineering
TDP: Technical Data Package

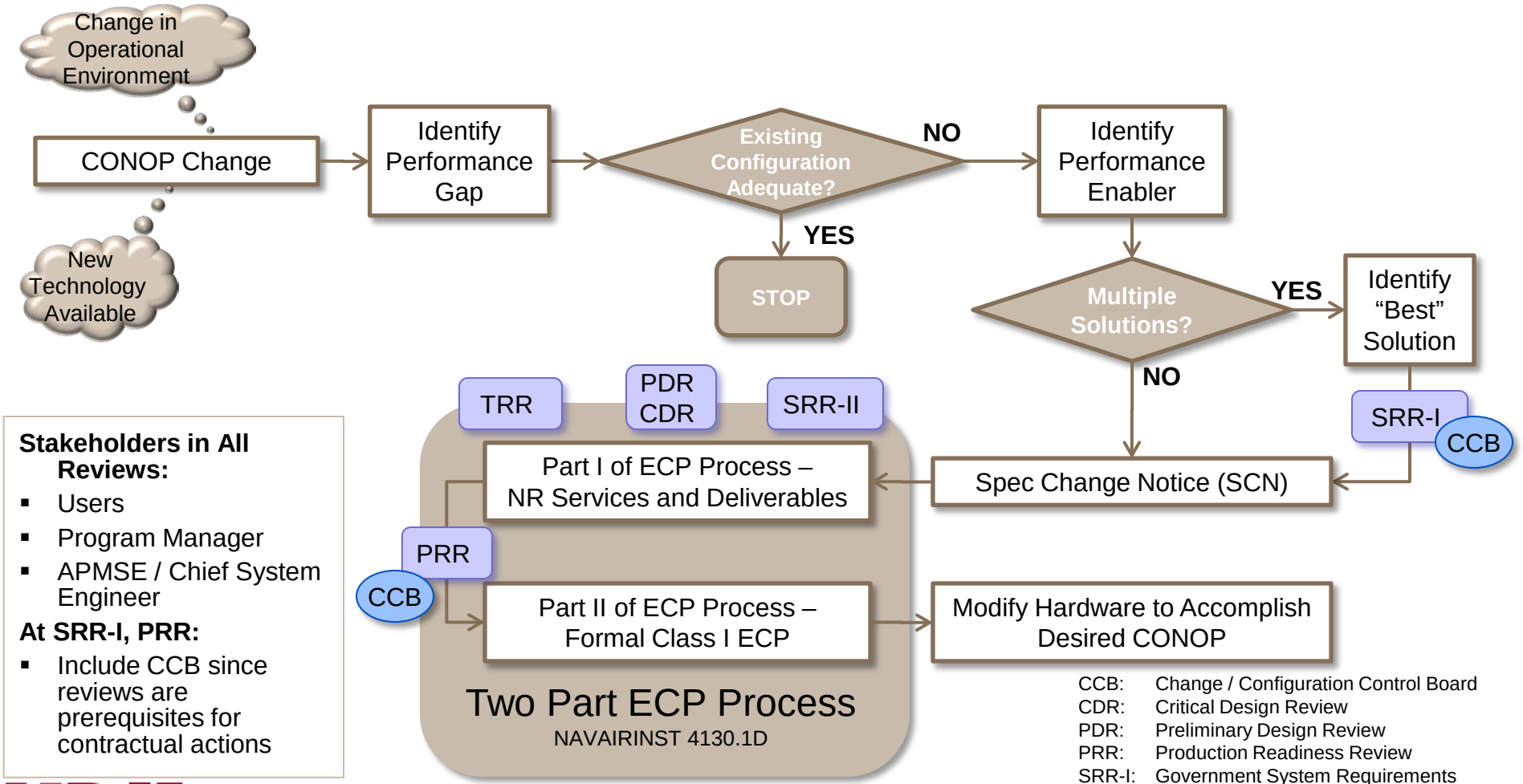
Upgrading NAVAIR Style … with a Twist

- **Issue**
  - NRE needs to be reviewed for technical accuracy and completeness
- **Solution**
  - Implement a series of tailored technical reviews during Part I of the ECP Process
- **Tailoring Responsibility**
  - PM, APMSE, and/or Chief System Engineer responsible for tailoring
  - CCB has insight, veto power



APMSE: Assistant Program Manager, System Engineering
CCB: Change / Configuration Control Board
CDD: Capabilities Development Document
CONOP: Concept of Operations
CPD: Capabilities Production Document
ECP: Engineering Change Proposal
ICD: Initial Capabilities Document
NRE: Non-Recurring Engineering
PM: Program Manager

Upgrading NAVAIR Style … with a Twist



Stakeholders in All Reviews:

- Users
- Program Manager
- APMSE / Chief System Engineer

At SRR-I, PRR:

- Include CCB since reviews are prerequisites for contractual actions

CCB: Change / Configuration Control Board
CDR: Critical Design Review
PDR: Preliminary Design Review
PRR: Production Readiness Review
SRR-I: Government System Requirements Review
SRR-II: Government-Industry SRR
TRR: Test Readiness Review

… The Twist

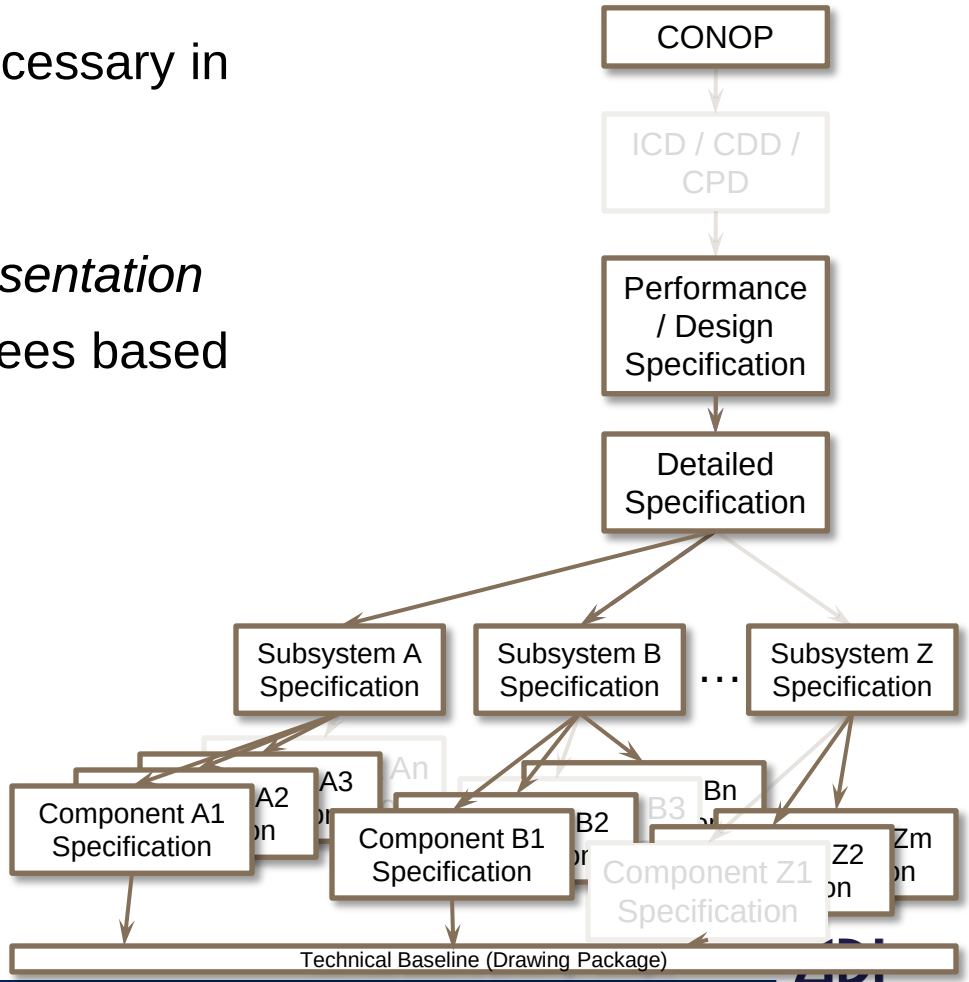
Tailored Review	Timing	Purpose
SRR-I* – Government System Requirements Review	Before Spec Change Notice is issued	Ensure tasking described in Statement of Work is sufficient to implement ECP on all applicable systems; certifies that traceability from system-level to subsystem- or component-level specifications is adequate.
SRR-II* – Govt / Industry System Requirements Review	After ECP Part I Contract Award	Ensure Contractor understands tasking and design goals and available resources support design, integration, certification and verification activities
Preliminary and/or Critical Design Review	During ECP Part I Execution	Determine if design has a reasonable chance of being operationally effective and suitable and being accomplished within the established cost / schedule.
Test Readiness Review	Before installing and testing prototype	Ensure that the configuration is stable and is ready to proceed into formal test.
Production Readiness Review	Before contract for Part II of ECP is let	Review the formal Class I ECP and technical directive to determine if the modification is ready for installation in all systems.

*SRR-I and SRR-II introduced in NAVAIRINST 4355.1D.

ECP: Engineering Change Proposal

More on … The Twist

- **Issue**
  - Full-blown technical reviews not necessary in most cases
- **Solution**
  - Emphasize *documentation*, not *presentation*
  - Tailor the depth, topics, and attendees based on:
    - Maturity of technologies
    - Maturity of integration effort
    - Completeness of design and documentation



Measures of Maturity

TRL: Technical Readiness Level

TRL	Definition
9	Actual System Proven Through Successful Mission Operations
8	Actual System Completed and Qualified Through Test and Demonstration
7	System Prototype Demonstrations in Relevant Environment
6	System/Subsystem Model or Prototype Demonstration in Relevant Environment
5	Component and/or Breadboard Validation in Relevant Environment
4	Component and/or Breadboard Validation in Laboratory Environment
3	Analytical and Experimental Critical Function and/or Characteristic Proof-of-Concept
2	Technology Concept and/or Application Formulated
1	Basic Principals Observed and Reported

Measures of Maturity

MRL: Manufacturing Readiness Level

MRL	Definition
10	Full rate production demonstrated and lean production practices in place
9	Low rate production demonstrated; capability in place to begin full rate production
8	Pilot line capability demonstrated; ready to begin low rate initial production
7	Demonstrated capability to produce systems, subsystems, or components in a production representative environment
6	Demonstrated capability to produce a prototype system or subsystem in a production relevant environment
5	Demonstrated capability to produce prototype components in a production relevant environment
4	Demonstrated capability to produce the technology in a laboratory environment
3	Manufacturing proof of concept developed
2	Manufacturing concepts identified
1	Basic manufacturing implications identified

From DoD Manufacturing Readiness Level (MRL) Deskbook, 20 July 2010.

Measures of Maturity
IRL: Integration Readiness Level

Description	IRL	Definition
Performs	**9**	Integration is Mission Proven through successful mission operations.
	8	Integration is Mission Qualified through test and demonstration in the system environment.
Conforms to Rules	**7**	Component integration is verified and validated with sufficient detail to ensure system is suitable for operation.
	6	Integrated components function appropriately and are ready to be incorporated into the rest of the system.
	5	Internal and external impacts of integrating technologies are understood and manageable.
	4	Sufficient detail is available in the specifications and standards to insure technologies can be integrated.
Defined	**3**	Components are compatible so that they can orderly and efficiently integrate and interact.
	2	Specific ways that the components impact and affect each other is well understood.
	1	An interface between components is defined and the relationship is characterized.

Adapted from "System of Systems Acquisition Maturity Models and Management Tools," Brian J. Sauser, Jose Ramirez-Marquez, Stevens Institute of Technology, 2009.

Measures of Maturity
Readiness Levels Applied to Tech Reviews

Tailored Review	Minimum Technology Readiness Level (TRL)	Minimum Manufacturing Readiness Level (MRL)	Minimum Integration Readiness Level (IRL)
Govt/Industry System Requirements Review (SRR-II)	Identify design elements with **TRL < 6**	**MRL = 5:** Can produce prototype components in a production relevant environment.	**Average IRL = 4:** Sufficient detail is available to insure technologies can be integrated.
Preliminary Design Review	**TRL = 6:** Prototype demonstrated in a relevant environment	**MRL = 6:** Can produce a prototype system or subsystem in a production relevant environment.	**Average IRL = 5:** Internal and external impacts of integrating technologies are understood and manageable.
Critical Design Review		**MRL = 7:** Can produce systems, subsystems, or components in a production representative environment.	**Average IRL = 6:** Integrated components function appropriately and can be incorporated into the rest of the system.
Test Readiness Review			
Production Readiness Review	**Threshold TRL = 7:** System prototype demonstrated in an operational environment. **Objective TRL = 8:** Actual system is qualified through test and demonstration.	**MRL = 8:** Pilot line demonstrated; ready to begin low rate initial production.	**Average IRL = 7:** Component integration is verified and validated with sufficient detail to ensure system is suitable for operation.

Measures of Maturity

Design Completeness Applied to Tech Reviews

Review	Requirements Definition	Interfaces	Tech Data Package	Certification and Testing	Risk
Government System Requirements Review (SRR-I)	• Requirements and tasking traced to desired CONOPS • Technical Performance Measures (TPMs) for modification effort established • Threshold and Objective values for non-tailorable design requirements established	N/A	N/A	• Certification requirements identified • Verification Method identified	Technical, cost, and schedule risk of not achieving specified performance identified
Govt/Industry System Requirements Review (SRR-II)	• Tailorable and non-tailorable T/O design requirements established • TPMs defined • Impact of modification on Program-level TPMs estimated	• Interfaces fully defined and documented • Interface Design Description (IDD) finalized	Functional requirements documented	• Certification requirements verified • Verification Method and approach is verified	Technical, cost, and schedule risk mitigation efforts planned and budgeted
Preliminary Design Review	• TPMs are allocated to Interface Control Documents (ICDs) and sub-systems • Functional baseline allocated	Design is compliant with IDD	Design documentation required to support training and modeling and simulation (M&S) identified	Design documentation supports analysis of attributes, interactions with loads and environment, and system level properties	• Design, integration and manufacturing risks assessed • Compliance risks to the ICDs are identified

*Concept for SRR-I and SRR-II introduced in NAVAIRINST 4355.1D

Measures of Maturity

Design Completeness Applied to Tech Reviews

Review	Requirements Definition	Interfaces	Tech Data Package	Certification and Testing	Risk
Critical Design Review	Analysis indicates threshold values for TPMs achievable	Interface Design Documents become Interface Control Documents (ICDs)	• Build baseline established • Specs/drawings sufficiently mature to build prototype hardware and software	Analysis of attributes, interactions with loads and environment, and system level properties shows system has reasonable probability of success	Design, integration, interface, and manufacturing risks addressed
Test Readiness Review	Same as Critical Design Review	Same as Critical Design Review	Same as Critical Design Review	• Clearances and safety certifications obtained • Safety standards met • Test events planned and resourced • Test objectives clearly stated • Test data requirements identified	Same as Critical Design Review
Production Readiness Review	• Traceability of final system requirements to final production system maintained • System requirements fully met in final production configuration	Same as Critical Design Review	Same as Critical Design Review	N/A	• schedule, performance, and cost criteria are supported by manufacturing processes, the quality system, and production planning support • Production capability forms a satisfactory basis to proceed into Full Rate Production

Putting It All Together
Tailoring the Reviews

Design Maturity	Design/Doc Completeness	Focus of Reviews	Peer/Stakeholder Participation
HIGH	**COMPLETE**	SE processes that maintain traceability and configuration control	Minimal
LOW	**COMPLETE**	Low maturity subsystems and interfaces	Subject Matter Experts that are experienced with the low-maturity subsystems, manufacturing processes, and interfaces
HIGH	**INCOMPLETE**	Subsystems, interfaces and components with unresolved change proposals (driven by unresolved specification changes)	Subject Matter Experts that are actively working unresolved specification changes and change proposals
LOW	**INCOMPLETE**	• Subsystems, interfaces and components with unresolved change proposals (driven by unresolved specification changes) • Low maturity subsystems and interfaces	• Subject Matter Experts that are actively working unresolved specification changes and change proposals • Subject Matter Experts that are experienced with the low-maturity subsystems, manufacturing processes, and interfaces

Definitions:

Design Maturity	**HIGH:** TRL ≥ 7, MRL ≥ 9, IRL ≥ 7 **LOW:** TRL ≤ 6, MRL = 6, IRL = 5
Design and Documentation Completeness	**COMPLETE:** Documentation is up-to-date, traceability is intact, system level impact is known and accepted **INCOMPLETE:** Documentation has unresolved SCNs (in addition to the proposed SCN), with uncertain system performance impact and unknown relationship to the proposed SCN

Putting It All Together
Pros and Cons

- **PROS**
  - Tailored reviews offer greater insight into design modifications before modification effort is initiated
  - Total project costs may be less than with no reviews
  - Tailoring reviews allows attention to be focused on areas of greatest needs
  - Impacts of upgrades are considered at the system level
- **CONS**
  - Before issuing a request for proposal, engineering team must understand:
    - maturity of components, subsystems and interfaces
    - completeness of the documentation
    - integration risk exposure
  - Costs are front-loaded
  - Reviews can be pared down to nothing
  - Effectiveness of tailored process is hard to measure

Putting It All Together
Conclusions

- **This approach combines “best practices” in a way that makes sense in today’s acquisition environment**
- **Impact of proposed changes are more likely to be understood “up front” (rather than stumbled upon)**
- **Self-assessment of maturity levels provides insights, identifies areas of technical risk that might otherwise go unnoticed (until too late)**
- **Honest evaluation of the completeness of existing design documentation provides opportunities to apply best systems engineering practices**
- **Tailored design reviews provide opportunities to focus attention on those areas where review is most required**

QUESTIONS?