FROM ACQUISITION DISASTER TO WORLD CLASS PERFORMANCE: A Case Study

Lifetime Achievement Talk for the 32nd International Forum on COCOMO® and System/Software Cost Modeling

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Haymarket, Virginia

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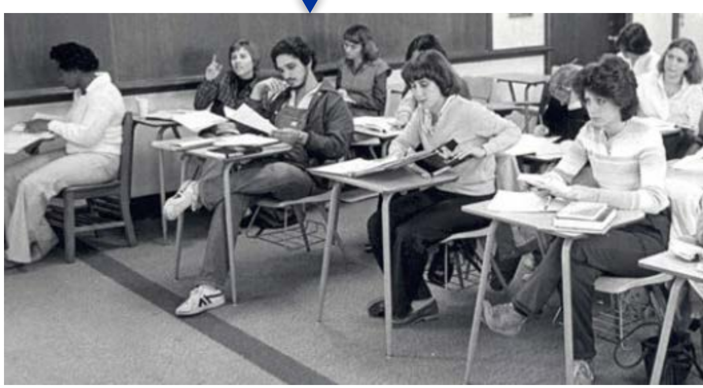
A Quick Stroll Down Memory Lane

- Beginnings in Cognitive Psychology
  - Experimental study of learning, memory, problem solving
  - My experimental subjects

cute lab rats



university freshmen (1970s)

programmers (early 1980s)

Main Areas of Interest

- Software Measurement
  - SEI Core measures
  - Practical Software and System Measurement (PSM)
- Cost and schedule estimation
  - Independent estimates for major acquisition programs
    - E.g., Heavy bomber study for Institute for Defense Analyses



- COCOTS
- Software sustainment/maintenance
- SCRAM
  - Framework for identifying root causes of schedule slippage
  - Techniques for schedule forecasting
- Today's presentation
  - case study of a successful acquisition program

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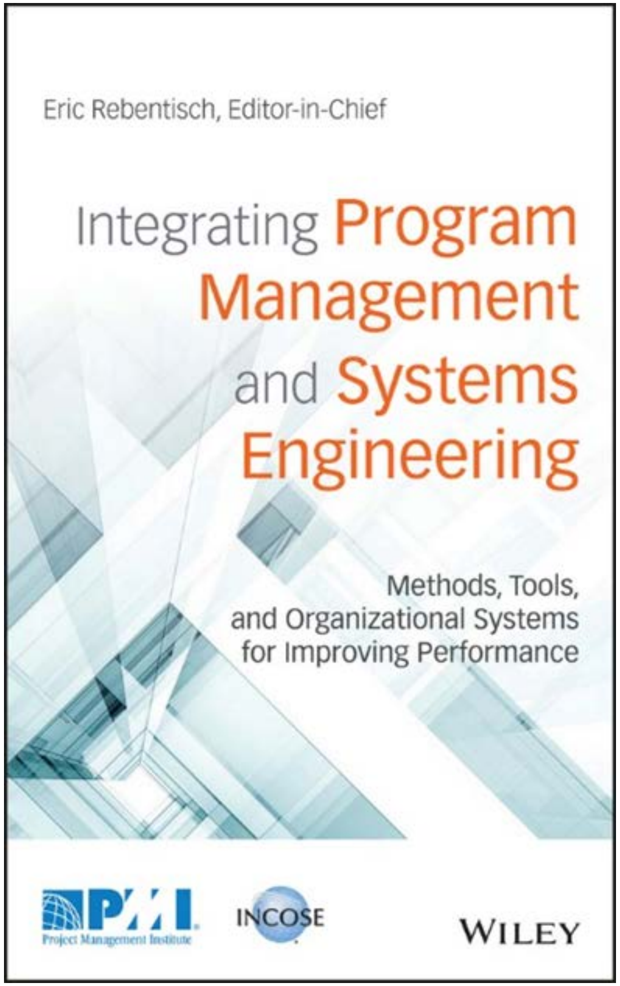
PMI-INCOSE-Sponsored Book

- This case study is presented in more detail as an entire chapter
- Even though I wrote this case study 20 years ago, it's a story that deserves to be told
- A lot of lessons, especially related to
  - strong, effective leadership
  - a culture of risk management



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Background

- In 1998, asked to write a case study of a successful acquisition
  - for US Deputy Assistant Secretary of Defense (Systems Engineering)
  - After a number general inquiries, the resounding recommendation was the F/A-18E/F Super Hornet
  - Conducted a series of interviews with the people who were part of that program
    - Both government and contractor

- In this presentation, as much as possible, I'll let the people interviewed tell their stories

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)
- Major subcontractors
  - Northrop (now Northrop Grumman)
    - aft fuselage
  - General Electric
    - engines
- Evolutionary design derived from the F/A-18C/D model
  - Increased range, survivability, carriage capability, growth capability and bring back
- Delivered on schedule, within budget and under weight

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

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Setting the Context - 2

- 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!

Setting the Context - 3

- F-18 Super Hornet is part of the US Navy's Naval Air Systems Command (NAVAIR)
  - Headquartered at Patuxent River Naval Air Station, Maryland

- At the time of the A-12 cancellation, NAVAIR was organized around strong functional stovepipes

> ***"We had strong functional management and weak program management. Each person reported up their own functional chain of command. The Program Manager subcontracted work to each of the functional organizations and was left herding cats."***
>
> -- Vice Admiral Joe Dyer, former Navy Program Manager

- Disagreements between functional organizations were elevated up the functional chains to be resolved at the top rather than at the level where they had surfaced

Setting the Context - 4

- 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 Proposal would start with an Operational Concept produced by the the operational side of the Navy (OPNAV), 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

Setting the Context

- Appropriate tradeoffs among functional disciplines were not being made
- August 1991 – review of high-level requirements
  - Navy and contractors had spent prior nine months working on a proposed concept
  - Everyone was optimizing from their perspective
  - Result was an aircraft that was over-weight and over-cost

"We don't have a program here. What we have is a mess."

--Captain Craig Steidle, F/A-18 Program Manager, 1991

Setting the Stage for Success

- This led to the "Twelve Days of August" which began the following Monday in St. Louis

> ***"The idea was that at the end of the twelve days, they would either have a viable, affordable program or there would be no program."***
>
> -- Larry Lemke, McDonnell Douglas F/A-18 General Manager, 1991

- High level objectives were outlined (essential requirements)
  - more range (fly farther without refueling),
  - improved survivability (increased stealth)
  - more bring back (weight of stores that could be brought back and landed on a carrier),
  - more carriage capability (could carry more bombs to a target), and
  - more growth capability built in (extra physical space for future growth)
  - Congress mandated that E/F could not exceed C/D model by more than 25%

Setting the Stage for Success

- Affordability was a big issue

> ***"We were told to question the 'what' and the 'how' of everything we did. What could we do to reduce weight and cost without impacting the high-level requirements?"***
>
> -- Jim Young, McDonnell Douglas Integrated Product Team Manager, 1991

- Came up with innovations to save weight and money
  - E.g., combined Navy-contractor Integrated Test Team for Development Test & Evaluation (DT&E)
  - 90% of avionics were common with C/D model (including software)

- Result was an aircraft that was an evolution from the previous model (C/D)

Getting it Right

- In 1992, new Concept of Operations for Acquisition Management in NAVAIR
- Move away from functional stovepipes to inter-disciplinary Integrated Product Teams (IPTs)
- F/A-18E/F Super Hornet was selected to be a prototype for implementing (IPTs)
- Joe Dyer selected as Program Manager

First Step: Co-location

- Dyer’s first step in breaking down the functional boundaries was to co-locate the system engineers and the program manager within the same building in Crystal City (Arlington) Virginia

- The heads of the different functional areas fought co-location

“The head of engineering protested by saying ‘You’re going to dilute our engineering resources. You’ll have our engineers worrying about contracting and finance’. To which I responded ‘You’re darn right’.

The head of logistics wanted all the logisticians together in Crystal City. So I let them stay together and I surrounded them with my team.”

-- Vice Admiral Joe Dyer, former Navy Program Manager

Defining ITPs – Product Focus

- 1994-1995: Definition of IPT structure and detailed procedures for how IPTs would work

"When we first started putting together IPTs, all of our functional groups wanted their own IPT - the Test and Evaluation people wanted a Test and Evaluation IPT, the logisticians wanted a Logistics IPT, the contracting officers wanted a Contracting IPT. By the time you got through, this looked just like where you came from. So we applied a test for IPTs; it had to be something the fleet asked for. 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

"The fleet and our foreign customers demand, for example, radars, landing gear, and weapons. They never send messages saying, 'Send us some test and evaluation', or 'send us some logistics.' Consequently...we have a radar team; we do not, and shall not, have a logistics or a T&E team."

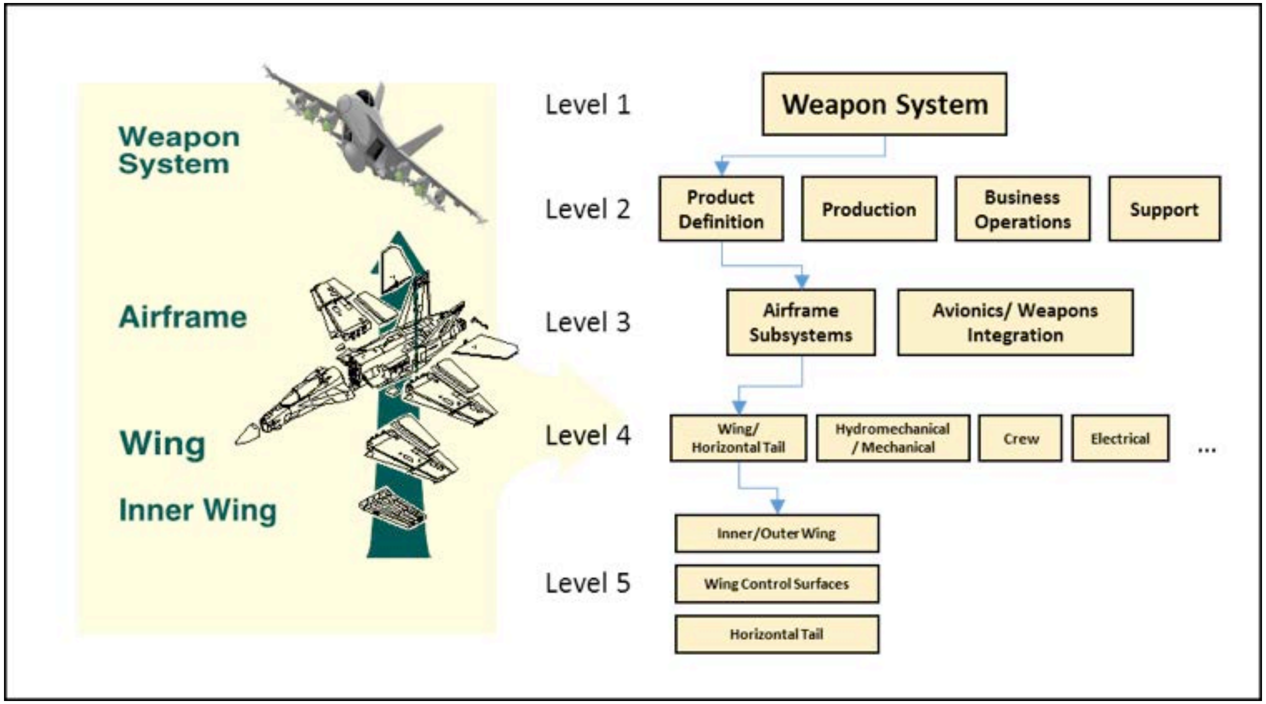
-- F/A-18E/F Program Operating Guide

IPT Structure: Government Side

- The Level 1 E/F IPT had two co-leads
  - Active duty military officer
  - Civilian with acquisition experience
- Two Level 2 IPTs
  - Air Vehicle
  - Propulsion
- Eight Level 3 IPTs
  - E.g., Propulsion was broken down into
    - Engines
    - Secondary Power
    - Electrical Power

IPT Structure: McDonnell Douglas

- Product-based work breakdown structure (WBS) was mirrored by the IPT structure
  - This structure was used for all management and technical reporting and measurement



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Six Key Concepts

1. Strong team culture
2. Individuals are empowered (given resources, authority and accountability) within clearly defined roles and responsibilities
3. The team leaders are key
4. Problems are surfaced early and openly and are solved at a low level
5. Technical conscience
6. High premium on quantitative information and communication

Strong team culture - 1

- A commonly expressed view from IPT leads
  – One person, no matter how smart, can never make decisions as well as a team

"We say to people, 'put your E/F hat on, join the team and learn all perspectives'. I'm a facilitator and a consensus builder. Team leaders are not defending their stovepipe but working together.

-- CAPT Jeff Wieringa, E/F Level 1 IPT Co-Lead

- Example - Engineering solution to an uncommanded roll during flight test was suggested by the test pilot who originally reported the problem

"In the old days, the test pilot would characterize the problem and let the engineers worry about fixing it. Now there is a collaborative relationship and the pilots can suggest solutions."

-- CAPT Jeff Wieringa, E/F Level 1 IPT Co-Lead

Strong team culture - 2

"We used to have responsibility for the quality of the product distributed all over the command. Now we say 'Mr. Level 1 IPT Lead, you're responsible for the product.' That was the shift that made us. Because all of the sudden, people who used to be adversaries - T&E, logistics - became the folks who are going to save you and keep you from being embarrassed, who are going to keep you from building a product that doesn't work."

-- Vice Admiral Joe Dyer, former Navy Program Manager

"I don't hear from the loggies anymore saying 'You dummy! Look at what you did to us'. As an example, recently we change the pylons to make them more stealthy. We installed a door to cover up the area. We left access holes so that the armament guys can see settings without having to open the door."

-- Rich Gilpin, the E/F Level 2 IPT Air Vehicle Leader

Strong team culture - 3

- The strong team culture extends to collaboration between government and contractors
  - Corresponding IPT structures facilitated joint problem-solving and communication
  - Government and contractor counterparts

- 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 a trust and 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

Strong team culture - 4

- It was everybody's job to be a team player
- Joe Dyer relayed the following scenario to illustrate this

> ***"We had a new government guy join us from another location. He stood up at a meeting and began by saying 'The contractor has failed to provide...'. You could have heard a pin drop, the other members were so quiet. We realized that we hadn't heard that kind of language for a long time. And I told him 'What you just said is not acceptable. If the contractor hasn't provided something, it's your problem too. What are you doing about it?***
>
> -- Vice Admiral Joe Dyer, former Navy Program Manager

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Individuals were empowered (given resources, authority and accountability) within clearly defined roles and responsibilities

"I can act a lot more autonomously now. I have much more freedom to do things as long as I operate within policy and procedures. I don't have to ask permission. I can just do it. But I do have to keep people informed about what I'm doing. I like this way better.

It's important to spend time at the beginning defining roles and responsibilities. You can't just assume that people automatically know. "

-- Rich Gilpin, the E/F Level 2 IPT Air Vehicle Lead

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The team leaders are key

- IPT leads have to function as consensus builders but also be willing to make a decision when consensus can't be reached within the team

"We're asking the leaders at each level to have a lot of breadth. If you don't have the right people, you're going to have problems."

-- CAPT Jeff Wieringa, E/F Level 1 IPT Co-Lead

"The F/A-18 is a premier program. We get the best people. IPTs work great here."

-- Rich Gilpin, Level 2 IPT Air Vehicle Lead

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Problems are surfaced early and openly and are solved at a low level

- People were encouraged to raise risks and problems
  - They only got into trouble for holding back information

"Our definition of good management is recognizing problems and asking for help early on. Anybody can define a risk. It's okay to have risks, we just need a risk mitigation plan.

There are three things that are necessary for an effective risk management system. First, you want to identify potential problems early. Secondly, you've got to have management that doesn't shoot the messenger. It's critical that your customer has the same opinion. You have to have people who don't go ballistic when they have a problem. And third, you've got to have management that will provide help when asked. The person at the top has got to have that attitude. And in asking for help, you have to be able to say what you need."

-- Henry Harchburger, Level 3 IPT Lead for Airframe Technology, McDonnell Douglas

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Technical conscience

- IPT members reported to their IPT Lead and also within their own functional area
- This matrix structure allowed for flexible staffing of IPTs
  - It also allowed each person to raise issues within their own functional area when necessary

"We were very careful to maintain a separate path for what we call 'technical conscience'. You cannot have IPT members who are oppressed by a strong team leader or who feel so heavily burdened by an integrated program that they swallow something that they just in their own conscience do not believe is right. So we've been careful to maintain a separate chain of technical conscience."

-- Vice Admiral Joe Dyer, former Navy Program Manager

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High Premium on Quantitative Information and Communication

- Communication within and between IPTs was key

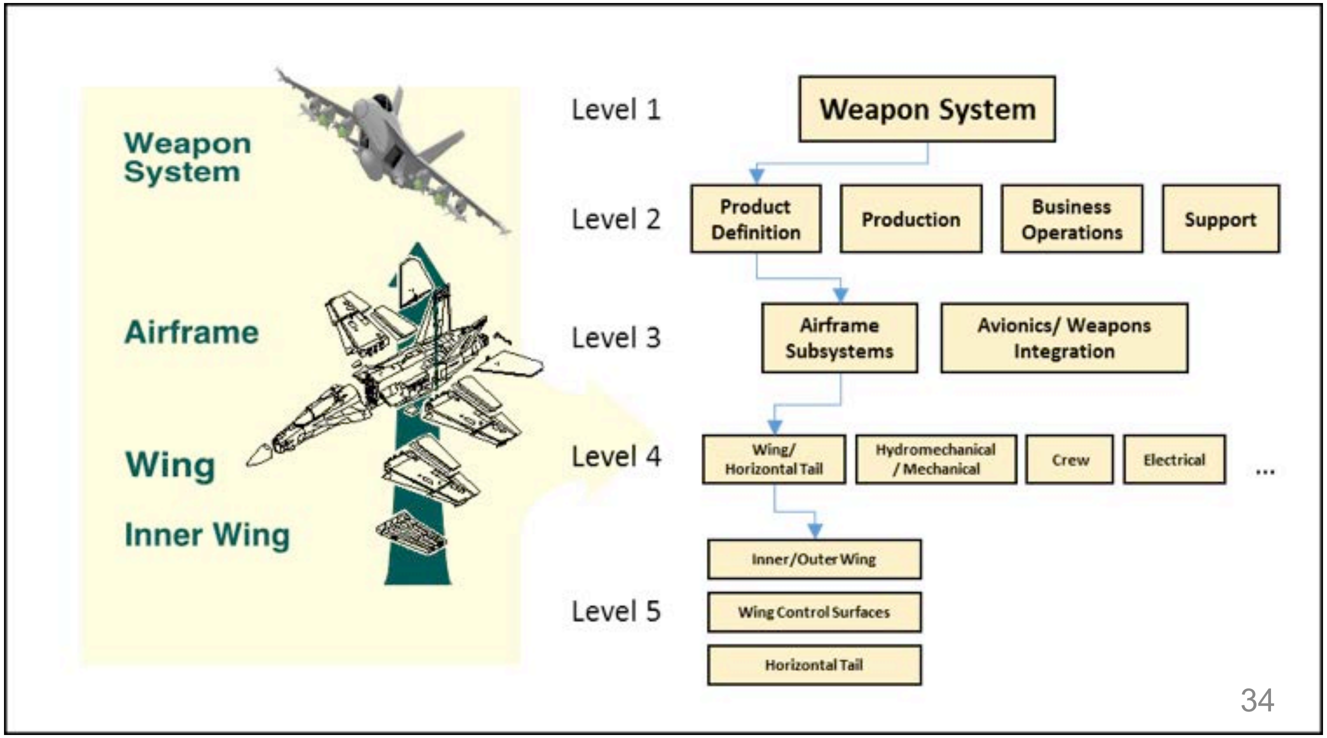
  "With IPTs, we have much more data. We're weighing things that we never considered before because we have so much more information. This can be frustrating to people. IPTs give you knowledge so that each discipline understands what other disciples really do. This is important because building aircraft is all about compromise."

  -- CAPT Jeff Wieringa, E/F Level 1 IPT Co-Lead

- Heavy reliance on detailed quantitative information
  - common, central database used by both government and contractor to manage the program
  - reviewed weekly through joint government-contractor status meeting
  - both sides working from the "same sheet of music"

High Premium on Quantitative Information and Communication - 2

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



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High Premium on Quantitative Information and Communication - 3

- Cost, schedule and technical measures were tracked down to Level 5 of the WBS
  - Problems in any of these areas were immediately apparent with clear accountability for who owned the problem
  - This structure served as the mechanism for integrating program management concerns (cost, schedule performance) with technical concerns (TPMs)

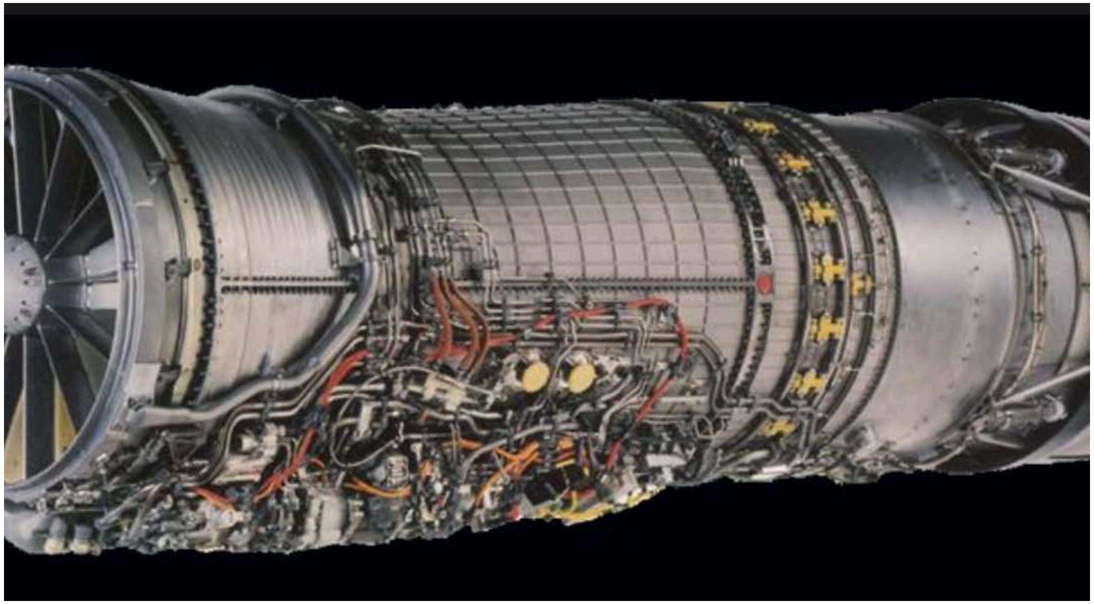
High Premium on Quantitative Information and Communication - 4

- Earned value used throughout the program as a management too

> ***"Earned value has been the centerpiece of the way we've measured the program. Early in the development, we set up weekly reporting of these measures. So I'm never more than a week away from knowing when I'm in trouble and where I'm in trouble...It's very hard to find leading indicators in this business but we found that granular earned value provides us, if not with a leading indicator, at least a cycle time to identify problems."***
>
> -- Vice Admiral Joe Dyer, former Navy Program Manager

Result of the Six Key Concepts: Rapid and Effective Decision Making

- Engine Stator Problem



Example of Rapid and Effective Decision Making - 1

- The Super Hornet has two GE engines
- During flight test, a stationary air foil fractured, causing significant damage to the engine and a high pressure stall
- The test pilot landed safely
- An examination of the remaining test aircraft showed fracturing in other engines as well
  - The problem wasn't just the result of a special combination of conditions that this one test aircraft met during this flight

Example of Rapid and Effective Decision Making - 2

- A meeting was convened with NAVAIR, General Electric as well as outside experts from
  - Air Force and Navy research labs
  - Department of Energy
  - MIT and Purdue University
- All data were discussed
- Fifty different action items were identified relating to different tests that could be performed in order to identify the cause of the fracturing
- One of the hypotheses was then verified through testing

Example of Rapid and Effective Decision Making - 3

"Under the old way of doing things, GE wouldn't communicate issues until they had a plan to go forward. They felt that problems and their solutions were entirely their responsibility.

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."

-- Steve Bizzaro, the E/F Level 2 IPT Leader for Propulsion

F-18 Super Hornet: Case Study Summary

- Much more detail is in the PMI/INCOSE book (an entire chapter)

- Summary Points
  - Strong, effective senior leadership was key
    - both government and contractor
  - Aircraft development is all about tradeoffs between cost, schedule and technical capability
    - Those tradeoffs were made right from the beginning
  - Reduced a lot of risk by evolving an existing design from the earlier C/D model
  - The product-based WBS served as an effective mechanism for integrating program management concerns (cost, schedule performance) with technical concerns (Technical Performance Measures)
    - provided visibility into where problems were occurring and who was responsible for fixing them
    - the impact on the product was clear

My Latest Project

- Writing a case study on the F-35 Joint Strike Fighter
  - Focus is on the turn-around of the program from the dark days of the Nunn-McCurdy Breach in 2010 to the current time
  - Also on dispelling a lot of the misconceptions that have appeared in the media about the program
- Interviewed a number of the major participants on the government and contractor side
- Since 2010, I have participated in nine separate reviews of the F-35, beginning with the Nunn McCurdy
- Forecasted schedule for both the on-board software and the ground-based logistics system beginning in 2013
- Will close this presentation with an important lesson learned from doing those forecasts

Lessons Learned in Forecasting Schedule for the F-35

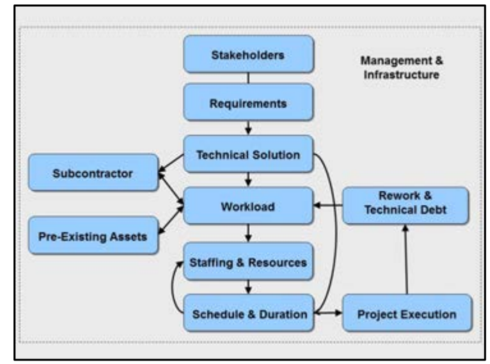
- Massive amounts of software
  - Almost 10M SLOC on-board the aircraft ("flying computer")
  - 20M SLOC ground support
- The prime contractor, Lockheed Martin, has excellent and extensive software data
  - Size
  - Effort
  - Defects
- Onboard software is developed using incremental waterfall
  - Main size measure is SLOC
- Logistics system follows a modified Agile approach
  - COTS intensive
  - Main size measure is story points

F-35 Program Reviews

- Seven of the nine reviews were conducted for the Australian government using a framework, SCRAM, developed by myself, Brad Clark, and two Australian colleagues
  - Adrian Pitman, Defence
  - Angela Tuffley, Redbay Consulting

scram™ SCHEDULE COMPLIANCE RISK ASSESSMENT METHODOLOGY

- Schedule Compliance Risk Assessment (SCRAM)
  - Includes a thought model for identifying root causes of schedule slippage
  - Uses two different methods for forecasting schedule
    - Schedule Risk Assessments
      - Three point estimates with Monte Carlo simulation
    - Dynamic estimation model for software
      - SLIM-Control
  - To date, we have conducted SCRAM Reviews of 32 different programs
    - Australia, UK, USA



- There are people from a number of different organizations making cost and schedule forecasts of the F-35 software
  - government, industry, outside organizations

- Over time, our SCRAM estimates proved to be the most accurate
  - In large part, due to our approach to collecting and validating data

SCRAM Testimonial

"The SCRAM reviews on the F-35 Program were extremely helpful to us. Within two weeks of coming in, the SCRAM reviews were able to point out areas where we were going to have problems. SCRAM also gave us new techniques for predicting how long the software development was going to take. In 2014, I briefed the SCRAM results to the Defense Acquisition Board. Of all the organizations that were making estimates, the SCRAM estimates, in hindsight, were the most accurate."

-- Lt. Gen. Chris Bogdan, Program Executive Officer, F-35 Program (24 March 2017)

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Lessons Learned in Forecasting Schedule on the F-35

- Data comes from the contractor(s) – must be validated by the contractor(s)
  - Never take data and just "run with it"

- The majority of time "modeling" should be spent understanding, summarizing and validating the data with the contractor
  - Especially critical in a large, complex program
    - F-35 data are contained in massive spreadsheets with hundreds of columns and thousands of rows
  - That's a critical step often missed by estimators
  - Running the model is the easy part

- I **always** show the results to the contractor(s) first
  - I don't surprise them by having the results "pop up" at a briefing to someone else
  - This goes a long way to building trust and future cooperation

Questions?

Source: ncchild.org


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