ASD(C3I)'s 2000 Command & Control Research & Technology Symposium

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Enabling Interoperability Via Software Architecture

Outline

- Introduction
  - Definitions
  - Doctrine, policy, operations and materiel
  - Systems of Systems
  - Software Architecture
- A Joint Interoperability Initiative from the Services
  - CIPOs
  - JFPO
  - CIPO/JFPO Architecture Research
- From Requirements to Design
  - Requirements engineering process improvement
  - Software architecture
  - Horizontal integration
- Conclusions
  - JFPO-JITC-JFCOM partnership
  - HI through software architecture = interoperability

Introduction

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  - **Definitions**
  - **Doctrine, policy, operations and materiel**
  - **Systems of Systems**
  - **Software Architecture**
- **A Joint Interoperability Initiative from the Services**
  - **CIPOs**
  - **JFPO**
  - **CIPO/JFPO Architecture Research**
- **From Requirements to Design**
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  - **HI through software architecture = interoperability**

Definitions

- **Interoperability: Joint Publication 1-02 defines interoperability as "the ability of systems, units or forces to provide services to and accept services from other systems, units or forces and use the services to enable them to operate effectively together."**
- **DOTML-P**
  - **Doctrine, organization, training, materiel, leadership, & personnel**
- **Our focus = JFCOM's focus:**
  - **Doctrine, organization, materiel (DOM)**
  - **System interoperability: materiel focus**
  - **System requirements: doctrine/organization focus**

Doctrine, Organization and Materiel

- **Interoperability requires**
  - **Doctrine: to identify why we interoperate.**
  - **Organization: to determine who interoperates**
  - **Materiel: to provide the technical "how" we interoperated**
- **Materiel solutions must span programs, services and system versions.**

Systems of Systems

- Example: GCCS in 3 dimensions:
- GCCS (DISA) -- Service subsystems
  - GCCS-A (Army)
  - GCCS-M (Navy)
  - GCCS-AF (USAF)
  - GCCS-K (ROK)
- GCCS – Application subsystems
  - JMTK
  - JOPES
  - GTN
  - ….
- Upgrade deliveries – Time domain

Transition

- Requirements engineering for future systems
- Software engineering for current systems

A Joint Interoperability Initiative

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Background

Section 912 of the FY 98 Defense Authorization Act included several requirements pertaining to acquisition.

To attack this problem, the Secretary directed the creation of a study group to examine ways to establish a joint command and control (C2) integrated system development process.

As a result of this study, the commanders of the service C2 acquisition centers

- Communications and Electronics Command, Fort Monmouth
- Space and Naval Warfare Systems Command, San Diego
- Electronic Systems Center, Hanscom, AFB

formed the Joint Command and Control Integration Interoperability Group (JC2I2G).

Joint Command & Control Integration/ Interoperability Group

- **CINC Interoperability Program Offices (CIPO) at each systems command.**
  - **Focal point for CINC integration/interoperability development issues**
  - **Six exchange officers from each systems command**
- **One Joint Forces Program Office (JFPO)**
  - **Jointly manned by the Services**
  - **Focus on cross-cutting interoperability/integration issues**
- **JFCOM J6 full member of JC2I2G**

CINC Interoperability Program Offices (CIPOs)

- **Initiate "bottom up" change to implement Joint C2 integration and interoperability.**
- **Support the unified commands in resolving interoperability issues of service-specific systems.**
- **Utilize service C2 laboratory facilities to support interoperability experimentation.**
- **Coordinate service-specific engineering reviews of emerging joint requirements by C2 SYSCOMs.**

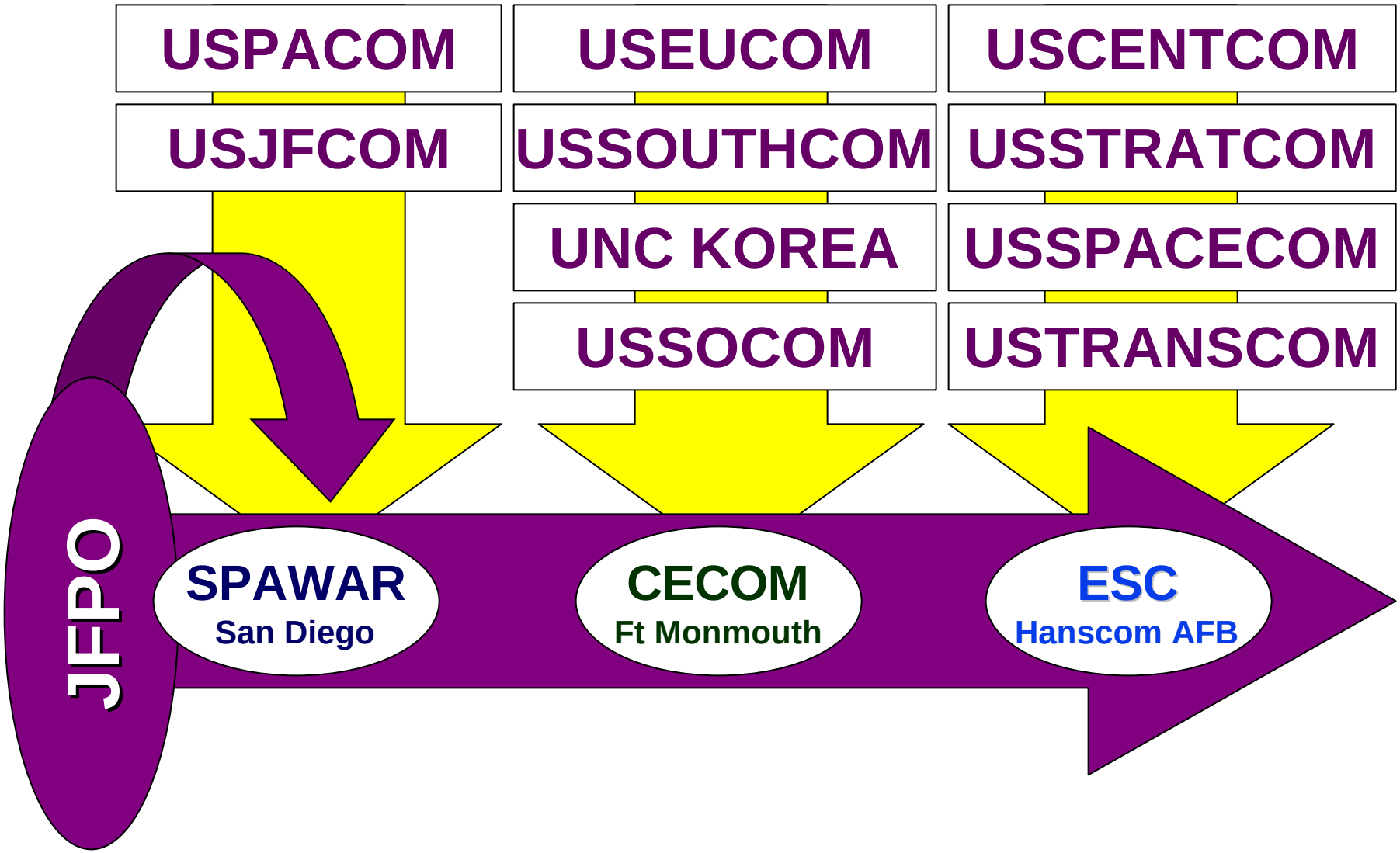
Software engineering support for fielded systems

Joint Forces Program Office

- A tenant of SPAWAR, *but* a JC2I2G organization.
- Responsible for the horizontal integration of CIPO efforts.
- Direct support of Joint Forces Command.
  - Act as CIPO coordinating authority to identify cross-CINC joint interoperability issues and synchronize cross-CINC solutions where feasible.
  - Provide technical/engineering support to USJFCOM in its role as executive agent for Joint Forces Integration, to include providing USJFCOM with technology insertion recommendations.
  - Support USJFCOM in assessing joint interoperability during MNS/ORD/CRD requirements and milestone reviews.
  - Support USJFCOM in tracing future C4 systems requirements to other CINC needs and solutions.
  - Oversees JFCOM CIPO support.
- CIPO liaison to ASD(C3I), Joint Staff, DISA and other Defense agencies.

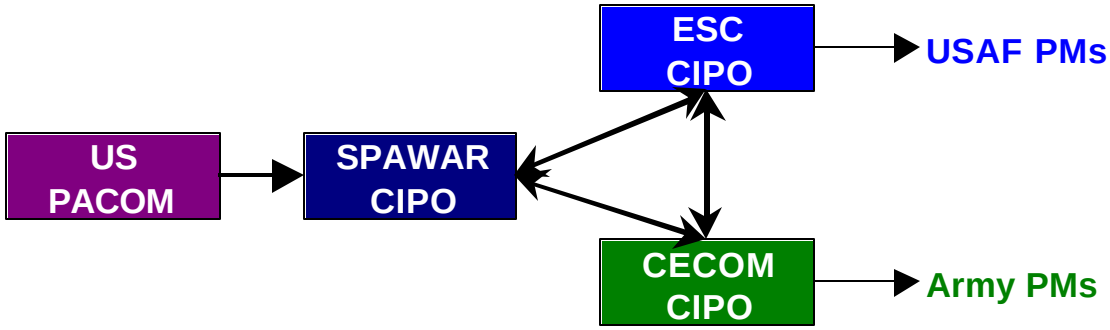
Requirements engineering support for new requirements

CINC/CIPO Allocation



Illustrating CIPOs at Work

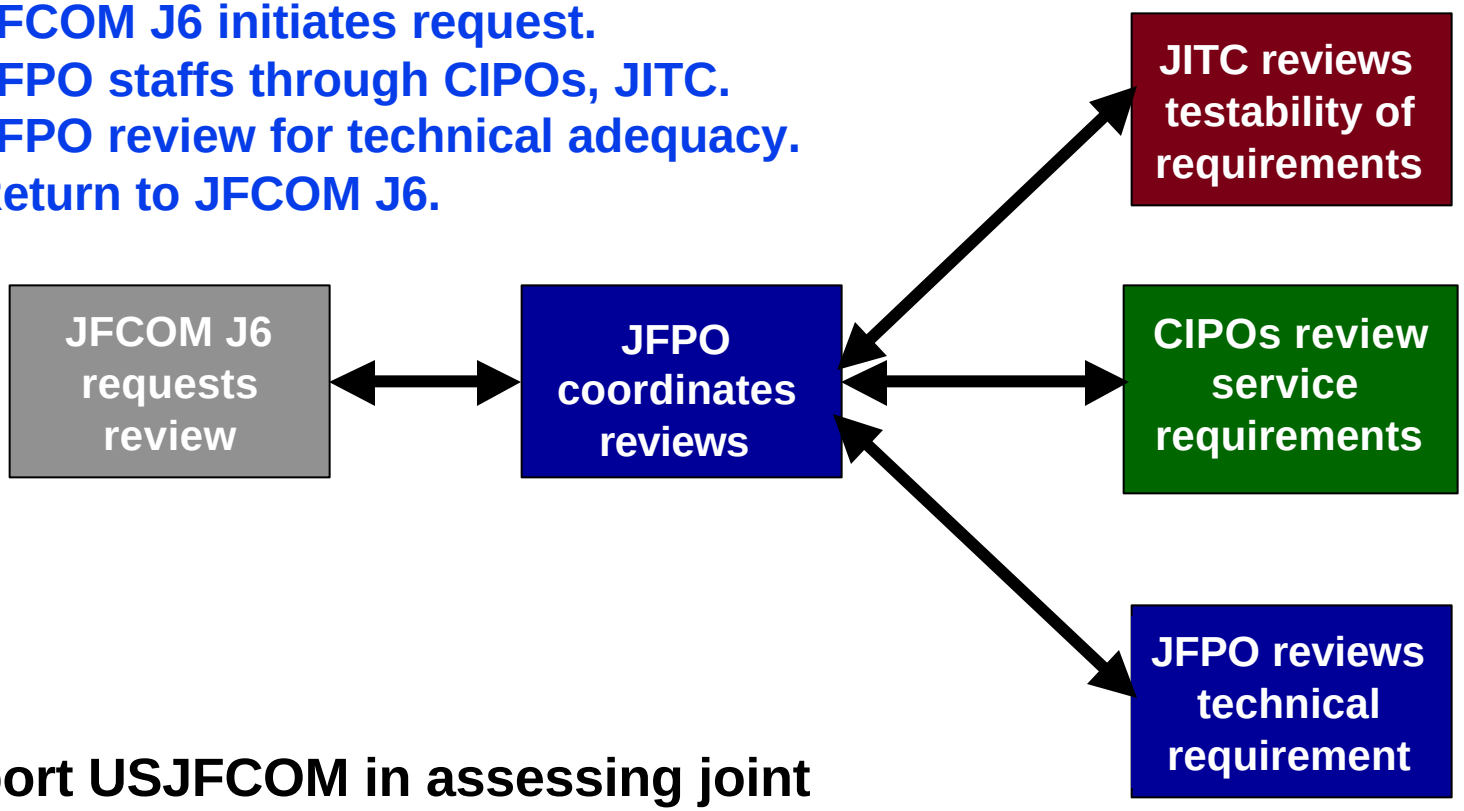
- Although each CINC is supported a single CIPO, the reality is that the interoperability problems will be solved in the system commands, regardless of which CIPO staffs the action.
- For example, consider an Army / Air Force interoperability program raised in the Pacific Command. The SPAWAR CIPO takes the issue back to the appropriate Army and Air Force PMs for action as illustrated below:



- It is not terribly important which CIPO initiates the action. The key capability is the reach back to the service program managers.

Improving joint requirements

1. JFCOM J6 initiates request.
2. JFPO staffs through CIPOs, JITC.
3. JFPO review for technical adequacy.
4. Return to JFCOM J6.



Support USJFCOM in assessing joint interoperability during MNS/ORD/CRD and milestone reviews.

Architecture

- **Scalability**
- **Maintainability**
- **Level of Detail – IAW CJCSI 3170 -- JIERs**
- **Man hour costs**
- **CINC Feedback:**

  System connectivity diagrams linked to planning tools.

Hard to develop interoperability requirements without architectural products but how much is enough?

Alaskan Command ROI

- **Projected cost**
  - Labor = 2400 hours
- **Actual cost**
  - Labor = 2104 hours
- **Data gathering and report generation**
  - 1097 man-hours
- **Data analysis and correlation**
  - 383 man-hours
- **JCAPS (prototype version) utilization and assessment**
  - 624 man-hours
- **Populated JCAPS Database**
  - 100 C2 Systems = 2200 Object Records
- **JCAPS-created Architecture Products**
  - 57 Operational and System Views
- **JCAPS Assessment Report**
  - Approx. 75 Observations Recorded

CIPO/JFPO & Interoperability

- **The CIPO/JFPO structure provides the Unified Commands with the engineering expertise to catch and correct errors in requirements before these errors propagate throughout the rest of the system.**
- **As the CINC staffs develop and refine *operational requirements*, technical expertise is required to develop the *system requirements*.**
- **As interoperability requirements between systems are developed and validated, a high level software architecture is needed for the system acquisition commands to develop *designs* that will be *interoperable*.**

From Requirements to Design

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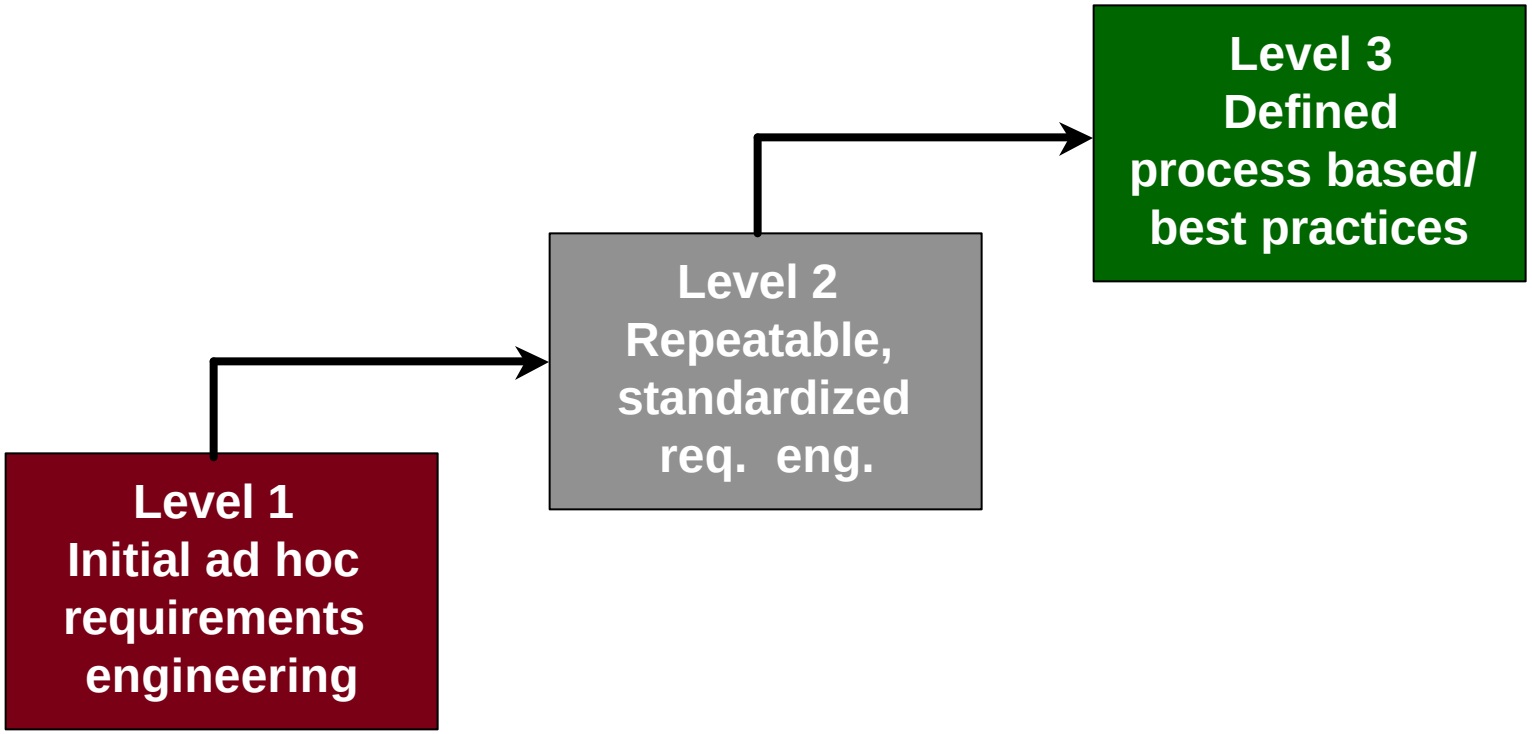
Requirements Engineering Process Improvement

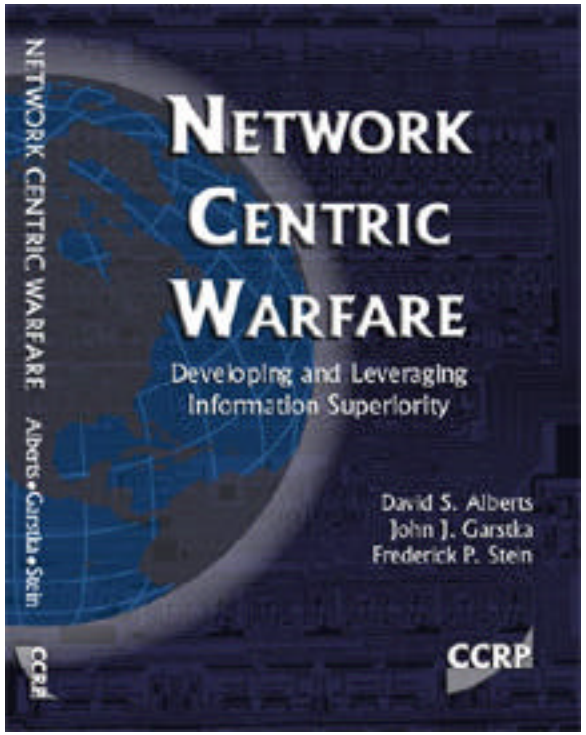
Kotonya & Sommerville



Maturity model guidelines

- **Level 1:**
  - Define a standard document structure
  - Uniquely identify each requirement
  - Define policies for requirements management
  - Use checklists for requirements analysis
- **Level 2:**
  - Use scenarios to elicit requirements
  - Specify requirements quantitatively
  - Use prototyping to animate requirements
- **Level 3:**
  - Reuse requirements
  - Specify systems using formal specifications

Interoperability is Software-Driven



"At a high level of abstraction, we can view the infostructure as an integrated network of communications and computational capabilities. The computational nodes and the communications links convey the seamless integration of computing and communications into a single backplane."

Network-Centric Warfare, page 189
Alberts, Garstka and Stein

Software Architecture

- **As noted in IEEE Standard 12207.0-1996 *Software Lifecycle Processes:***

1. **Software architecture describes the top-level structure of the over-arching system and describes the software components.**
2. **Specifically, developers adhering to the standard are required to develop and document a top-level design for the interfaces external to the software item and between the software components of the software item.**
3. **This is an essential first step in achieving interoperability between any two systems.**

Software Architecture Bridging Requirements and HI

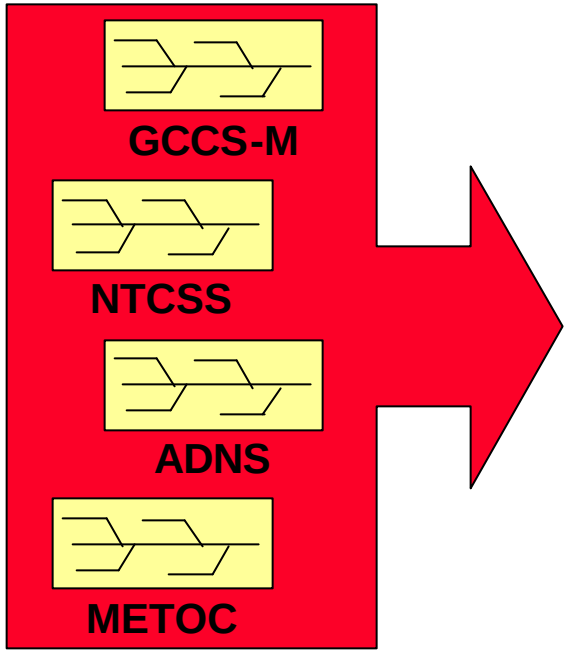
- Software architecture is the high-level design developed from the requirements
- Horizontal integration is achieved by low-level design which conforms to the software architecture

Horizontal Integration Overview

- **Interfaced systems = $(N^2-N)/2$ external interfaces**
- **Integrated systems = single product delivery, no after-delivery interfaces between systems.**

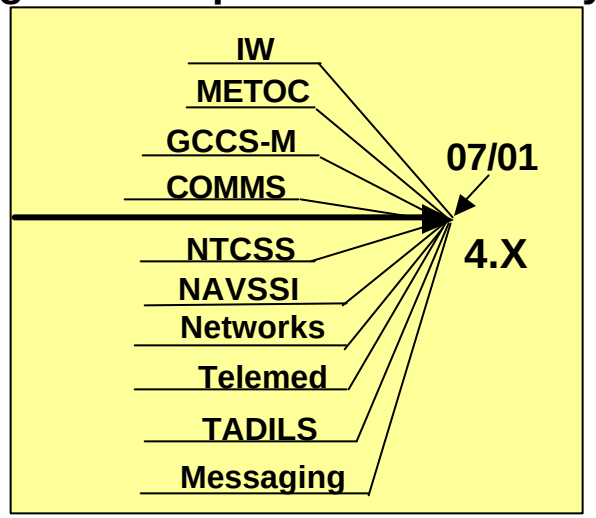
Multiple Developments and Deliveries

Today



Horizontal Integration

Single Development and Delivery



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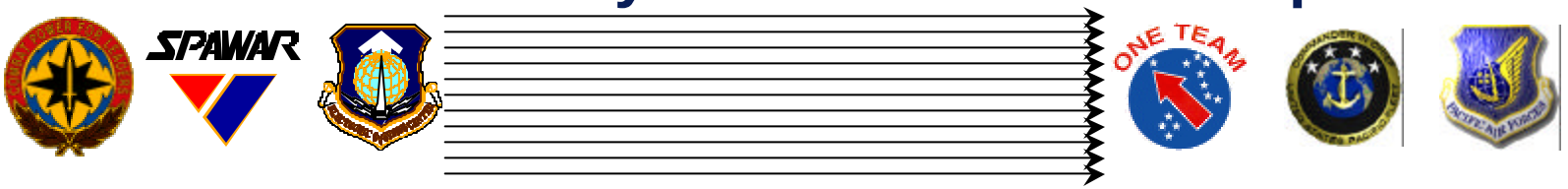
Joint Horizontal Integration Strategy

- **Current: PMs field systems to service components**



- **Near-term: PMs field integrated product lines to service components (Intra-service interoperability)**

- **Future: PMs field integrated product lines directly to the Unified Commands**

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Strategic Partnership

- **JFCOM – Joint Force Integrator**
- **JFPO – Requirements engineering support to JFCOM**
  - **Specific support to interoperability KPPs**
- **JITC – Sole certifier of joint interoperability**
  - **Evaluates testability of requirements early**

JFPO

SPAWAR

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Conclusions

- Only a limited number of interoperability issues in currently fielded systems can realistically be resolved.
- True joint interoperability is in the domain of future system design.
- Joint Interoperability only achievable through some integrated development and delivery strategy.
  - Too many interfaces between systems to maintain
- Software architecture is the bridge between single system requirements and integrated joint systems.
- Integrated product lines will dramatically reduce the number of interfaces between systems – thus considerably simplifying joint system interoperability.