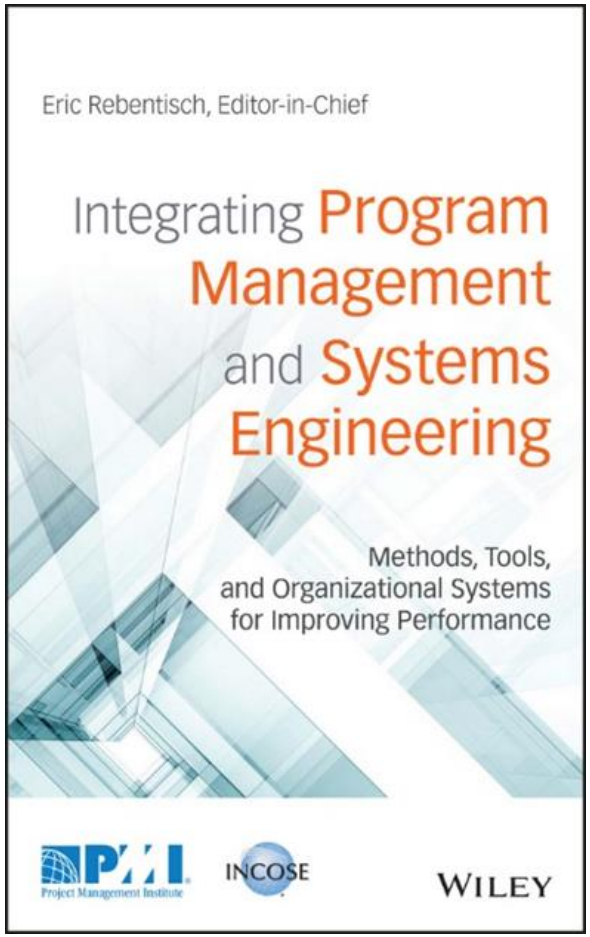



# *Integrating Program Management and Systems Engineering*

*Methods, Tools, and Organizational Systems for Improving Performance*

**Presented by Marvin Nelson**
**PMI Standards Specialist**

# Implementing Integration of Program Management and Systems Engineering

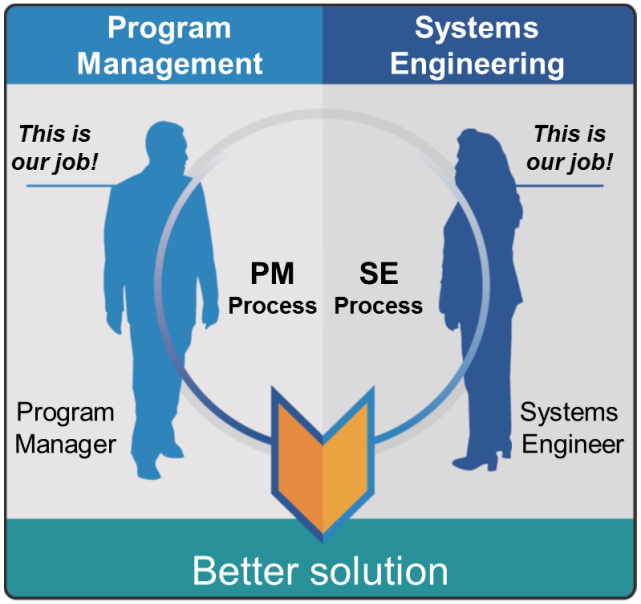
- Four main sections proceed from issues to actions
  1. Why is integration important to program outcomes?
  2. What actions produce better integrated programs?
  3. How to improve integration in programs and organizations?
  4. Who must act to make this happen?

- Case studies illustrate the principles in application, e.g.,
  – Aerospace, large infrastructure, automotive, information systems, and other major programs

- Tools provide guidance for application, including standards, best practices, and methods

# Vision: Toward a New Mindset of Integrated Program Management and Systems Engineering Disciplines

- Current state: "*…some systems engineers and program managers have developed the mindset that their work activities are separate from each other rather than part of the organic whole…*"
- Result: routine failure of complex and large-scale engineering programs to meet cost budgets, schedule, and requirements
- Vision: "*…an understanding that all of the work is relevant to both groups, and that the delivery of stakeholder value requires an appropriate contribution from both areas of professional expertise.*"

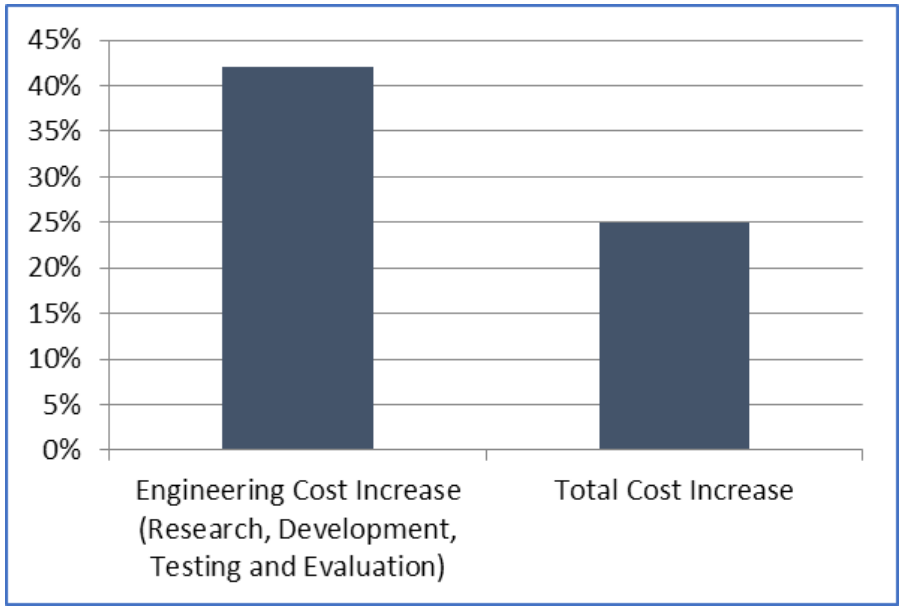



Source: PMI

See: Langley, M., Robitaille, S., & Thomas, J. (2011). Toward a new mindset: Bridging the gap between program management and systems engineering. *PM Network*,

# Disappointing Outcomes from Large-Scale Engineering Programs

**US Department of Defense Development Portfolio – Change from initial estimate (2008)**




- Total cost growth: **$296 billion**
- Average schedule overrun: **22 months**
- Similar situation in other industries

Sources: GAO 06-368 (April 2006), Bloomberg, GAO 10-374T (January 2010)

# Few Organizations Are "Fully" Integrated

Most organizations are *somewhat* or *mostly* integrated and its occurring as a mix of formal and informal methods

Majority find the integration of the two roles to be *somewhat effective*

*Some* unproductive tension is occurring between the roles that makes it challenging for them to work together

*Lack of planning for the integration* is seen as the main source of tension

## Integration of Program Management and Systems Engineering

Those who perform both roles are more likely to rate the integration at their organization as *highly effective*

Systems engineers are more likely to say there is unproductive tension between the roles than program managers

Systems engineers are more likely to attribute the tension to unclear expectation and authority than program managers

# Program Manager and Chief Engineer are Distinct Roles – With Some Important Overlap

| **Program Managers (PM)** view their responsibilities as: | **Chief Systems Engineers (CSE)** view their responsibilities as: | **Both** roles are responsible for: |
|---|---|---|
| • Overall Results<br>• Goals & Objectives<br>• Program & Project Risk<br>• External Supplier Relations<br>• Lifecycle Planning | • Technical Requirements<br>• Systems Definition<br>• Systems Requirements<br>• Configuration Management | • Program/Project Risk<br>• External Supplier Relations<br>• Quality Management<br>• Lifecycle Planning |

The integration must clarify how:

- **Responsibility can be effectively shared** for risk management, external suppliers, quality management and lifecycle planning; and
- **Communication optimized** for the other domains of responsibility.

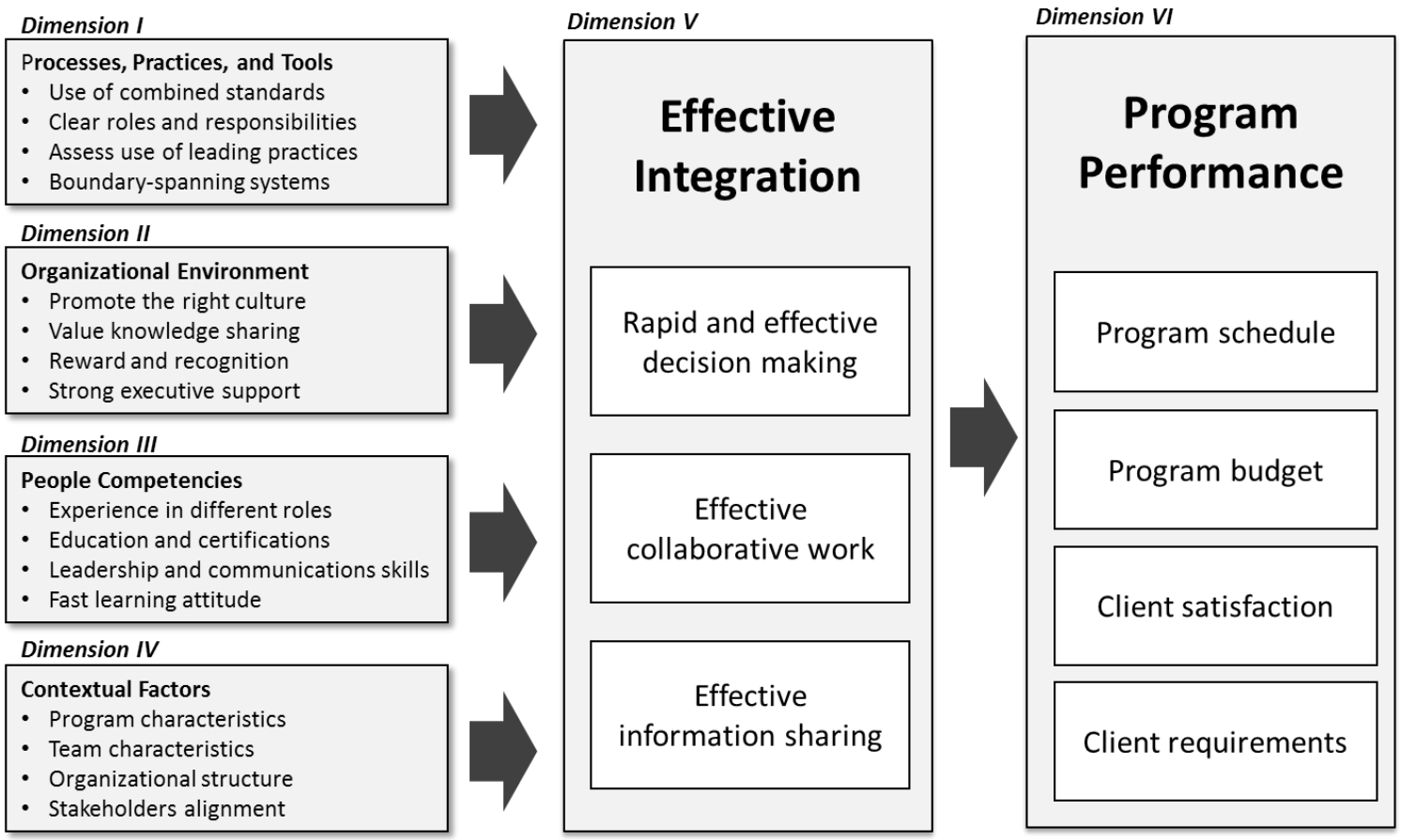
# Integration is…

- Having a shared set of objectives defined by the success of the overall effort…
- Everyone knowing what those objectives are…
- Clarity and understanding around everyone's roles and how they contribute to achieving the objectives…
- Respecting the value of the other's role and contribution to achieving the objectives…
- Valuing and promoting "collaboration" over "competition"…

## Unproductive Tension Results From…

- Failing to communicate and establish a common set of objectives "vision" shared by all…
- Individuals/groups focusing on achieving objectives defined by their own discipline identity and/or processes…
- Being unable to work together to achieve the globally superior outcome…
- Not valuing the other's role and contributions to achieving the globally superior outcome…

# A Systems View of PM/SE Integration

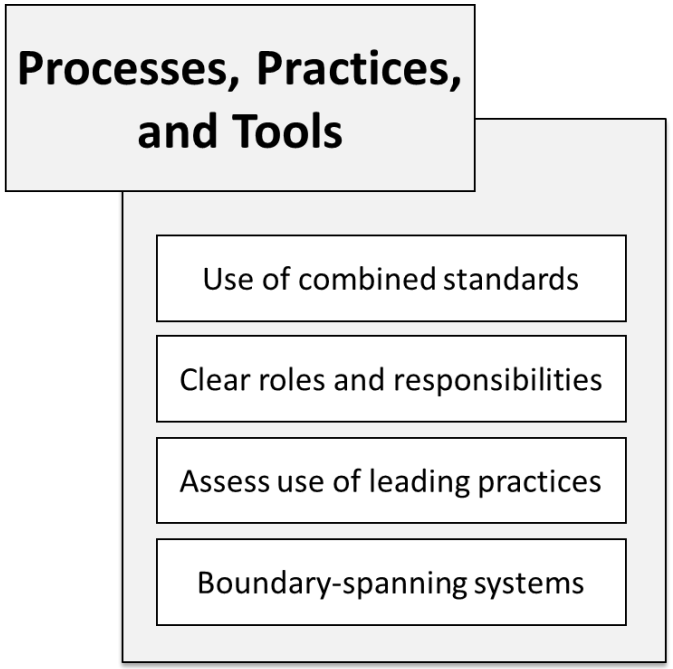



Source: Rebentisch et al (2017)

# Processes, Practices, and Tools

Processes, practices, and tools help to enable integration by:

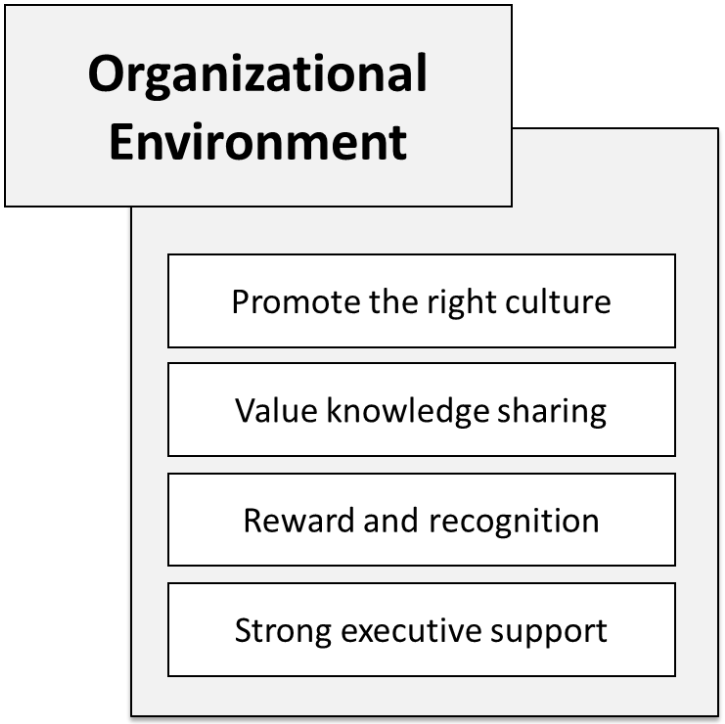
- Enabling communication and common understanding
- Defining specific work activities
- Establishing expectations of each person's contribution
- Documenting approaches for coordinating and tracking work efforts
- Identifying critical points where individual and group work efforts must come together
- Facilitating problem identification and resolution
- Applying and updating best practices
- Supporting and improving specific work activities




Source: Rebentisch et al (2017)

# Organizational Environment

- Organizational structures, behaviors, and norms shape how program participants work and interact with each other, and determine the nature of relationships
- An integrated program environment should:
  - Narrow the cultural divide between PM and SE disciplines
  - Foster team building
  - Develop respect for each-others' views and opinions
  - Build trust between executive management and program teams

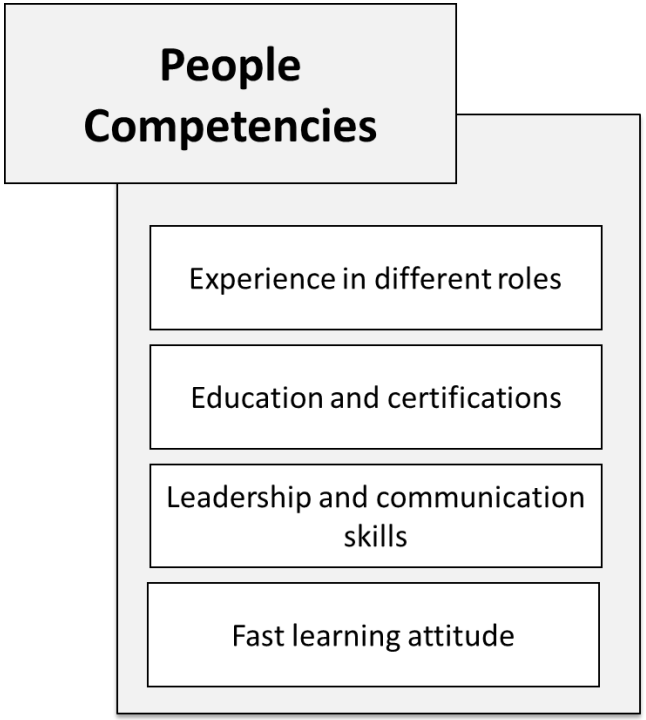



Source: Rebentisch et al (2017)

# Developing Integration Competencies in People

Organizations develop integration competencies in people by:

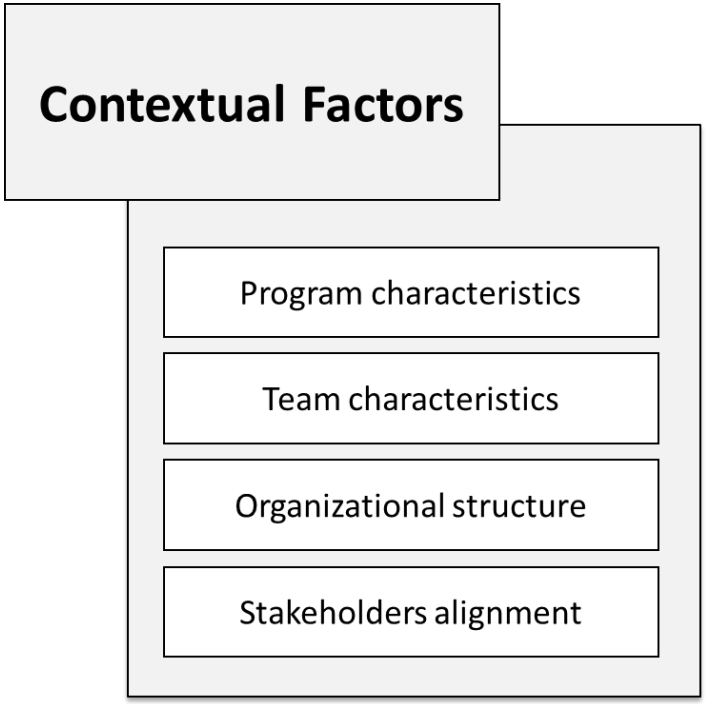
- Defining integration competencies using, e.g., standards, role definitions, and assessments
- Using education and training to develop integration competencies and teaming behaviors
- Managing integration competencies in the workforce at the individual and organizational levels




Source: Rebentisch et al (2017)

# Contextual Factors

- Program and organizational characteristics influence management approaches
  - Management approach needs to be tailored to program realities
  - Management owns program culture which influences behavior throughout the program life cycle
  - Stakeholder alignment requires significant management and engagement
    - One view of the program
    - Transparency
    - Engagement/community




Source: Rebentisch et al (2017)

# Integration as a Characteristic of the Organization

Integration is a reflection of the organization's ability to combine program management and systems engineering practices, tools and techniques, experience, and knowledge in a collaborative and systematic approach in the face of different challenges, in order to be more effective in achieving a common goal/objective in complex program development environments.

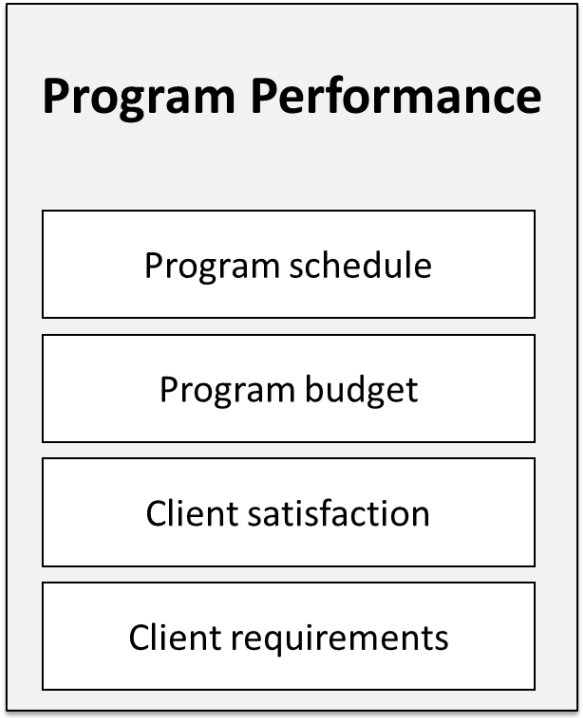
Source: Rebentisch et al (2017)

**Effective Integration**

- Rapid and effective decision making
- Effective collaborative work
- Effective information sharing

# Program Performance

- Integration influences key program performance elements
  - Cost and time show better performance with higher integration
  - Outcomes are more predictive with higher integration
  - Programs with schedule pressure are more resilient with higher integration



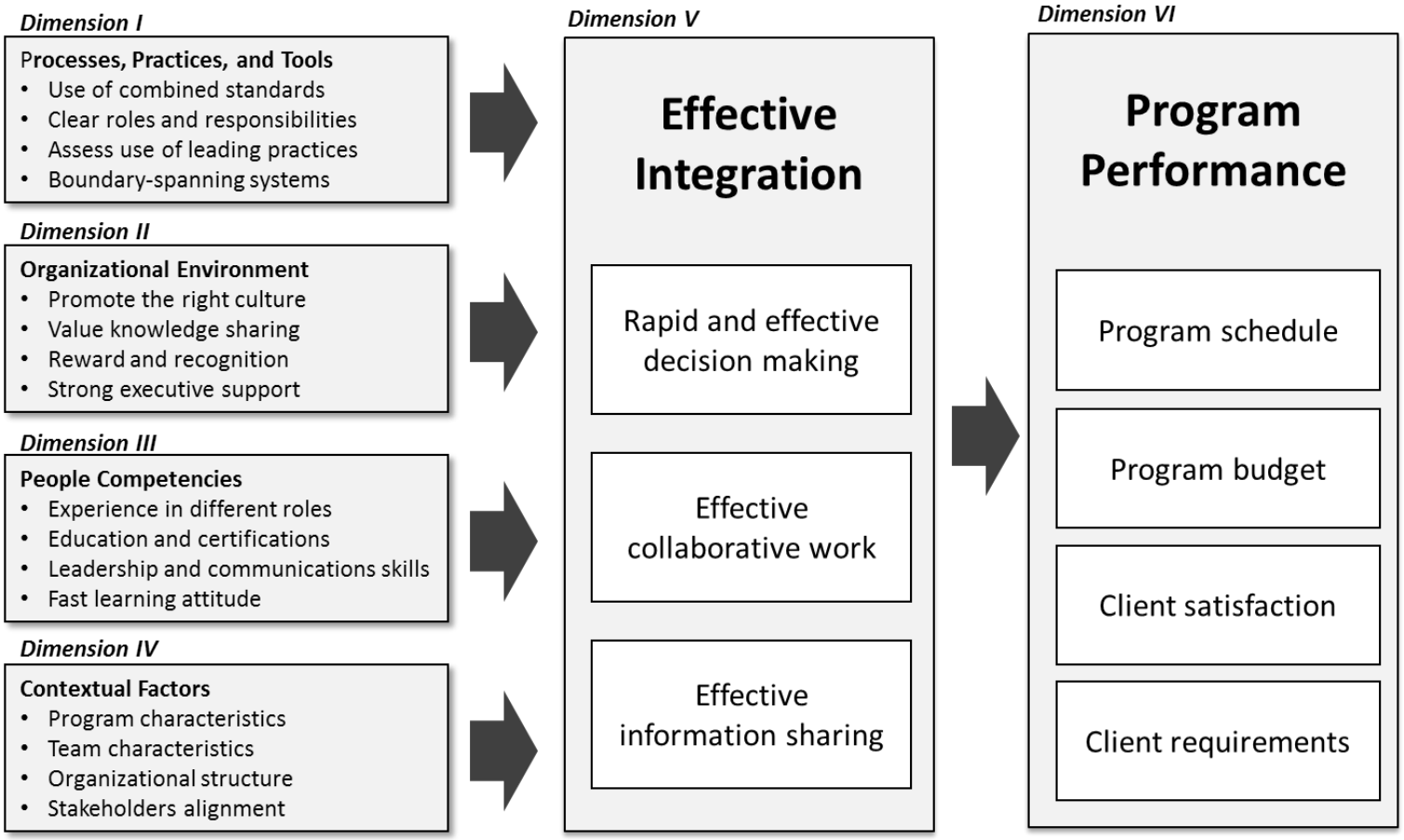

Source: Rebentisch et al (2017)

# Two Case Studies

- US Navy's F-18 Super Hornet

- Royal Australian Navy's Electronic Support Upgrade for the Anzac class frigate

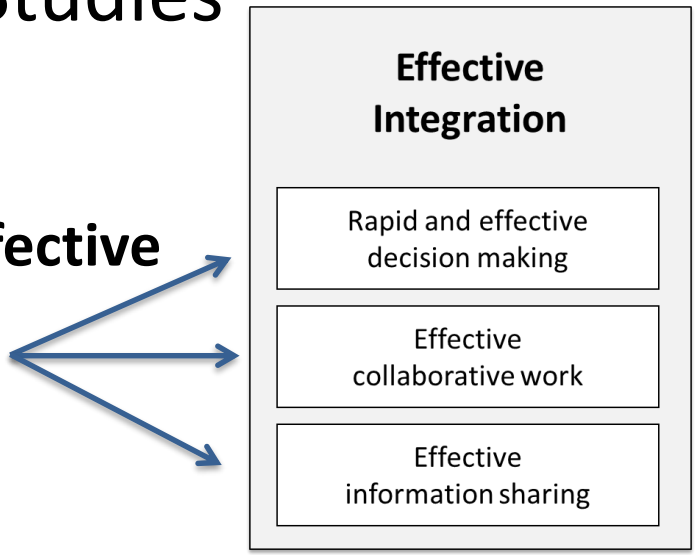
# A Systems View of PM/SE Integration




Source: Rebentisch et al (2017)

# Case Studies

- Both case studies achieved **effective integration** as evidenced by




- They differed in their approaches but both achieved the outcome of a well-performing system delivered within cost and schedule

# F/A-18E/F Super Hornet

- Dual-purpose carrier aircraft (air-to-air, air-to-ground combat)
- Prime contractor was McDonnell Douglas (now Boeing Corporation)
- Northrop (now Northrop Grumman) and General Electric were major subcontractors
- Evolutionary design derived from the F-18C/D model
  - Increased range, survivability, carriage capability, growth capability, and bring back

# Setting the Context

- Development followed the cancellation of the US Navy's A-12 program in 1991

  ***"Within the A-12, there was the perception that everything was fine one day and a disaster the next. Clearly, the right information was not getting to the right people"***

  -- Vice Admiral Joe Dyer, former Navy Program Manager

- The Navy's reputation for acquisition management was at a low point

  ***"The Navy's ability to manage such a program is atrocious."***

  -- US Senator John Glenn during Congressional hearings on the A-12

- The Super Hornet was critical for maintaining operational effectiveness in light of an aging fleet of older aircraft with limited options for capability improvement

- The Navy had to get it right!

# Getting it Right

- With the Super Hornet – there was a premium on open communications, decision-making based on objective data, and collaboration across functional disciplines
  - The old way of working was in a serial fashion across different functional organizations leading to a great deal of rework
    - For example, a Request for Tender would start with an Operational Concept produced by the the operational side of the Navy, then would go to engineering for a delineation of requirements, then to logistics to identify sustainment requirements, then to contracting, then finance, then legal.

***"As the activity moved from one functional area to the next, it would be clear that a decision made earlier could not be implemented by the next area. So things were sent back, rework had to be done. This was expensive and caused delay."***

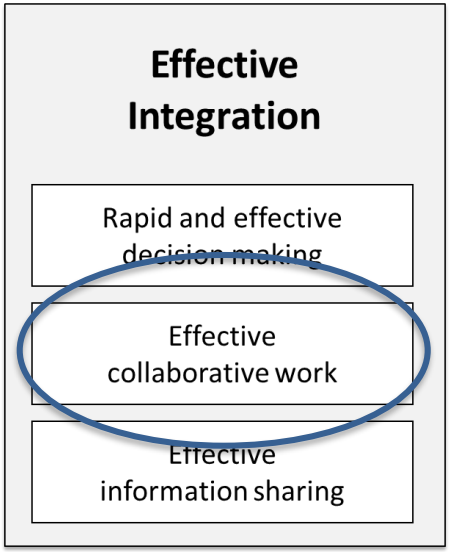
-- Vice Admiral Joe Dyer, former Navy Program Manager

# Collaboration Across Disciplines Achieved via IPTs

- Moved away from functional stovepipes to Integrated Product Teams (IPTs)
  - Each team was responsible for a part of the overall product
  - Teams were multi-disciplinary

***"We focused our IPTs on product and then asked 'What does it take to deliver the product?' These are the disciplines that have to come into every IPT."***

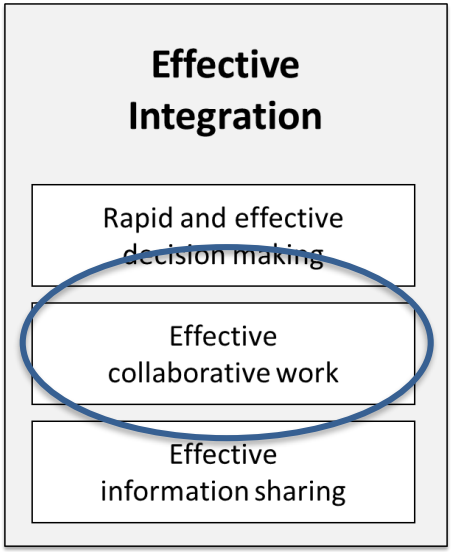
-- Vice Admiral Joe Dyer, former Navy Program Manager




- IPTs were used on the government and contractor sides
  - Corresponding structures facilitated joint problem-solving and communication

# Collaboration Required a Cultural Change

- A hallmark of the program was effective collaboration
  - within and across IPTs, and across the boundary between contractor and government
- How did the program foster real teamwork between government and contractor personnel?

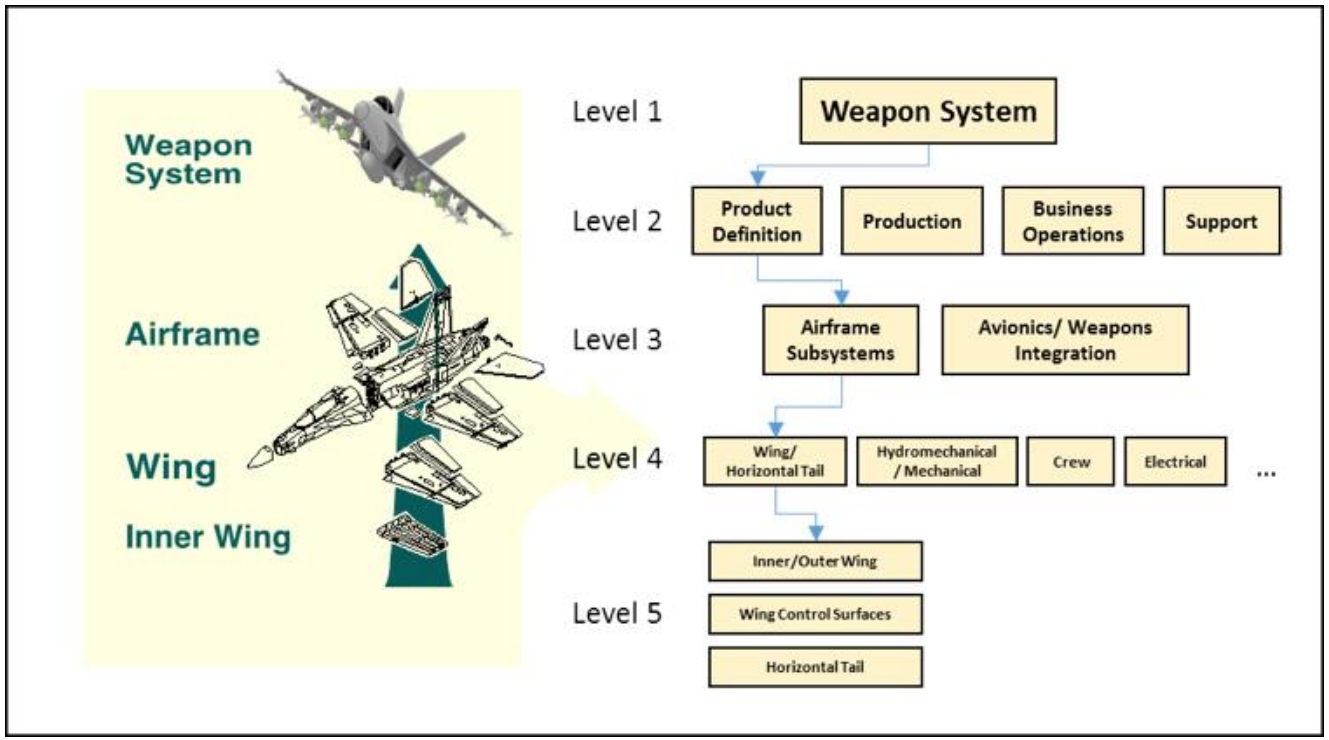



***"Leadership matters and personalities matter. The Vice-President for F/A-18 at McDonnell Douglas and I had an openness with one another that we knew we could build on. We knew that we could flow it down to others and that we would both insist on it. There really is a cultural change required. We're not taught to be team players."***

-- Vice Admiral Joe Dyer, former Navy Program Manager

# Rapid and Effective Decision Making Enabled via Organizational Structure

- Product-based work breakdown structure (WBS) was mirrored by the IPT structure




**Effective Integration**

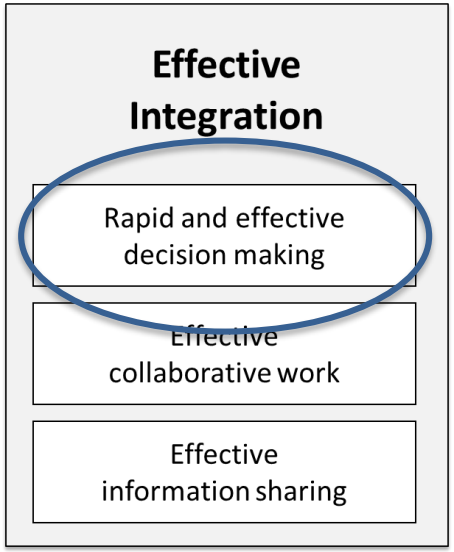
- Rapid and effective decision making
- Effective collaborative work
- Effective information sharing

# Rapid and Effective Decision Making Enabled via Organizational Structure

- Decisions were made at the **lowest level** consistent with scope of responsibilities (Level 5 team leaders controlled their own budgets)

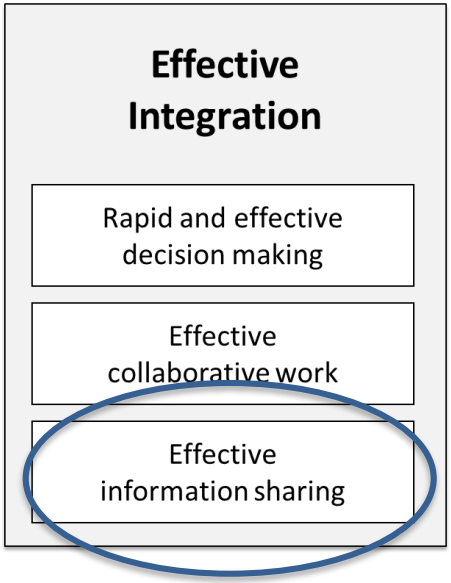
  ***"Team leaders have to balance cost, quality, and schedule. They have to be good business folks as well as engineers. As a Level 5 team leader, I am running my own business."***

- WBS and corresponding organizational structure
  - Used to track cost, schedule, technical performance measures (TPMs) such as weight and power at the lowest level of the WBS (with roll up)
  - Same structure used on government side promoted joint government-contractor problem solving



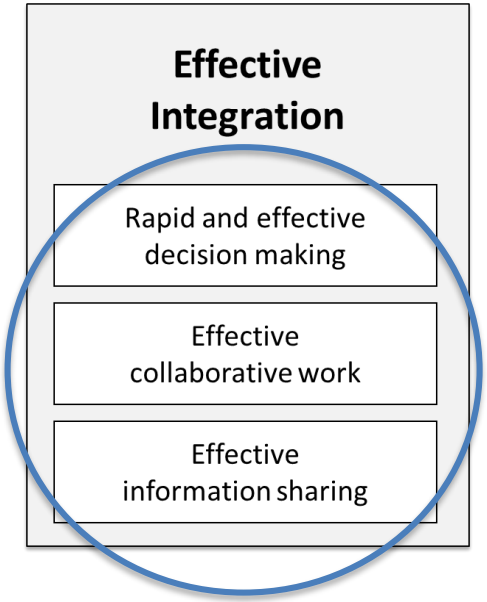
# Effective Information Sharing Enabled via Several Mechanisms

- A high value was placed on open communications and quantitative data
- Common central database used by government and contractor with weekly reporting
  - Cost, schedule, and technical measures down to Level 5 of the WBS
  - Problems in any of these areas were immediately apparent with clear accountability for who owned the problem
- A variety of program wide tools and databases



# Engine Stator Problem

- The Super Hornet has two GE engines
- During flight test, a stationary air foil fractured, causing significant damage to the engine
- An examination of the remaining test aircraft showed fracturing in other engines as well




***"Under the old way of doing things, GE wouldn't communicate issues until they had a plan to go forward. Now, if there's an issue we're [the Navy] the first to know. This actually works to GE's advantage because we have talented people here who can help.***
***In just six weeks, we went full cycle from having the problem surface to diagnosing it and to installing new parts. All of us—the Propulsion IPT, the Flight Test Team, McDonnell Douglas, and GE—had a real sense of working as a team. Under the old way of doing things, this would have taken five or six months."***

# F-18 Super Hornet: Case Study Summary

- Much more detail is in the PMI/INCOSE book (an entire chapter)
- Senior leadership (both government and contractor) were key in establishing the vision for greater integration across all disciplines and perspectives
- Aircraft development is all about tradeoffs between cost, schedule, and technical capability (program management and engineering)

# F-18 Super Hornet: Summary of Integration Practices

| Integration Practices | |
|---|---|
| **Integration Processes, Practices, and Tools**<br>• Clear requirements for the program were established early through a collaborative process involving all program stakeholders.<br>• Key technical performance measures defined early and shared across the program.<br>• WBS was based on the product architecture to unite management and technical efforts.<br>• Common central database (HornetWEB, IMICS) with weekly reporting.<br>• WBS linked to EVMS to measure progress against tasks.<br>• Mod SDF used as a common analysis environment.<br>• Aggressive risk identification and management.<br>• Flow-down of various technical- and management-related budgets to the IPTs. | **Organizational Environment**<br>• Leadership at multiple levels advocated and modeled integrated behavior.<br>• Strong push by NAVAIR to prioritize integration in program teams.<br>• Program/product identity prioritized over functional identity.<br>• Use of IPTs to bridge functional groups.<br>• Co-location of program management and systems engineering/engineering disciplines.<br>• Emphasis on effective communication across functional boundaries.<br>• Culture of shared responsibility for outcomes across NAVAIR and McDonnell Douglas. |

Source: Rebentisch et al (2017)

# F-18 Super Hornet: Summary of Integration Practices (continued)

| Integration Practices | |
|---|---|
| **People Competencies**<br>• Support at NAVAIR to develop integration competencies.<br>• Clear roles and authorities defined.<br>• Leadership selection based on experience and ability to foster relationships.<br>• Decisions made by capable people at the point where work is performed.<br>  | **Contextual Factors**<br>• Urgent aircraft replacement needed after A-12 program cancellation and need to use existing funding. Prior history of arms-length relationships seen as a barrier to effective program execution.<br>• The program budget was fixed by multiple stakeholders and there were requirements to stay within budgeted cost.<br>• The program was funded as needed to meet its execution requirements and reflect its priority in the Navy acquisition portfolio.<br>• Program complexity was reduced by using a derivative product strategy and leveraging existing organizational relationships.<br>• Mature technologies were selected to limit overall program scope.<br>• Non-essential upgrades were placed on a separate development path for later integration into the system. |

Source: Rebentisch et al (2017)

# Two Case Studies

- US Navy's F-18 Super Hornet

- Royal Australian Navy's Electronic Support Upgrade for the Anzac class frigate

# Electronic Support Upgrade for the Anzac Class Frigate

- Anzac class Navy frigate was first commissioned in 1996
  - Eight ships operated by the Royal Australian Navy
- Electronic Support (ES) systems gather information through passive analysis of electromagnetic radiations
  - to detect and distinguish between friendly and adversary emissions and provide warning if an attack appears imminent
- One component of a larger domain known as Electronic Warfare (EW)
  - Technically complex area
- Maritime Electronic Warfare Systems Program Office (MEWSPO) established within the Australian Defence's Capability Acquisition and Sustainment Group (CASG) managed the ES upgrade

# Setting the Context

- To save on costs in acquisition and sustainment, the decision was made to acquire a common ES system across several classes of Navy ships
- Team of four contractors
  - Exelis (now Harris Corporation) as the prime contractor
  - Jenkins Engineering Defence Systems or JEDS
  - Ultra Electronics
  - Southwest Research Institute (SwRI)
- Three additional contractors whose activities or systems must integrate with the ES system
  - BAE Systems-Australia (BAES-A) – Henderson Shipyard in WA
  - CAE Technologies
  - Saab Australia
- In addition, two CASG System Program Offices had to work closely together
  - MEWSPO (overseeing ES system acquisition) and the Anzac SPO (responsible for scheduling and overseeing ship maintenance and upgrades)

# Setting the Context (continued)

- There was a two-year period between selection of the common ES system and full funding approval for the Anzac ships
- Both the Project Manager and the Chief Engineer had engineering backgrounds
  - The Chief Engineer also had an operational background having been an EW operator with the Australian Navy
- Project Manager, Dan Keleher, obtained funding to support a series of risk-reduction workshops during the two-year period
  - Brought together all seven contractors to identify technical risks and mitigation strategies
- In 2013, the Electronic Support Upgrade project obtained full funding

# Setting the Context (continued)

- Ship upgrades are limited to specific windows of time when the ships are taken out the water and placed on a dry stand
- The ES upgrade for the Anzac ships was a high priority of the Chief of Navy
- The project looked for ways to accelerate system delivery

  ***"All along we kept focusing on how we could get the capability onboard more quickly without sacrificing quality or safety."***

  -- Dan Keleher, Program Director

- One strategy was to pre-install system components on individual ships while they were on the dry stand before the full ES system was developed and delivered. This included
  - Cabling
  - Mast
  - Foundations for equipment racks
  - Multi-function console

# Setting the Context (continued)

- This strategy saved having to re-open ship compartments at a later time
  - remaining system components could be installed when the ships were back in the water
- This “fitted-for-but-not-with” strategy was possible because of knowledge gained during the pre-contract workshops (e.g., length of cabling)
- While this activity was going on, it became clear that other maintenance and upgrade activities (outside the ES Upgrade project) were slipping schedule
  - The ship that was planned for installation of the first complete ES system (i.e., first of class) was almost six months behind its delivery schedule.

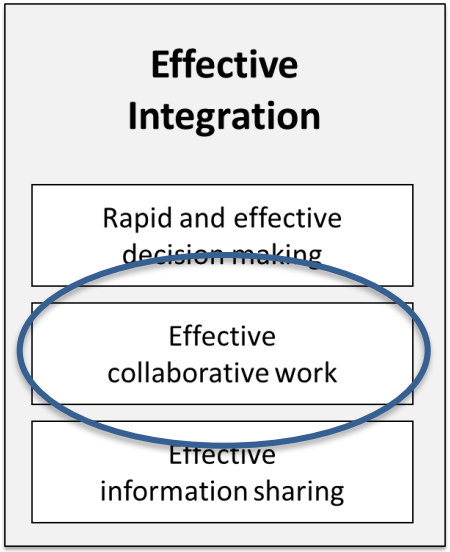
# Setting the Context (continued)

- In order to field the ES capability as quickly as possible, the project decided to switch the installation of the first system to another ship that would be returning to the water sooner and that had been "fitted for but not with" the ES system
  - That was done as soon as the full ES system was delivered to WA
- While this sounds simple, there were a number of planned activities tied to installation and test on the original first-of-class ship, including payment milestones
  - This switch required flexibility from both the government and contractors
- Outcome-focused attitude

**"We knew that the Chief of Navy wanted this capability as quickly as possible. When we ran into problems, such as the first ship slipping schedule, we didn't say 'tough, it's not our fault. We can't install the system.' Rather, we asked 'what can we do instead'? And we did it."**

# Promoting Effective Collaboration

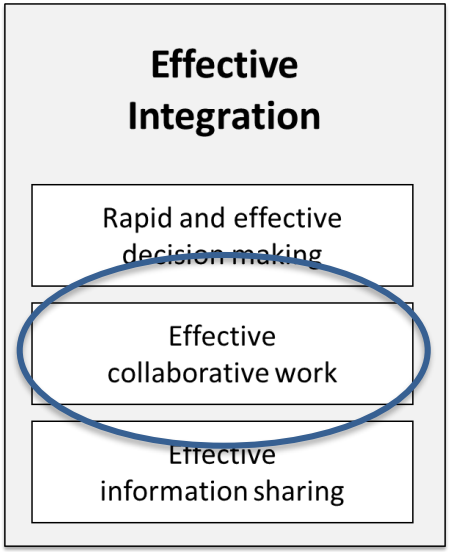
- The risk-reduction workshops set the groundwork early on for mutual respect and direct communications




***"On this project, we were empowered to talk to each other directly with no communication bottlenecks. All the players participated in the workshops. We were drawing boxes on a white board and talking about how to integrate them without getting too much into the weeds. Dan sat back and let it happen because he could see it was a healthy thing."***

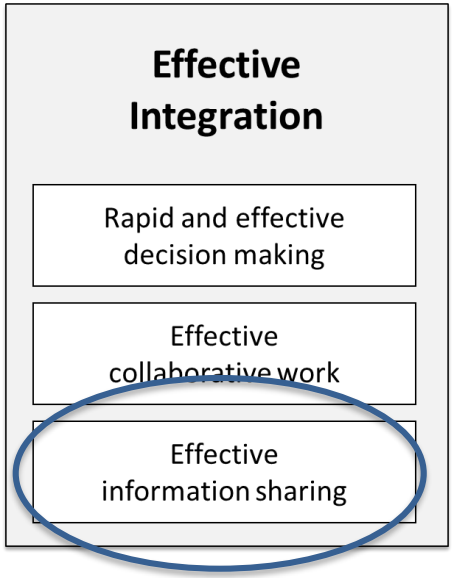
# Promoting Effective Collaboration

- The two government program offices, MEWSPO and the Anzac SPO, worked constructively and collaboratively with each other
  - A Project Implementation Plan clearly defined the roles and responsibilities of each of the SPOs



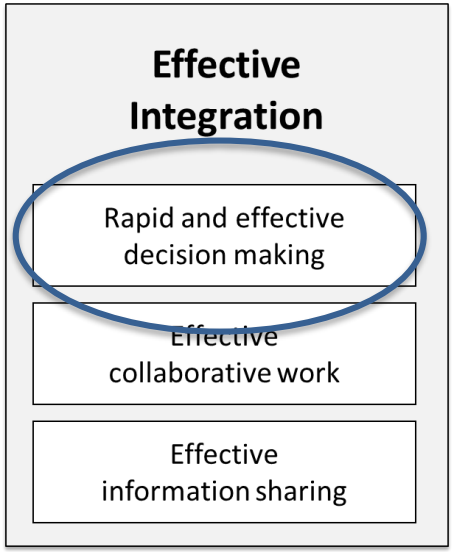
# Effective Information Sharing

- In addition to the risk-reduction workshops and direct communications, information was shared via computer simulations of each of the interfacing systems provided by the system developers
  - Saab for the Combat Management System
  - CEA for the phased array radar
  - Exelis for the ES system
- These computer simulations allowed any interfacing component or system to be tested early in their development against the simulated interfaces
  - Result was a relatively smooth integration and test of the actual systems



# Rapid and Effective Decision Making

- Demonstrated by the project's ability to adapt to changing circumstances, all the while maintaining a laser-like focus on delivering the capability as early as possible



# Anzac ES Upgrade: Case Study Summary

- As with the Super Hornet, leadership from the top is key

***"Dan Keleher understands that his role is to set expectations and let us do our work. He encourages an outcome attitude. He listens to us and doesn't just tell us what we should do. Throughout the entire project, Dan has worked with us rather than against us. There have been times we've called him at 11:00 at night…Gary Crawford has an amazing amount of experience and competency. He's very hard working but also relaxed. When he walks in, everyone calms down. We can always talk to Gary or to Dan about anything."***

**Postscript**

- On June 6, 2016, the ES capability installed on the Anzac class was approved for initial operations by the Chief of Navy after completing a successful series of sea trials and operational testing

# Royal Australian Navy's Anzac Class Frigate

| Integration Practices | |
|---|---|
| **Integration Processes, Practices, and Tools**<br>• PM/SE leadership sponsored early risk reduction workshops from 7 different companies delivering systems or subsystems to ensure seamless work<br>• Ensured contractors had direct links with each other to reduce third party bottlenecks | **Organizational Environment**<br>• PM/SE leaders worked closely to foster a laser focus on the outcome of delivering the required capability<br>• Navy flexed some of its traditional practices to allow for a more agile kick-off that eventually paid off in stronger performance |
| **People Competencies**<br>• Empowered team demonstrated creative problem-solving and "can do" attitude despite major barriers put in their way<br>• Team members creatively solved problems that emerged as a team, knowing they needed to keep the initiative on track | **Contextual Factors**<br>• High priority capability directed by the Chief of Navy to de delivered as rapidly as possible.<br>• Leveraged time when ships were taken out of the water for upgrades/repairs and installed "fit for but not with" system components (cables, equipment rack foundations, etc.). |


Source: Rebentisch et al (2017)

# Questions?


Source: ncchild.org


Marvin Nelson
marvin.nelson@pmi.org
Steve Townsend
stephen.townsend@pmi.org