Seven Key Principles of Program and Project Success – A Best Practices Survey

NASA Project Management Challenge Conference

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I. Introduction

Organization Design Team (ODT) Motivation

"The organizational causes of this accident are rooted in ... history and culture, including original compromises that were required to gain approval ..., subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization ... as operational rather than developmental, and lack of an agreed national vision for human space flight. [Detrimental] cultural traits and organizational practices were allowed to develop ..."

Columbia Accident Investigation Board Report Volume I, August 2003, pg. 9 (Emphasis added.)

ODT Charter: Develop an Agency capability to design, model, simulate, analyze and understand our "human systems" (i.e. our program, project and line organizations) with the same rigor we apply to our flight and ground mission systems.

Organization Design Team Membership

Name	Organization	Title
Vincent J. Bilardo, Jr.	NASA Glenn Research Center	Co-chair of Organization Design Team; GRC Crew Launch Vehicle Project Office
Dr. John J. Korte	NASA Langley Research Center	Co-chair of Organization Design Team; Chief, Vehicle Analysis Branch
Dallas Bienhoff	The Boeing Company	Chief Architect, Space Exploration Systems
Darrell R. Branscome	SAIC Hampton, Virginia	Senior Systems Engineer
David Cheuvront	NASA Johnson Space Center	Senior Systems Engineer, Exploration Systems Engineering Office
Dr. Robert L. Chick	The Boeing Company	Lead, Boeing Best Practices
Walter Dankhoff	SAIC/Space Propulsion Synergy Team	Chairman; Retired NASA HQ, GRC
Freddie Douglas, III	NASA Stennis Space Flight Center	Head, Systems Management Office
Dale Dugal	Hernandez Engineering Incorporated	Senior Product Assurance Engineer, MSFC Support
Joseph R. Fragola	Valador, Inc.	Vice President
Thomas J. Gormley	Gormley & Associates	President
Patrick Gorman	ePM, LLC	Director of Development
Dr. Walter E. Hammond	Jacobs Engineering, Sverdrup	Senior Systems Engineer, MSFC Support
James J. Hollopeter	Earth Space Applications	President
Kevin J. Langan	SAIC – Hampton, Virginia	Senior Systems Engineer
Neal Lovell	SAIC – Huntsville, Alabama	Chief Technical Officer, Space Technology Operations
Albert E. Motley, III	NASA Langley Research Center	Senior Systems Engineer, Systems Management Office
Deborah J. Neubek	NASA Johnson Space Center	Deputy Manager, Advanced Design Office
Mark Prill	NASA Marshall Space Flight Center	Head, Technology Requirements Planning
Randy Sweet	Lockheed Martin Corporation	NGLT Deputy Program Manager
Dr. Alan Wilhite	National Institute of Aerospace	Langley Distinguished Professor
Keith L. Woodman	NASA Langley Research Center	Systems Engineer, Space Access & Exploration Program Office

ODT Investigation Process

- Track 1 – Lessons Learned: Invite lectures from veteran program managers, system engineers, and academics from current and historical complex technical programs/projects in order to identify organizational best practices and lessons learned.

Focus of this presentation

- Track 2 – Tools & Methods: Identify tools, methods and databases that could be used by NASA to design, model, simulate, and assess future program, project, and line organizations.
- Track 3 – Pilot Studies: Apply the most promising tools and methods identified in Track 2 in a series of pilot studies to assess their usefulness to future NASA programs and projects, focused on the Vision for Space Exploration.
- Track 4 – Knowledge Capture: Capture the knowledge developed in tracks 1-3 into a "toolkit" to enable a broader dissemination and adoption of more rigorous project formulation and organization design best practices across the agency.

Please see: http://pmtoolkit.saic.com/

Track 1 - List of Invited Lectures

1. **Aaron Cohen**, Professor Emeritus Texas A&M University and former Center Director, Johnson Space Center, "Comments about the Apollo Program".
2. **Dr. Roger Launius**, Chair, Division of Space History, National Air and Space Museum, Smithsonian Institute, Washington, DC, "Reflections on Project Apollo".
3. **Sherman Mullin**, President, Lockheed Martin Skunkworks (Retired), "Have Blue & F-117A Stealth Fighter Effective Rapid Prototyping".
4. **Gwynne Shotwell**, VP for Business Development, Space Exploration Technologies (SpaceX), "Space Exploration Technologies (SpaceX)".
5. **Dan Dumbacher**, DC-XA and X-37 Program Manager, NASA Marshall Space Flight Center, "DC-XA Program".
6. **John Muratore**, X-38 Program Manager, NASA Johnson Space Flight Center, "X-38 Program".
7. **Ming Tang**, Deputy Director for Military Programs, NASA Langley Research Center, "National Aero-Space Plane Organization and Management Lessons Learned".
8. **Walt Dankhoff**, Ex Sec. SPST, Retired NASA (GRC, HQ), "Review of the Nova / Super Saturn Program with a Focus on the M-1 Rocket Engine".
9. **George Drakeley**, Deputy Program Manager for Virginia Class Attack Submarine Program, "Virginia Class Submarine".
10. **Paul Wiedenhaefer**, Consultant to the JSF Program Office, "JSF Requirements Definition Process & Lessons Learned".
11. **Major Andrew Chang**, Deputy Chief Engineer, EELV Program Office, USAF Space and Missile Center, Los Angeles AFB, "EELV SPO Overview".
12. **Freddie Douglas**, NASA Stennis Space Center, "Customer's Perspective of Space Launch Systems Development Process".

13. **Tim Brady**, NASA Johnson Space Center, "Framework for Evaluating Architecture, Technology and Organization Options".
14. **Dr. William Starbuck**, Stern School of Business, New York University, "Keeping Organizations Effective Over The Long Run".
15. **Dr. Elisabeth Paté-Cornell**, Management Science and Engineering, Stanford University, "On Signals, Response and Risk Mitigation: A Probabilistic Approach to Precursors' Detection and Analysis".
16. **Dr. Walter Hammond**, Jacobs Engineering/Sverdrup, "Optimizing Synergetic Organizations".
17. **Dr. Richard T. Beck**, NASA Director of Resources Management, "Assessment of Interagency Program Management Approaches".
18. **Russ Turner**, President, Honeywell Engines, Systems & Services and Former CEO of United Space Alliance, "Contractor Perspective On The Space Flight Operations Contract (SFOC)".
19. **Dr. John Sterman**, Director, Massachusetts institute of Technology Systems Dynamics Group, "Learning and Process Improvement in Complex Organizations".
20. **Stanley Schneider**, NPOESS Integrated program Office, "National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office".
21. **Richard H. Buenneke**, Senior Aerospace Engineer, The Aerospace Corporation and CAIB Consultant, "On Not Confusing Ourselves: Insights on Risk, Organization and Culture from the Columbia Accident Investigation".
22. **David L. Christensen**, Lockheed Martin Space Systems, "Space Program Lessons Learned/Best Practices".
23. **Jim Snoddy**, NASA Marshall Space Flight Center, "Defining and Applying Insight".
24. **Greg Allison**, Hernandez Engineering, NASA Marshall Space Flight Center, "Private Venture: Kistler K-1".

Chapter II –
Seven Key Principles of Program and Project Success

Seven Key Principles of Program and Project Success

1. Establish a Clear and Compelling Vision.
2. Secure Sustained Support “from the Top”.
3. Exercise Strong Leadership & Management.
4. Facilitate Wide-Open Communication.
5. Develop a Strong Organization.
6. Manage Risk.
7. Implement Effective System Engineering and Integration.

Seven Key Principles Evident in the Invited Lectures

Program Organizations	Key Principles of Success (from Table 2)						
	1	2	3	4	5	6	7
Apollo	+	+	+	+	+		+
ALS/NLS		–	+	+			
DC-XA SSTO	–	–		+	+	–	+
EELV			+	+		+	
Have Blue/F-117A	+	+	+	+	+	+	
Joint Strike Fighter		+	+	+		+	+
K-1 Launch Vehicle		–			+		
National Aerospace Plane		–			–	–	
Nova Super Saturn M1			+	+			
NPOESS	+	+			+		+
Space Exploration Initiative (1987-91)	–	–					
Space Flight Operations Contract					–		
Space X Falcon	+	+	+		+		
Space Shuttle		–		–	–	–	
Virginia Class Nuclear Submarine		+	+	+	+		+
X-33	–	–		+		–	
X-34							
X-37							
X-38		–		+	+	+	+

\+ *Strong implementation of key principle found*

\- *Weak implementation of key principle found*

No evidence of key principle found

Principle 1. Establish a Clear and Compelling Vision

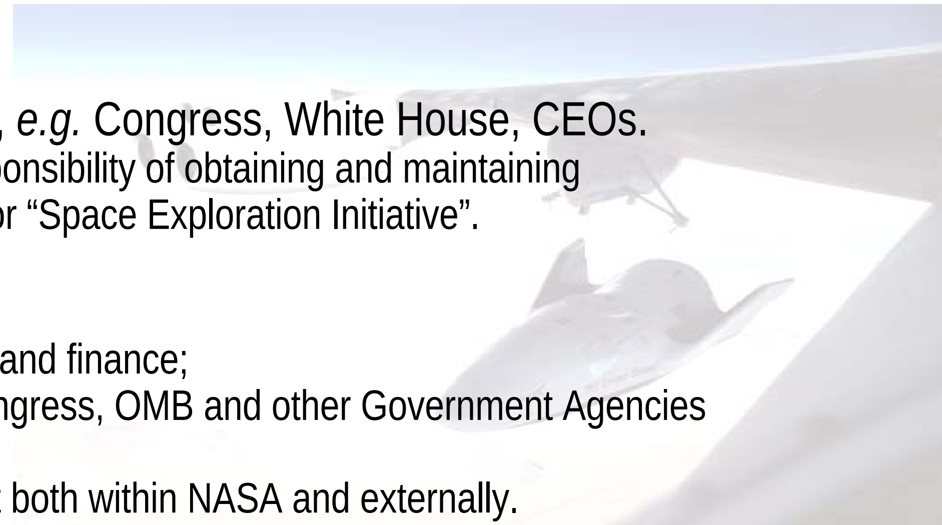
- Implementation Techniques:
  - Top organization leader must focus the program goals and mission, and clearly enunciate the vision of the future.
  - Organizational leaders can then develop a plan consistent with the focused goals and requirements. This facilitates team focus and provides a means to communicate the vision to the general public.

- Successful Program Examples:
  - Apollo Program.[1,2*]
  - 2004 Vision for Space Exploration.
  - F-117A Stealth Fighter.[3]
  - SpaceX: A single focused goal – significant improvement in reliability and cost.[4]
  - NPOESS.[20]

- Unsuccessful Program Examples:
  - DC-XA.[5]
  - 1987-1991 Space Exploration Initiatives.
  - X-33.

*See *Section III-Invited Lecture Synopses* for references.

Principle 2. Secure Sustained Support "from the Top"



- <u>Implementation Techniques</u>:
  - Develop/maintain Program Protectors, *e.g.* Congress, White House, CEOs.
    - NASA Administrator has primary responsibility of obtaining and maintaining support from the top (White House) for "Space Exploration Initiative".
  - HQ Program Management must:
    - Develop overall Program Plan;
    - Sell the Program, and obtain support and finance;
    - Ensure an effective interface with Congress, OMB and other Government Agencies as needed; and
    - Promote and protect program interest both within NASA and externally.
    - Isolate Programs from non-value added, de-focusing requirements.

- <u>Successful Program Examples</u>:
  - Apollo Program Protectors: Presidents Kennedy and Johnson, NASA Administrator James Webb.[1,2]
  - F-117A: Program Protectors: Senators, Staff, DoD, USAF, LMCO CEO.[3]
  - JSF: Dr Paul Kaminski (USD AT&L).[10]

- <u>Unsuccessful Program Examples</u>:
  - ALS/NLS, DC-XA[5], X-38[6], NASP[7].

Principle 3. Exercise Strong Leadership & Management

- Implementation Techniques:
  - Practice Sound Project Management.
    - Communicate a clear and credible set of key objectives.
    - Organize and conduct Program Reviews with all program elements represented; then be decisive and move forward.
    - Balance, link, and closely control schedule and budget.
  - Define Clear Authority and Accountability.
    - Maintain an "open door" policy; be willing to take the time to listen to team members.
    - Clearly define each employee's deliverables and how they map into the bigger picture.
    - Limit required reporting to only the minimum information needed to effectively manage the program.
    - Delegate and document responsibility and decision making authority down to the lowest appropriate level in the organization.
    - Hold every employee accountable to deliver on time, on budget.
    - Provide customer insight at only the level required to ensure contractor performance.
  - Identify and Develop Leaders.
    - Assemble & organize a team of individuals with the capabilities and special expertise needed to meet objectives.
    - Strong Leadership is required on BOTH sides of the aisle – Industry and Government Teams.
  - Demonstrate Uncompromising Ethics
    - High integrity (ethics, follow-through, honesty) builds respect and develops a team committed to achieving the leaders' goals.
- Strong Implementation Examples:
  - Apollo Program[1,2], M-1 Rocket Engine R&D Program[8], F-117A[3]; SpaceX[4], Virginia Class Submarine[9], ALS/NLS, JSF[10], EELV[11].

Principle 4. Facilitate Wide-Open Communication

- Implementation Techniques:
  - Senior leaders must foster open and honest communication without retribution.
    - Do not hide bad news, in fact bad news should be broadcast first!
  - Utilize "open door" policy to encourage upward communication.
  - Downplay the "cult of personality" culture.
  - Emphasize person to person (eyeball-to-eyeball) communication; do not overly rely on e-mail, voicemail, etc.
  - Walk around the office, shop floor, etc. as much as possible.
  - Praise in public, criticize in private.

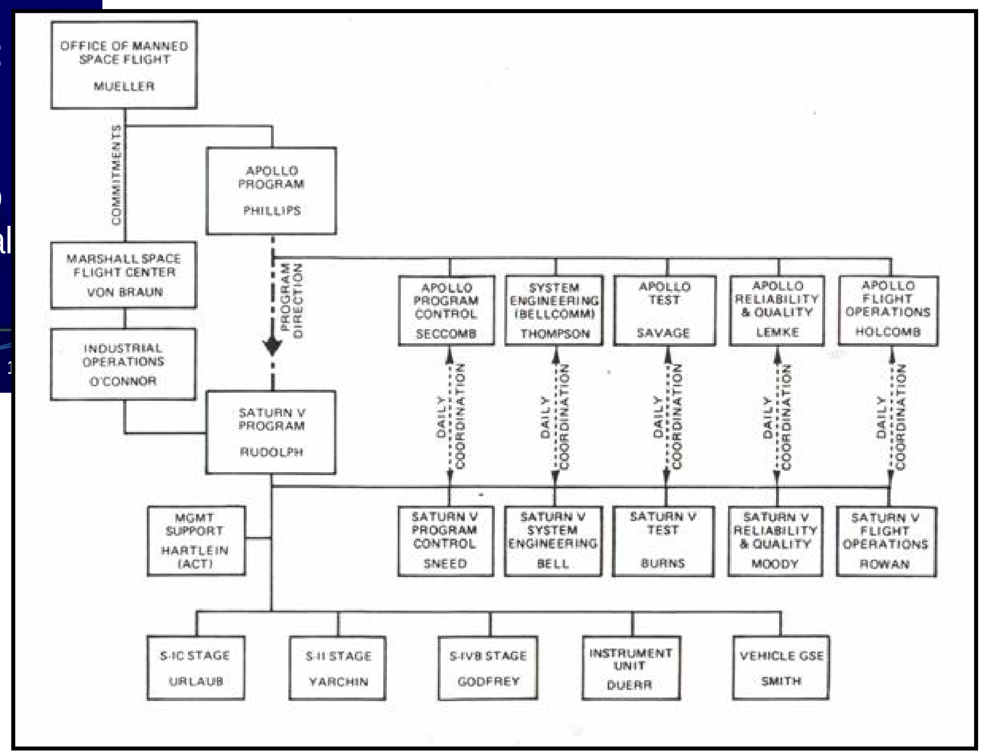
- Strong Implementation Examples:
  - DoD: F-117A.[3], Virginia Class Sub[9], JSF[10], ALS/NLS, EELV[11]
  - NASA: Apollo, M-1 Rocket Engine for Super Saturn NOVA.[8,] X-38[6]

- Weak Implementation Examples:
  - Space Shuttle[21]

Apollo Program – Wide Open Communication at Work!

DISTRIBUTED PROGRAM OFFICE
MULTIPLE LINES OF COMMUNICATION

- Example: Apollo Program Office Began in Washington, had Branches in MSFC, JSC, and KSC which in turn had counterparts at each of the Major Contractors
- Each Program Office had Five Functional/Staff Offices: 1) Program Control, 2) Systems Engineering, 3) Test, 4) Reliability and Quality and 5) Flight Operations
- The Functional Offices provided Daily Status reports to and from Their Counterparts, thus Achieving Near Total Program Visibility

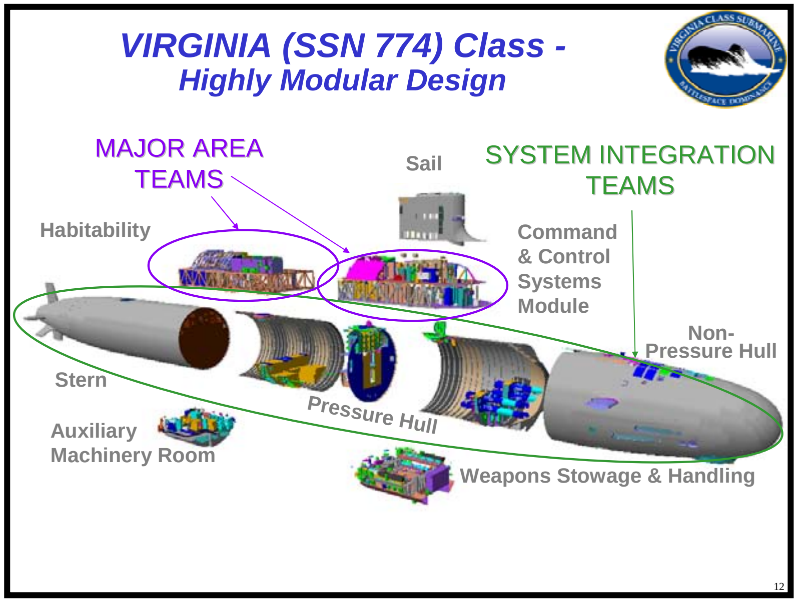


Principle 5. Develop a Strong Organization

- Implementation Techniques:
  - Align Culture, Rewards and Structure.
    - Reward desired behavior throughout the organization.
    - Reward good performance (sometimes outside of normal policy).
  - Establish Clean Organizational Interfaces.
    - Design the program organization to mirror the system architecture.
    - Avoid government-enforced contractor teaming.
      - Let the prime contractor select subs to keep accountability clear.
      - Clearly define and document responsibilities, authorities and accountability of organization on each side of "interface".
  - Create a Learning Organization.
  - Utilize Small Teams.
    - Co-locate all team personnel in same facility whenever possible.
    - Select team members with the best technical expertise and experience.
  - Apply organizational analysis tools and techniques to supplement program manager's judgment.

- Strong Program Examples:
  - Apollo[1]
  - F-117A Stealth Fighter[3]
  - SpaceX[4]
  - NPOESS[20]
  - Virginia Class Submarine[9]
- Weak Program Examples:
  - NASP[7],
  - Space Shuttle[18,21]

Virginia Class Submarine – Strong Org via IPPD*



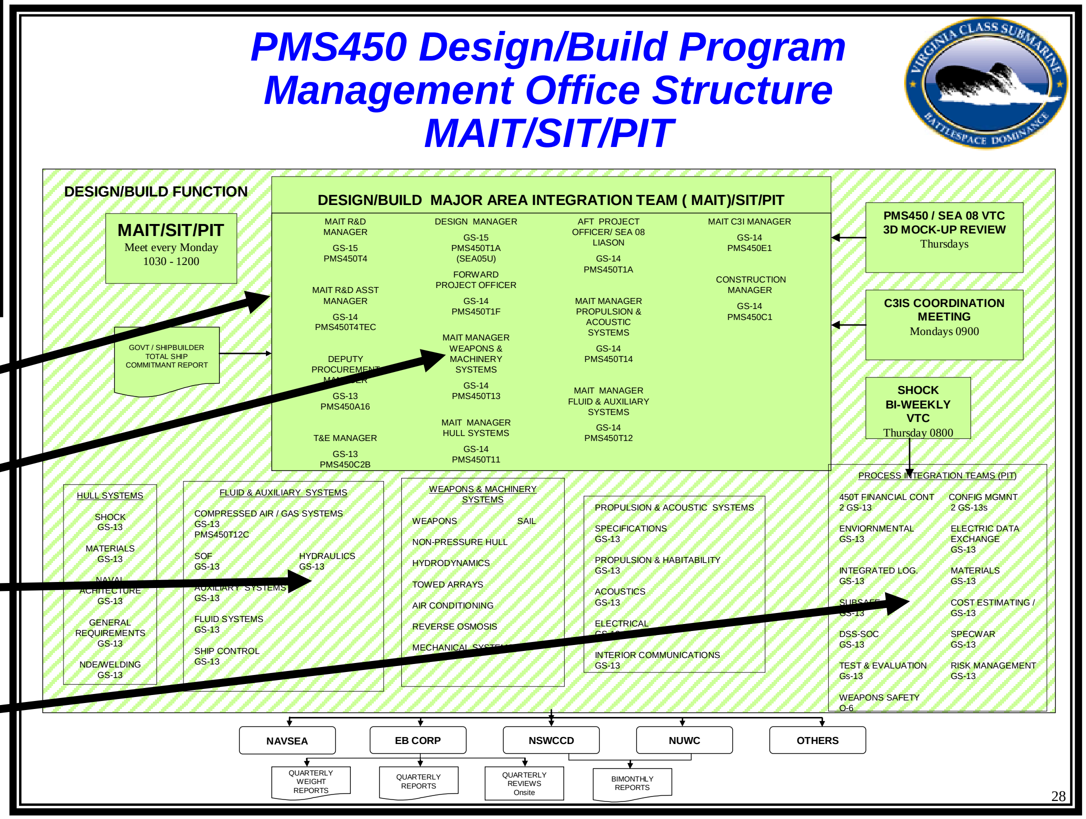
*** IPPD = Integrated Product and Process Development**

MAIT = Major Area Integration Team

MAT = Major Area Teams

SIT = Systems Integration Teams

PIT = Process Integration Team

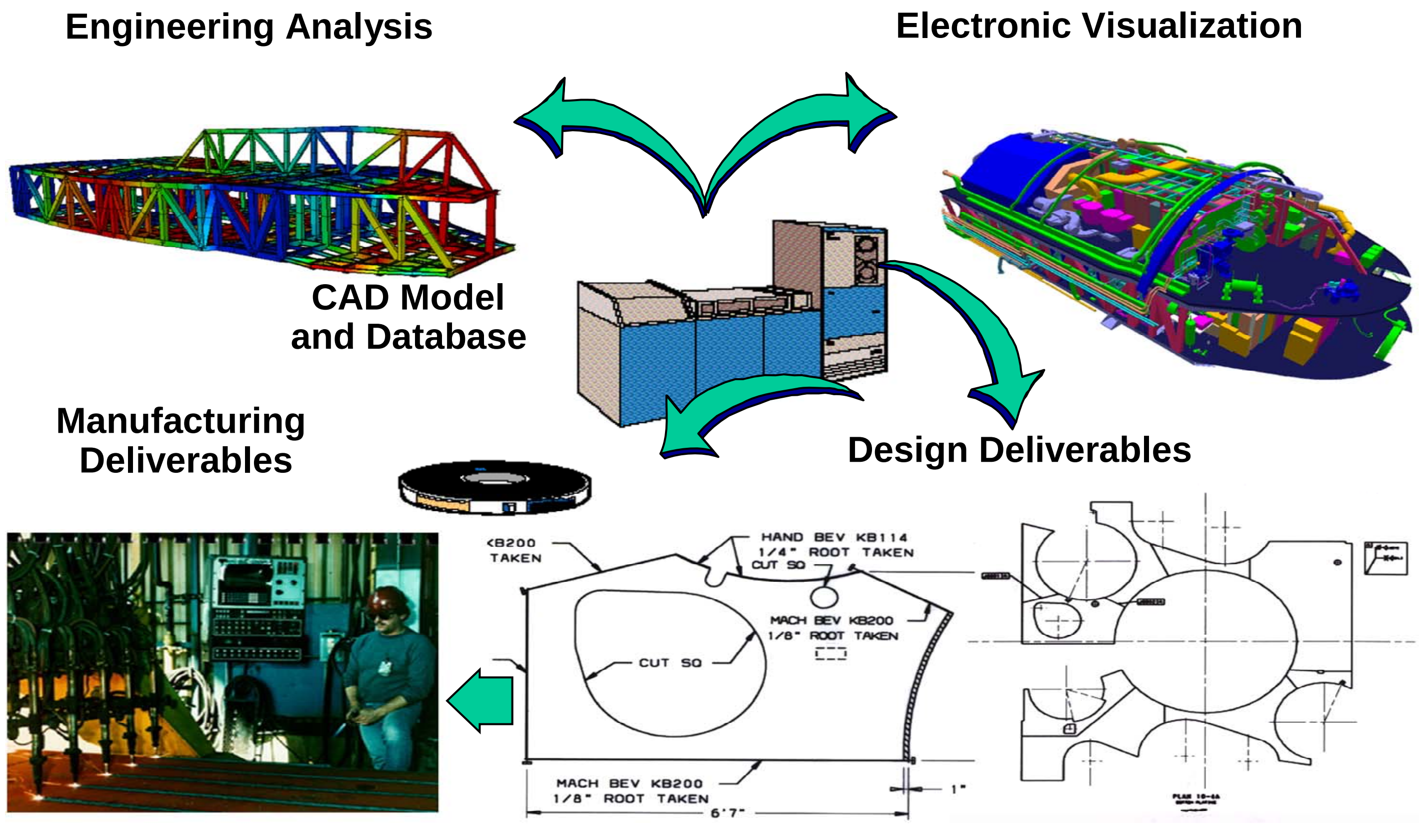


- Implementation Techniques:
  - Establish a living risk management process.
    - Investigate and Organize Relevant Historical Information (Developmental and Programmatic, as well as Safety and Mission Risk).
    - Construct and Validate Logical Models.
    - Continually Update Process with Newly Acquired Information.
    - Identify and Track Precursor Indicators of Potential Trouble Spots.
  - Employ rapid prototyping.
    - Use Realistic Modeling and Simulation to complement rapid test approach.
    - Prototype Early, Fast, and Often.
      - Build-Test-Learn cycle.
      - Validate Requirements as early as possible in the system life cycle.
  - Perform frequent integration tests.
      - These can be defining moments for a program.
      - Push for opportunities to bring things together for early integration and validation.
      - Assess how integration is going without waiting to the end of the project.
- Strong Examples:
  - X-38[6], JSF[10], F-117A[3], EELV[11]
- Weak Examples:
  - Space Shuttle[15,21], NASP[7], X-33

Principle 7: Implement Effective Systems Engineering & Integration

- Implementation Techniques:
  - Develop Clear, Stable Objectives from the Outset.
    - Limit top level program requirements to one page.
    - Establish and focus on achieving key driving requirements.
    - Take the necessary time on the front end of each program spiral to develop and stabilize the requirements, and develop consensus around them!
    - Identify what the system has to do, not how to do it.
    - Design into the system state-of-the-art automated tracking of requirements for the operational phase.
  - Use Modern Analytical Tools and Methods to:
    - Simulate system behavior before bending metal.
    - Capture, supplement and focus expert judgment.
    - Capture knowledge, but don't generate volumes of data for data sake.
  - Identify Clear and Clean System Interfaces.
    - Decompose the system to establish simple and clearly identified interfaces between elements.
  - Maintain Effective Configuration Control.
    - Use simple, effective Configuration Management Systems.
    - Provide single, controlled database with "instant access" for all team members.
  - Allocate Resources as required based on criticality and risk.
- Strong Implementation Examples:
  - Apollo[1,2], JSF[10], Virginia Class Nuclear Submarine[9], F117A[3] , EELV Program[11].

Takes Full Advantage of State-of-the-Market Computer Tools, Technology



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Seven Key Principles Evident in the Invited Lectures

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Have Blue/F-117A	+	+	+	+	+	+	
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X-33	–	–		+		–	
X-34							
X-37							
X-38		–		+	+	+	+

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\- *Weak implementation of key principle found*

No evidence of key principle found

III. Invited Lecture Synopses

Aaron Cohen

Professor Emeritus Texas A&M University and former Center Director, NASA Johnson Space Center

SYNOPSIS/KEY LESSONS LEARNED:

- Environment: The primary motivation for President Kennedy initiating the Apollo Program was the "Cold War. With the support from Congress and the public, the funding for the project was supported. Another area of support was from the scientific community although there were sectors of the science community that were not supportive. Another aspect was the acceptance of risk that the program presented to human life.

- Management: Apollo was successful because of strong leadership at NASA Headquarters; strong Center Directors at JSC, MSFC, and KSC; and strong Program Managers at Headquarters, MSFC, JSC, and KSC. The integration of the Apollo Program was performed out of Headquarters with the support of General Electric, Bellcom, and later Boeing. Integration of the various stages of launch vehicle was performed by MSFC and its contractors, the integration of CSM/LM was performed by JSC and its contractors, and the integration of the launch complex was performed by KSC and its contractors.

- Reliability and crew safety were recognized as critical design drivers. However there were critical systems in the Apollo program that had a single string design that likely would not be acceptable today.

- Examples: see next page.

EXAMPLES

- If you had to single out one subsystem as being the most important, most complex, and yet most demanding in performance and precision, it would be guidance and navigation. Its function: to guide Apollo across 250,000 miles of empty space; achieve a precise orbit around the moon; land on its surface within a few yards of a predetermined spot; guide the LM from the surface to a rendezvous in lunar orbit; guide the CM to hit the Earth's atmosphere within a 27-mile corridor where the air was thick enough to capture the spacecraft, and yet thin enough so as not to burn it up; and finally land it close enough to a recovery ship in the middle of the Pacific Ocean." The very interesting characteristic about this system is that on the CM it was single string. The system had one computer and one inertial measurement unit. The LM had one primary system like the CM and a backup strap-down system. The launch vehicle also had a single string guidance and navigation system termed the instrument unit. Another example of Apollo single string critical systems was the single lunar ascent propulsion system.

- The major themes of the management system were communications, teamwork, and paying attention to details. The policy was to speak and to listen and to always bring up issues that are not fully understood.. The following exchange with Dr. George Low is provided as an example:
  \- Apollo 11 was on the launch pad going through checkout for its mission to land the first crew on the moon. During the checkout, it was noticed that the drift rate of the gyros on the Inertial Measurement Unit (IMU) in the LM had suddenly increased but was still within its specification. The IMU was required to maintain attitude and was also used to determine position and velocity after a propulsion maneuver. As a result, it was required for a Lunar landing. The team of experts from JSC, MIT Instruments Lab, other contractors, and I took this information to Dr. Low. We all agreed and recommended to him that we did not need to change out the IMU. He listened and then asked one question, "Do you understand why the drift rate has changed?" We said no and he said since we do not understand the problem, even though it is with in specification, we will change it out.

2. Reflections on Project Apollo

Dr. Roger Launius

Chair, Division of Space History, National Air and Space Museum, Smithsonian Institute, Washington, DC

SYNOPSIS/KEY LESSONS LEARNED:

- Project Apollo was a result of the US-Soviet Union Cold War rivalry. The unique circumstances at the time made it possible for JFK to receive Congressional and popular support for an ambitious plan to land an American on the Moon before the end of the 1960s.
- Key Apollo decisions included:
  (1) Project Management Approach; (2) Mode Decision (lunar orbit rendezvous); (3) All-up Testing;
  (4) Circumlunar Flight Before Landing; (5) An Exit Strategy.
    - Apollo actually skipped several steps in the traditional von Braun space exploration paradigm: (1) robotic Earth satellites; (2) human Earth orbital flights; (3) winged reusable spacecraft; (4) permanently inhabited space station; (5) human lunar exploration; (6) human expeditions to Mars.
- There are only five rationales for spaceflight:
  (1) geopolitics/national prestige; (2) military/national security; (3) human destiny/survival of the species;
  (4) scientific discovery and understanding; (5) economic advantage.
- NASA budgets have a "set point" of slightly under some 1% of the Federal budget
    - The one-time Apollo era reached a peak of about 3.3% in 1964-1967.
- The public generally supported the Apollo Program, but has remained almost evenly split over whether the Government should fund human trips to the Moon.

KEY TAKEAWAYS for NASA:

- Core lessons from Apollo include:
  (1) The Importance of Maintaining Political Will and Resolve; (2) Decision-making by Consensus;
  (3) Adequate and Consistent Resources; (4) Program Planning with Clear Objectives, Well-defined Lines of Accountability/Authority, Consistent Management; (5) Adequacy of Complex Systems Integration.
- Apollo left us with some key legacies and technical management lessons learned. There are several reasons to return to the Moon-humans must return if only to demonstrate that we can. A case is made for making the Moon a second home for humans in future decades.

3. Have Blue & F-117A Stealth Fighter
Effective Rapid Prototyping

Sherman Mullin

President, Lockheed Martin Skunkworks (Retired)

SYNOPSIS/KEY LESSONS LEARNED:

- Many of the earlier LM Skunk Works Programs were successful due to the level of autonomy the Programs enjoyed due to being classified with access severely and rigorously limited. This autonomy enables both the government and contractor organizations to streamline execution of the program.
- The Program Managers must be demanding, decisive with total responsibility and authority.
- Both contractor and customer Program Managers must have "protectors" in their chain of command to ensure that nobody interferes with them.
- The Program manager's ability to control team compensation – which may not be in accordance with company policies – allows for better team building and promotes excellence.
- The program must have a focused (one page) set of clear and demanding objectives of National importance.
  - The technical specification should include only three or four mandatory requirements with everything else as best effort although life cycle requirements such as reliability and maintainability must not be overlooked.
  - The master schedule must be well thought out, on one sheet of paper with the critical path defined.
- The team should not include partners or teammates – this only complicates decision making, hinders rapid prototyping and precludes co-location. A rapid competition with no more than three companies is best.
- A simple cost and schedule reporting system without a massive information system allows for efficient use of business resources.
- Use of commercial-type contracting procedures and sole source where possible simplifies procurement and subcontracting.
- Maximize the use of existing, off-the-shelf equipment where possible.

References: http://www.geocities.com/extraterrestrial_research/haveblue.html
http://www.stealthskater.com/Documents/HaveBlue_01.doc

4. Space Exploration Technologies (SpaceX)

Gwynne Shotwell

VP for Business Development, Space Exploration Technologies (SpaceX)

SYNOPSIS/LESSONS LEARNED:

- This presentation provided an overview of Space Exploration Technologies and its Falcon launch vehicle from the founding of the company in August 2002, to its projected first launch in September 2004.
- Space Exploration Technologies, or SpaceX, was created by Elon Musk using proceeds from the sale of his internet company, PayPal. His goal was to provide the cheapest launch service in the world for similar performance capability.
- The Falcon launch vehicle design was developed to avoid the most common launch vehicle failure sources: engines and separation, resulting in a two stage series burn vehicle with a single engine per stage configuration. Design trades were made to achieve cost and high reliability rather than performance.
    - Falcon I that can deliver 1500 lbs to a due east orbit from KSC for a price of $5.9 M plus ~$800 K for range safety. SpaceX will launch from multiple launch sites, each with different costs for range safety, which leads to their pricing policy of launch price plus range safety.
    - Vehicle descriptions are provided for both the Falcon and Falcon V. They are almost fully manifested at 4 – 5 launches per year for Falcon I and have sold their first Falcon V launch, scheduled for 2005.
    - Any fabrication savings will be passed on to the customer through reduced prices, as was done when FTS cost reduction led to price reduction from $6 M to $5.9 M per launch. First stage recovery will be tested to determine economic viability, leading to additional price reduction. Falcon V is projected to provide 9200 lbs to LEO for $12-14M.
- The key to their success in record time is the availability of sufficient, uninterrupted funding.

KEY TAKEAWAYS for NASA:

- Have a well defined goal – provide lowest cost launch in the world for similar capability.
- Have sufficient uninterrupted resources – CEO self-funded.
- 25 months from no company to first launch (8/2002 – 9/2004).

References: http://www.SpaceX.com/

5. DC-XA Program

Dan Dumbacher

DC-XA and X-37 Program Manager, NASA Marshall Space Flight Center

<u>SYNOPSIS/KEY LESSONS LEARNED:</u>

- The Delta Clipper-Experimental (Advanced) (DC-XA) was the first flight test vehicle in the Reusable Launch Vehicle Program designed to significantly reduce the cost of access to space. NASA inherited this project from the US Air Force. Cooperative agreements were used as the contract mechanism to provide the technology components.
- DC-XA provided the first flight tests in a real-world environment for composite liquid hydrogen tankage, aluminum-lithium tankage, and composite primary structure.

<u>KEY TAKEAWAYS for NASA</u>:

- Project Manager must be on board at the very beginning (before execution). Those who made decisions in the contract evaluation and negotiation phases must live with their decisions; those who negotiate should also manage the project over the life of the project, if at all possible.
- Daily telecons with all the contractors and leaders from the appropriate disciplines identified issues and formulated a plan to resolve them. Near-term schedules were used as a point of reference in all discussions.
- Spend sufficient time in upfront cost estimation preparation. Estimating must be reviewed by performing departments; should be bottoms up; should use charged rates; should not use ground test costs as value for flight test costs.
- Program plan must be well laid-out with time- and task-phasing.
- NASA accounting structure needs to be aligned with the management structure.
- Cooperative agreements provide no leverage with contractors. Changes are very difficult to make (for DC-XA changes were not allowed). <u>What you sign up for on day one will haunt your every waking hour!</u>
- Be careful of test estimates. Evaluate the need for on on-site program/project manager to help manage test activities.
- Reserves are needed to deal with the unknowns. Contractors need to identify the unknowns in their proposals and make sure the project/program budget has money for the unknown unknowns.

<u>References</u>: http://spacelink.nasa.gov/NASA.Projects/Aerospace.Technology/Research.Aircraft/X-38.Crew.Return.Vehicle/
http://www.dfrc.nasa.gov/Newsroom/FactSheets/FS-038-DFRC.html

John Muratore

X-38 Program Manager, NASA Johnson Space Flight Center

SYNOPSIS/KEY LESSONS LEARNED:

- The X-38 was a first in that a prototype crewed space vehicle was built-up in-house by NASA, rather than by a prime contractor. By building the vehicles in-house, NASA engineers gained understanding of the problems contractors experience when they build vehicles for NASA. The experience helped attract and retain highly skilled engineers. The working environment was highly productive because labor hours were spent directly producing the desired product rather than on writing RFPs, evaluating contractor proposals, and reviewing contractor's work.

- The X-38 program decided early on to focus on the identification of a few key requirements then set out to build prototype hardware. The approach taken was somewhat novel in that the team attempted to identify the most difficult elements of the design, and to focus on refining them first.

KEY TAKEAWAYS for NASA:

- Define areas needing attention and work those first. Don't drive all technologies/disciplines the same way. But, be careful of control interface tracking and how margins get tracked. Don't let everyone keep the margins.
- Avoid writing documents/specs just to fill the squares or because they were used before. Make sure requirements and traceability improve the product, adding real value. Quick sketches communicate an incredible amount of information.
- Model consistent with your understanding: Anchor with real data, don't extrapolate beyond known physics; test assumptions, and iterate.
- Build a little, test a little & grow a little: Build prototypes, perform frequent integration tests, push for opportunities to bring things together for early integration and validation, data should prune decision paths - not be the sole decision gate.
- Tools/Techniques must be consistent with program's need; Configuration Management must be simple and usable.

References:
http://spacelink.nasa.gov/NASA.Projects/Aerospace.Technology/Research.Aircraft/X-38.Crew.Return.Vehicle/
http://www.dfrc.nasa.gov/Newsroom/FactSheets/FS-038-DFRC.html

7. National Aero-Space Plane Organization and Management Lessons Learned

Ming Tang

Deputy Director for Military Programs, NASA Langley Research Center

SYNOPSIS/LESSONS LEARNED:

- NASP started as Copper Canyon in 1983.
- Quad chart that was sold to Reagan/Bush inherited 93 Plan: Phase 3 decision, 1999 first flight, 2001 SSTO flight - HTHL SSTO Hypersonic AB propulsion - Once National program established, President has to approve any change. NASP Phase 3 Jan 14, 1993 had Baseline NASP and HYFLITE in response to AW&ST headline said AF Abandons Orbit from AF Lead.
- Need a national interest to do something, not just because it is of a technologist's interest. National programs get blank check or renewable resources (Manhattan Project, Apollo, etc.). For technology push, need to bang it against other ways to do the job, need to push technology to TRL 6, more than just viewgraph engineering, need to accomplish something or funding dies.
- NASP had a whole suite of technologies it was working to a point where they could fly - NASP put more technology on the table than any program that followed it.
- NASP org – 3 charts; hard to draw, everyone draws their own.
- NPO, when beginning, contractors brought out the best and brightest; after being sold, best and brightest move on, and average come on – need to make sure the ones that are offered are the ones the program keeps.
- DOD and NASA funding support shows how poor NASA did; President's budget request for NASP with results after going through budget committees that actually made it to NASA and AF.

KEY TAKEAWAYS for NASA:

- NASP developed lots of technology; what we can sell, we can't do; what we can do, we can't sell.

Walt Dankhoff

Space Propulsion Synergy Team, NASA (ret. GRC, HQ)

SYNOPSIS/KEY LESSONS LEARNED:

- To put this program review in perspective it should be noted that it addresses a program that took place about 40 years ago. Clearly the international geo-political environment was different compared to today: but the physics haven't changed. Also since we are attempting to identify the best program organization and management approaches; it is important to note that the key element "human resources" is still the key: and the human physic and needs are still the same. Therefore "lesson learned" on the subject M-1 Rocket Engine Program are very valid, and applicable to the Space Exploration Program.
- The M-1 Rocket Engine Program, was initiated at MSFC: but responsibility for the program was transferred to the then Lewis Research Center in 1962. Dr. Abe Silverstein Center Director named Mr. Walter Dankhoff the Project Manager. A previously negotiated "letter" R&D contract with the Aerojet General Corp. was consummated in early 63 and Mr. Daniel Price was appointed as Aerojet Project Manager for both the M-1 engine R&D contract and the test facility construction contract.
- From the beginning, these two Project Managers agreed that the M-1 program should be addressed as one team, in all respects. In this way the rocket engineering technical expertise of Lewis was effectively utilized along with the Aerojet engineers in addressing the many challenges, involved in developing a very large LH2/O2 rocket engine. We also appreciated and utilized the "know how" of the MSFC engineers; especially regarding the manufacturing of large rocket engine hardware.
- A good example of this "single team" approach was in the conduct of the program reviews. We held "joint" monthly program reviews, of progress, where we openly addressed the current problems. We would alternate the location, one month it was held at Aerojet and the next month it was held at Lewis. Senior technical, financial and contractual personnel from both organizations attended (about 20 total). Our theme was to"Work hard but also to play hard".
- The result was that in a period from 1962-1965 this team was able to design, fabricate and successfully test full scale, all of the rocket engine components-turbo pumps (lox & LH2) gas generator, and the thrust chamber. Based on these results it was concluded that the development and qualification and operation of a large LH2/LOX. Rocket Engine is feasible. There is now available a technology and manufacturing data base available for application to a large LH2/Lox rocket if required in the transportation system for the new "Space Exploration Program".

8. A Review of the Nova/ Super Saturn Program with a Focus on the M-1 Rocket Engine (Con't.)

SYNOPSIS/KEY LESSONS LEARNED:

- The M-1 Rocket program was successfully executed under the NASA Program Project Manager method, which can be very effective; but does require the clear definition and documentation of the responsibilities, authority and accountability.
- Of course, for the Space Exportation Program, there will be several projects managed by different centers; however, the key is the same. That is the Program Manager must clearly define and document the objective/requirements of each project for the NASA Center Project Manager who is responsible. It is well recognized that a crucial element in the success of a Program and the supporting Project Team is the "effective communication". Also, it is recognized that there are currently much more sophisticated communication tools (voice mail, e-mail, etc.) available that were not available at the time of the subject M-1 Rocket Program. However, excessive utilization of these modern tools has made most of our current communication very impersonal and sometimes "counterproductive". It must be recognized that these rapid communication tools do not replace the critical need for personal (face to face) communication. It is only by "eyeball to eyeball" exchange that both parties understand the subject, the question and the response fully.
- An outline of responsibilities and authorities that have been successfully applied on the NOVA/M-1 Project and many other programs is attached in the notes portion of this slide.

9. NAVSEA Virginia Class Submarine Program

George Drakeley

Deputy Program Manager for Virginia Class Attack Submarine Program

SYNOPSIS/KEY LESSONS LEARNED:

- The Virginia class submarine was developed to build from the knowledge gained from the Seawolf class submarine. Seawolf was determined to be too expensive, and its mission had evolved. The Virginia class submarine was designed with a new mission set, and is being built in modules that can then be integrated at a final construction facility.

- The design was developed by the General Dynamics Electric Boat Division. However, a political decision was made to include the Northrop Grumman Newport News shipyard as an equal partner. This decision alone added hundreds of millions of dollars to each submarine to be built. In addition, the final integration is to be done at alternate construction facilities, also adding to the cost. Since Newport News has not built a submarine in over 30 years, their lack of experience has also added to the cost of the program.

- Cost Savings Technologies employed on the program:
    - The entire design was done using modern CAD/CAM computer programs and a single database. This greatly reduced the number of "hits" (errors) discovered in final assembly. CAD/CAM also allowed remote design reviews using A/V technology at separate sites. Electric Boat was the single organization responsible for the complete design.
    - The design incorporates a COTS open architecture data bus that will allow future upgrades as the technology evolves. This is viewed as a major cost avoidance measure that will keep this subclass viable for the entire 30 year design life.
    - The construction teams are organized as Integrated Product and Process Teams (IPPT's) that integrate all the management and build functions into Major Team Areas, as well as System Integration teams that were aligned with all the key major project areas and products. This has improved the overall cost avoidance and greatly reduced the number of change orders produced so far on the program.
    - The program office was able to convince Congress to allow multi-year program funding that reduced the cost of long lead items that reduced the total program cost as well.

KEY TAKEAWAYS for NASA:

- Outstanding implementation of IPPD in lieu of separate SE&I contract; Use of open architectures and COTS derived avionics.

10. JSF Requirements Definition Process and Lessons Learned

Paul Wiedenhaefer

Consultant to the JSF Program Office

SYNOPSIS/LESSONS LEARNED:

- Cost As an Independent Variable (CAIV). Requirements Process requires significant up-front investment in terms of time and money, and requires lead time in the schedule for requirements analysis. JSF executed continuous trades to identify "Best Value" solutions.
- JSF developed Performance Based Specification (PBS) that tell the contractor what it has to do, not *how* to do it. Acquisition and contract management issues associated with PBS could be addresses by developing a hybrid specification with the contractor "derived" requirements becoming contractual after award.
- The PBS was captured in an Operational Requirements Document (ORD) that was jointly developed by ALL parties - Government, Contractor(s), Warfighter, Test, Ops, etc. - ORD took over 5 years to develop while rapid system prototyping (fly-offs) was occurring.
- Developed, maintained, and matured a CONOPS model to evaluate contractor developed architectures. Developed common ground for architecture and technology evaluation.
- JSF spent significant effort in achieving Buy-in to the Cost Model(s) to deflect downstream challenges to cost analysis and modeling results. In addition to cost experts, this agreement spanned the war-fighter, technologists, and designers (government and industry elements) and even extended to the GAO.
- A Strategy-to-Task-to-Technology approach was utilized. Based on the ORD and CONOPS Model, the Program identified and prioritized enabling attributes and then identified and prioritized enabling technologies based on the end-user (Warfighter) inputs. The Program invested $Billions into enabling performance and affordability technologies. Not all technologies required a huge investment, but required a change in philosophy (e.g., Avionics Open Architectures to address affordability).

KEY TAKEAWAYS for NASA:

- CAIV/Best Value; Performance Based Spec; Strategy-to-Task-to-Technology Prioritization Process; CONOPS/ORD Model.

Major Andrew Chang

Deputy Chief Engineer, EELV Program Office, USAF Space and Missile Center, Los Angeles AFB

SYNOPSIS/KEY LESSONS LEARNED:

- After a review of the performance history of their ELVs in the early 1990s, the USAF determined that their experience with launch failures was worse than that of NASA. Prior to the development of new EELVS (Atlas V and Delta IV), decisions were then made to:
  - Concentrate their space resources under a unified command;
  - Establish and Independent Readiness Review team similar to NASA's Flight Readiness Reviews;
  - Establish an independent Risk Management Council and a single government mission director for each individual mission.

- As of 2005, 6 flights - 3 on Atlas V and 3 on Delta IV – have been flown and all have been successful.
  - This achievement was accomplished with considerable increased government resources. They originally started with 150 FTEs and they are now up to 350-400. By FY2005 they expect to add 60 more FTEs.
  - To the resources indicated above were added individuals from the customer organization, the National Reconnaissance Office (NRO), who conduct their own independent reviews.
  - In line with the single command concept, the USAF Space and Missiles Systems Center (SMC) is part of Space Command.

KEY TAKEAWAYS for NASA:

- If you really are serious about reliability improvement and you have the budget available, it appears that you can build on the heritage of the past and, at least so far, demonstrate high reliabilities. Whether NASA can accomplish the same objective with far less available resources is not so clear.

12. Customer's Perspective of Space Launch Systems Development Process

Freddie Douglas
NASA Stennis Space Center

SYNOPSIS/LESSONS LEARNED:

- The space launch system framework brings to the forefront the implications of multiple stakeholders, market conditions, the convoluted manner in which public sector programs are conceived and implemented, and the perceived smoother and focused manner for private sector efforts.
- Value is Derived Through Relationship Management Using the Principles of Service Management Model - “Gap” Management & Dimensions - Service Profit Chain - Customer Value Definition Customer Value = (Results Produced for Customer + Process Quality) divided by (Price to the Customer + Cost of Acquiring the Service).
- The Service Management Models and Techniques Can be Used To Achieve Success in the Program/Project Preparation Phase - Recognizing the Preparation Phase State Includes Both Tangible and Intangible Issues and Products; Recognizing the Interaction with the Customer is Where Value is Created and Captured; Achieving Success is Through Managing the “Gaps” in Customer Expectations and Supplier Perceptions.
- Failure…Can Be Attributable to “gaps” in Customer/Stakeholder Expectations and Perceptions of Actual Characteristics of the Management and Physical System Performance.
- Reducing the cost-per-pound-to-orbit as a measure of competitive effectiveness or advantage. However, the appropriateness of this measure changes as the customer/supplier relationship changes from Public Sector, to launch service provider, to satellite developer, to the General Public. Measures for these relationships move from cost-per-pound-to-orbit, to providing assurances of affordability, profitability, reliability, capability, and availability to maximizing benefit from a multi-billion dollar revenue stream.

KEY TAKEAWAY for NASA:

- “It is Not the Fact That Value or Priorities Have Changed; it is the Perception That Nothing has Changed That is Real.”

13. Framework for Evaluating Architecture, Technology and Organization Options

Dr. Tim Brady

NASA Johnson Space Center

SYNOPSIS/LESSONS LEARNED:

- Project Failure Correlations: 1990's arrived with some project failures including a flaw in the Hubble Space Telescope's primary mirror, and the loss of three spacecraft sent to Mars. Following the determination of the cause for the 1999 loss of Mars Climate Orbiter, the mishap investigation board reviewed eight previous failure investigation reports and identified a correlation between other project failures and a few common themes. The most common themes included inadequate project reviews, poor risk management, insufficient testing, and inadequate communications. Most project managers are aware of the possibilities of and the consequences of these risk areas in complex technical projects – so why do many projects make these same mistakes?
- Early decisions – Large Impact: Decisions such as establishing a system architecture and selecting technology of particular maturity, can have lasting impact throughout the project development process and during the project's operation phase. The ultimate goal of this thesis was to develop an analytical framework that could be used, along with other sound system engineering tools, to expand the management team's holistic view of the project, which could then be used to enhance project implementation decision-making.
- Analytical Framework Case Studies: The analytical framework was applied to seven spacecraft projects which served as case studies. Successful and unsuccessful projects were included in the set of cases. Analytical observations were compared to post-project lessons learned to develop a general understanding of the relationship between the project structure and the implementation approach for each case.
- The DSM Analysis Framework described provides an opportunity to view long term impacts of architecture and technology decisions. The technology risk DSM can be used to identify risk "hot spots" where risk mitigation strategies must be in place. Successful projects make good decisions based on in-depth technical understanding.

KEY TAKEAWAY for NASA:

- DSM analysis can facilitate the collective understanding required for decision-making.

14. Keeping Organizations Effective Over The Long Run

Dr. William Starbuck

Stern School of Business, New York University

SYNOPSIS/LESSONS LEARNED

- Trouble learning from success: Although learning can produce benefits, many organizations have trouble with learning from success. They over-learn successful behaviors and become over-confident. Success rigidifies behaviors and limits awareness of environmental changes. One result is that failures become inevitable. Then when serious problems develop and call for new behaviors, organizations have difficulty unlearning what they learned earlier. "Success leads to specialization and exaggeration, to confidence and complacency, to dogma and ritual." – Danny Miller (1990)
- Trouble learning from failure: Organizations also have trouble learning from their failures – both small failures and large ones. They have strong tendencies to explain away failures as being idiosyncratic and to overlook possible systemic causes. Incomplete and biased reporting keeps top managers blind to impending failures.
- Learning from success rigidifies behaviors and limits awareness of environmental changes - Both the Challenger and Columbia disasters. Environments amplify rigidity by demanding rationalizations, predictions, and reliability. NASA's environments have not understood the uncertainty attending space travel. Organizations have limited abilities to block environmental changes. Environmental changes occur largely outside organizations' vision.
- Manage three Interdependent Organizational Elements: To create organizations that remain effective over long periods, one must manage three interdependent subsystems – culture, rewards, and structures. Cultures influence the ability to surface and manage disagreements and the ability to communicate openly. Rewards need to align with cultures and organizational goals, but NASA has limited control over rewards. Structures should focus on communication channels rather than rules. Disagreements between managers and engineers should be useful.

KEY TAKEAWAY for NASA:

- Organizations are not machines; culture and rewards must also be carefully designed and monitored over project lifecycle.

Dr. Elisabeth Paté-Cornell

Management Science and Engineering, Stanford University

SYNOPSIS/LESSONS LEARNED:

- Job is Risk Analysis – how does it work, figure out how it fails, then try to prevent it from happening. Looking at Risk triggers and precursors. Most technological failures of critical systems are preceded by events that constitute warnings that the system has deteriorated, that some flaws exist, that the loads on the system is going to be higher than expected or that an accident or an attack is going to happen in the near future. Examples include the two space shuttle accidents, the case of the Concord, and of the intelligence information that needs to be collected and interpreted in time to prevent terrorist attacks.
- Design the Organization to Observe Signals and Manage Risk - essential to success. Structure, procedures, and Culture determine information, incentives, and spectrum of possible actions. Filtering involves information and values. Warning systems : what are the weaknesses; where should we look; how fast will the system deteriorate; rates of false positives and false negatives; who sees what or does not; the telephone game (blockage or passage); decision maker response – act or kill messenger.
- Pertinent Examples were Reviewed: Examples include the two space shuttle accidents, the case of the Concord, and of the intelligence information that needs to be collected and interpreted in time to prevent terrorist attacks. I will present a few examples of such situations and a method based on systems analysis and probability that allows identifying precursors and filtering the information.
- Missed Precursors - Concord: 57 tire bursts before fatal crash on 7/25/2000 after about 75,000 flights; Several came close to puncturing the fuel tank; "It will not bite us because we have survived several such events in the past" (the zillion-miles argument). Ignoring randomness. The gap between the "safety-first" discourse and the reaction to precursors.

KEY TAKEAWAY for NASA:

- When the Job Is Well Done, No One Hears About It.

16. Optimizing Synergetic Organizations

Dr. Walter Hammond

Jacobs Engineering/Sverdrup

SYNOPSIS/LESSONS LEARNED:

- Increasing globalization (Economies of Scale): The world as a "multi-cultural milieu" versus a spreading "cross-cultural glue" (the present, *i.e.*, a McDonald's in every country).
- Follow the Golden Rules: Always treat others as you would like to be treated; Hammond's Law #9: Treat others as they want to be treated. As always, beware of Murphy's Law.
- Surround yourself with the highest talent: People are simply your greatest resource, in any company/agency; Spend the most time with your best people; Focus on strengths, not weaknesses or failures - Create Heroes in Every Role.
- Create and continuously nurture the right corporate culture: Participation enhances understanding and acceptance; ability to communicate openly and freely. DO NOT: Arbitrarily bring people together (again, communicate !); Divide people (he said..she said…they said…); Create ambiguity (need I say again, communicate !); Hide the bad news/the truth (ALWAYS be honest); Discourage the ability to surface and discuss grievances.
- How to Synergize From NASA's point of view: Consolidation and economies of scale make more sense in the Government sector: No such thing as a "monopoly", The public usually seeks a "single voice" from the Government. Remember, you still have to earn the trust of a company, regardless of your government position.

KEY TAKEAWAY for NASA:

- Always treat others as you would like to be treated; treat others as they want to be treated.

17. Assessment of Interagency Program Management Approaches

Dr. Richard T. Beck

NASA Director of Resources Management

SYNOPSIS/LESSONS LEARNED:

- Merged military and civil programs to save taxpayer money (DOD, NASA, and NOAA).

- Defined an approach that capitalized on each organization strengths:
  - Integrated vs. joint program approach vs. interagency approach. Single agency approach.
    - Certain technical needs of the individual participants too detailed for single agency approach.
    - Too much burden on one agency.

- Distributed agency approach / Joint program.
  - Each individual element focused mostly on its own challenges, coordination between elements difficult, sometimes missing the overall program perspective.

- Integrated program approach.
  - Considered most successful, especially NEXRAD.
    - Despite NOSS cancellation by senior Navy management.
  - Focus is more inward on all the pieces of the program than outward toward the source organizations, easing coordination and increasing collaboration.
  - Personnel from participating agencies; mixed set of director and deputies gain shared perspectives of needs and skills:
    - Lead roles instead of performing/delegated roles for agencies which send representatives to IPO; take lead role in a function that they specialize in with deputy from other agency to provide broader perspective.
    - For NPOESS, Acquisition lead role staffed by DoD (NOAA Deputy); Operations lead role staffed by NOAA (DoD Deputy); Technology Transition lead role staffed by NASA (DoD Deputy).

KEY TAKEAWAYS for NASA:

- There is No One Right Approach – Program Will Adapt What is Best for Them.

Russ Turner

President, Honeywell Engines, Systems & Services and Former CEO of United Space Alliance
CAIB Testimony (6/12/04) Videotape at Workshop III on December 10-11, 2003

SYNOPSIS/LESSONS LEARNED:

- SFOC Emphasized Contractor Performance Accountability: NASA established goals and objectives and owned requirements. NASA changed from insight to predominantly oversight. Scope written broadly to minimize change traffic. Retain Contractor Accountability. Recommendations: Completion Form contract that enables a systems perspective; Clear, unambiguous contractor accountability; Terms and Conditions aligned to NASA's goals and priorities; Terms and Conditions that enable contractor reinvestment decisions; Terms and Conditions that reward excellent performance.
- Terms & Conditions motivated USA to take a long-term systems view of Shuttle. USA had a long term stake in Shuttle Operations success. USA had the discretion to "reinvest" savings for system improvements - $190M to date.
- Retain alignment of organization to process and system – Do not re-separate aligned work content. Ensure process commonality for core processes. Retain single contract instrument for a company.
- Contractual Features Not Aligned To NASA's Goals and Culture: Cost incentive provision did not benefit Space Shuttle Program; Performance incentive provisions were Inconsistent with NASA manifest priorities Objective Performance Measurement System (metrics) did not correlate to NASA Award Fee evaluation system; NASA Center programmatic role diminished.
- Short Term Financial Driven: NASA Annual funding process drove short term thinking Shuttle Budget reduction resulted in 700 USA layoffs – In 1999 NASA recommends USA hire more employees.

KEY TAKEAWAYS for NASA:

- Keep It Simple – Organizational Complexity Created an Upper Bound for Shuttle Safety/Quality Performance.

19. Learning and Process Improvement in Complex Organizations

Dr. John Sterman

Director, Massachusetts institute of Technology Systems Dynamics Group

SYNOPSIS/LESSONS LEARNED:

- Improved implementation requires a more effective set of tools AND processes and organizations that use them effectively. While much current research focuses on the design of new tools and processes, organizations also struggle with the implementation and execution of existing best practices. This often occurs despite general agreement that the prescribed methods are better than those in use.
- Common Program Problems: The 90% syndrome; Conflicts over Concurrent Development; Firefighting; The Liars' Club; The Self-Confirming Attribution Error; Failed improvement programs: Sometimes, trying to be Faster, Cheaper, Better yields Slower, Costlier, Worse.
- Conflict over Concurrence: How much can development activities be overlapped? What are tradeoffs between iteration, rework and time-to-complete? What is the impact on quality? Optimal overlap (concurrence) depends on technology, development tools, organization structure; Perceptions of optimal concurrence often erroneous; differ across phases; Misperceptions create conflict; erode quality, schedule, cost performance.
- Biases towards downstream work: People overweight salient and tangible features of their environment. Projects in the design phase are more salient and tangible than projects in the concept development phase. People are risk averse and 'ambiguity' averse - investments in design activities have a more certain outcome than investments in concept development. People are biased toward activities that produce immediate returns - The benefits of concept development are realized with a longer delay than the benefits of design work.
- Organizational Fire Fighting: Focusing attention on the product nearest its launch causes people to spend more time on product design and less time on concept development. This has two effects. Initially, the performance of the specific project improves...this happens immediately, it is easy to observe, the impact is very certain, and the benefits accrue to the firefighting managers and engineers. Over time, the performance of the system declines. This happens only with a delay, it is hard to observe, the impact is very uncertain, and the pain is borne by all—hard to attribute to the managers/function responsible.

KEY TAKEAWAYS for NASA:

- o Why products/projects go wrong - 90% syndrome.

References: http://sysdyn.clexchange.org/sd-group/

20. National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office

Stanley Schneider

NPOESS Integrated program Office

SYNOPSIS/LESSONS LEARNED

- President Directed, Tri-agency Effort to Leverage and Combine Environmental Satellite Activities. DOC and DOD funded agency 50/50; NASA brings technology. Members have to put the agency above their home organization. Contract does not include launch services – AF insisted EELV be used; budget location is in EELV line, not interagency budget.
- Creative and Cost Effective Risk Reduction Plan: Validate technological approach to remote sensing; Early delivery of NPOESS data to users; Sensor demonstrations on non-operational platforms - Lower risk to operational users - Lower risk of launch delays due to operational schedule; Shared cost & risk among agencies.
- Prime contractor award fee is 20% - unheard of (cost + for two; last four are fixed price + incentive – options). Certain milestones have large mission success fees.
- Integrated Program Office should not generate its own requirements – need to be source organizations; EXCOM and Program Office is implementer.
- AF, OSD, NOAA, DoC, NASA must act as one for NPOESS to succeed: AF, NOAA, and NASA cannot take independent program/budget actions without significant political and programmatic consequences. DoC - DoD budget processes are very different; Civil - National Security OMB processes are very different; NOAA/AF Congressional Committees all have a vote. EUMETSAT role takes significant energy and sophistication to make it work. Sustaining budget continuity takes significant energy and "Washington street smarts".

KEY TAKEAWAYS for NASA:

Members have to put the agency above their home organization.

Reference: http://www.ipo. ww.NOAA.gov.

21. On Not Confusing Ourselves: Insights on Risk, Organization and Culture from the Columbia Accident Investigation

Richard H. Buenneke
Senior Aerospace Engineer, The Aerospace Corporation and CAIB Consultant

SYNOPSIS/LESSONS LEARNED:

- Columbia Technical and Organizational Issues: The physical cause of the loss of *Columbia* and its crew was a breach in the Thermal Protection System on the leading edge of the left wing. The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the shuttle program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human spaceflight.
- Space Shuttle Program Organizational Structure: Has ineffective checks and balances to achieve safety and mission assurance. NASA's Office of Safety & Mission Assurance didnot have the *authority* that the Board and many outside reviews believe is necessary. Other CAIB volumes contain important relevant information, especially Holden from Aerospace on IV&V and the Broad Area Review following Titan failures.
- Task Force on Acquisition of National Security Space Programs: Cost is primary driver in managing acquisition process. Unrealistic budgets—unrealistic/optimistic program plan. Undisciplined requirements definition and uncontrolled growth. Inadequate government acquisition approach. Industry implementation deficiencies. Result - Significant cost growths and schedule delays.
- Unrealistic Budgeting: Advocacy dominates program formulation phase of acquisition process. Independent cost and program assessments have been ineffective or ineffectively utilized. Most programs are budgeted at 50% probability.
- Requirements growth: Dominant driver of cost increases and schedule delays. Recommendations: Give a single senior leader authority to accept or reject requirements. Ensure the requirements development process includes operators, users and acquisition personnel. Provide system engineering support to execute the requirements trades process. Institute training and certification programs for requirements managers.

KEY TAKEAWAYS for NASA:

- Responsibility for technical requirements and safety should be independent of program management.

22. Space Program Lessons Learned/Best Practices

David L. Christensen
Lockheed Martin Space Systems

SYNOPSIS/LESSONS LEARNED:

- Prologue: Space Program Lessons Learned/Best Practices Must Read for Young and Old Alike – 1907 vision of flight 50 years hence - History of rocket and space travel. Keep using what works-Keep production line going; Put together physical 3-D models; Jupiter rocket 1956-1960; Bottom-up vs. top-down costing; Series of cost drivers – good, common sense info; Designate end-item owner.
- Cost Drivers: Maintaining a dedicated infrastructure and services (standby army) to satisfy a specified launch rate (regardless of actual number of launches); Manned space programs have higher cost impacts than unmanned (30-50% higher); Excessive concern / sensitivity to risk due to high visibility of large programs; Institutional overhead, excessive program reviews, and status reports are major cost drivers; Most cost is driven by doing things over; Underestimating original cost due to lack of an adequate cost database.
- Program Requirement Rules (Must meet these criteria); Function (It must work); Performance (It must meet mission requirements); Safety (It must be safe and reliable) And It Should Be: Timely (Meet schedules) and Affordable (Meet budgeted cost level).
- General Rules: Implementing New Initiatives; Policy and Budget: Procurement and Contract Rules; Cost Estimating Rules; Program/Schedules; Program Management Rules; Requirements and Specifications; Technical, Additional efforts are needed to understand systems engineering processes and prepare viable assessments and recommended practices to reduce system costs and improve system safety and dependability.
- Design Rules: Manufacturing; Design Rules for Testing; Design Rules for Operations. Cost Reduction is an extremely important design factor and must be equally considered with performance as a design objective.
- Recommendations: Prepare a Best Practice Manual for space transportation system cost reduction which expands on this study effort. Prepare and use a short course or training package on cost reduction (for all elements of space transportation systems). Develop and apply improved analysis and design tools that incorporate "Design for Mission Success" as a primary objective. Develop and use accurate (activity based) cost estimating databases for design of space transportation systems.

KEY TAKEAWAYS for NASA:

- Keep using what works.

23. Defining and Applying Insight

Jim Snoddy

NASA Marshall Space Flight Center

SYNOPSIS/KEY LESSONS LEARNED:

- What is "Insight" and how should the government allocate resources to effectively manage risk with accountability for Government contracted efforts? The answer is that it depends on the program's priority to meeting the mission. Insight includes visibility if it fails, human rating, technology readiness, amount of money and the level of risk for the particular program that must be decided by the program manager and history with a particular contractor with input from the performing organizations; provides a contractual definition of "insight" with risk defining the appropriate level of penetration; and defines penetration from "No Penetration" [Level -1] to "Inline Task" [Level 5].

KEY TAKEAWAYS for NASA:

- Start with insight and don't try to add it in later - it will not be effective.
- Most insight should be gained through the Systems Integration Team.
- Insight is expensive and difficult to manage.
- The cost of insight is typically about 10% of contract value.
    - Level of insight can not be defined by number of people on the project.
    - Level of technology, complexity and contractor capability can be used to define required insight.
- Insight is difficult, if not impossible, to add on the back end. It must be built upon.

24. Private Venture: Kistler K-1

Greg Allison
Hernandez Engineering, NASA Marshall Space Flight Center

SYNOPSIS/KEY LESSONS LEARNED:

- Private ventures offer alternative views into methods employed to accomplish project management. The highest requirement in a private venture is to provide the investor(s) with a satisfactory Return on Investment (ROI). This functions as a challenging driver which forces the venture to find innovative ways to compress schedule and reduce budget, while producing a commercially viable product. These constraints are quite demanding as compared to typical government-sponsored projects. For these reasons, a survey of private venture practices is very instructive. Indeed, many of these practices are not applicable to government programs, but there exists a number of ideas worthy of consideration.

- Due to the downturn in the commercial satellite market, the presentation focused on the main K-1 subsystem, the K-1 structures development. Also highlighted are the key innovations employed by Kistler to deal with their no-bid contractors.

KEY TAKEAWAYS for NASA:

- To compress schedule, Kistler:
  - Awarded no-bid contracts, which eliminated RFP generation and review process; and
  - Selected up front companies deemed the industries' best, enabling the contractor proposals and requirements to be jointly developed, and engineering to start immediately.
    - Tooling and manufacturing started as soon as outer mold lines were determined (prior to PDR/CDR).
- To reduce budget, Kistler:
  - Decided not to build a full-scale structural test article; the first article was to be flight hardware. Materials coupon testing, nondestructive evaluation of completed structure, and finite element modeling performed in lieu of structural test article testing.

Reference: http://www.kistleraerospace.com

ODT Workshop History

Workshop	Location, Date	Title	Highlights
I	LaRC, August 2003	Tools and Methods for Organization Design & Analysis	Five invited talks. Dependency Structure Matrix (DSM) tool for evaluating organizations.
II	JSC, October 2003	Advanced Mission Operations and Analysis	Five invited talks focused on autonomous space flight as means of reducing organization costs.
III	Williamsburg, VA. Decemenber 2003	Organizational Design and Best Practices	Eight invited talks focused on program/organization design.
IV	SSC, February 2004	Layout of the Next Program Organization Structure	Prototyping an organization design process.
V	LaRC, March 2004	Layout of the JSF-Like Program Structure	Project life-cycle definition and FTE estimation process.
VI	JSC, May 2004	Building a Historical Program Database	Twelve invited talks focusing on program best practices and lessons learned.
VII	New York University, June 2004	Conference on Organization Design, co-sponsored by NYU Stern School and National Science Foundation	Key org design tools identified for application in pilot studies.
VIII	LaRC, August 2004	Analyzing the Results and Writing the Final Report	Synthesis of Seven Key Principles.

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Appendix: Invited Lectures on Companion CD

Appendix A. Workshop I: Tools and Methods for Organization Design & Analysis. NASA Langley Research Center, August 2003.

A.1 Freddie Douglas, NASA Stennis Space Center, “Lean Principles Implementation in the Program Preparation Phase.”
A.2 Tim Brady, NASA Johnson Space Center, “Framework for Evaluating Architecture, Technology and Organization Options.”
A.3 Dr. William Starbuck, Stern School of Business, New York University, “Keeping Organizations Effective Over The Long Run.”
A.4 Dr. Elisabeth Paté-Cornell, Management Science and Engineering, Stanford University, “On Signals, Response and Risk Mitigation: A Probabilistic Approach to Precursors' Detection and Analysis.”
A.5 Dr. Walter Hammond, Jacobs Engineering/Sverdrup, “Optimizing and Synergizing Organizations.”

Appendix B. Workshop II: Advanced Mission Operations and Analysis. NASA Johson Space Center, October 2003.

B.1 Barbara Stone-Towns, “NASA/Air Force Cost Model (NAFCOM 2002) Overview, NAFCOM and Organization Structure.”
B.2 John D. (Doug) Rask, “MOD Advanced Operations Cadre (AOC).”
B.3 Howard Hu, Jeremy Hart, Ryan Proud and Timothy Straube, “Spacecraft Mission Assessment and Replanning Tool (SMART): A Real-time, Intelligent Autonomous Flight Management (AFM) System for Increased Safety and Performance of Spaceflight Vehicles ”
B.4 John D. (Doug) Rask, “Potential Impacts of Automation Technologies on Mission Operations.”
B.5 Bebe Ly, Lui Wang, “Autonomous System Architecture.”
B.6 Mike Evans, “Overview of Flight Design templates for crewed space flight.”
B.7 John D. (Doug) Rask and Marty Linde, “Flyback Booster Issues.”
B.8 Mike Evans and John D. (Doug) Rask, “SLI/CART Trajectory Scenarios.”
B.9 Phil Varghese, “On the Road to Autonomous Space Missions, Deep Space 1 Experience.”

Appendix C. Workshop III: Organization Design and Best Practice. Williamsburg, VA, Decemeber 2003.

C.1 Dr. John Sterman, “Learning and Process Improvement in Complex Organizations.”
C.2 Dave Christensen, “Space Program Lessons Learned/Best Practices.”
C.3 Dr. Richard Beck, “Assessment of Intergency Program Management Approaches.”
C.4 Stanley Schneider, “National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office.”
C.5 Darrell Branscome, “Advanced Launch System.”
C.6 Russell Turner, “Contractor Perspective on the Space Flight Operations Contract (SFOC).” Recorded presentation from the CAIB testimony June 12, 2003.
C.7 Richard H. Buenneke, “On Not Confusing Ourselves: Insights on Organization, Policy and Culture from the Columbia Accident Investigation.”
C.8 Ming Tang, “National Aerospace Plane Organization and Management.”
C.9 Carey M. McCleskey, “STS Root Cause Analysis Organization Insight.”

Appendix: Invited Lectures on Companion DVD

Appendix D. Workshop IV: Layout of the Next Program Organization Structure. NASA Stennis Space Flight Center, February 2004.
D.1 Howard Cotterman, John Chiorini, "Technology Management Strategy and Project Cycle."
D.2 Dr. Richard Chick, "Program Management Best Practice Overview."

Appendix E. Workshop V: Layout of the JSF-Like Program Structure. NASA Langley Research Center, March 2004.
E.1 Jim Whalen, "Development Methods/Strategies and the Project Cycle, DOD 5000.1 & 2, NASA 7120.5B, and Visual PM Comparison."

Appendix F: Workshop VI: Building a Program Uncertainty Database. NASA Johnson Space Cneter, May 2004.
F.1 Gwynne Shotwell, "SpaceX Overview."
F.2 Dr. Aaron Cohen, "Comments about the Apollo Program."
F.3 Walt Dankhoff, "NOVA, Super Saturn Program."
F.4 John F. Muratore, "X38 Program System Engineering Lessons."
F.5 Dan Dumbacher, "DC-XA Lessons Learned Discussions"
F.6 Major Andrew Chang, "EELV SPO Overview"
F.7 Greg Allison, "Kistler, HyTEx, PARSEC and Sundry Approaches to Project Management."
F.8 Dr. Roger Launius, "Reflections on Project Apollo."
F.9 Sherman N. Mullin, "Lockheed Skunk Works Program Management with Focus on the F-117 Stealth Fighter Program"
F.10 George M. Drakeley III, "Virginia (SSN 774) Class Submarine Program."
F.11 Jim Snoddy, "Defining and Applying Insight."
F.12 Greg Smith, "Schedule Risk Algorithm Development"

Appendix G: Workshop VII: Writing the Report. NASA Langley Research Center, August 2004.
G.1 None.

Appendix H: Special Web Presentations.
H.1 Paul Wiedenhaefer, "JSF, The Affordable Solution, Requirements Definition Process & Lessons Learned." Pre-Workshop VI Presentation on May 13, 2004.
H.2 Dr. George Mueller, "Apollo: First Space System of Systems," presented to NASA Exploration Systems SE&I Benchmarking Workshop, Pasadena, California, December 2004.
H.3 Vincent J. Bilardo Jr, Program/Organization Modeling & Simulation (POMS) Initiative, June 13, 2005.