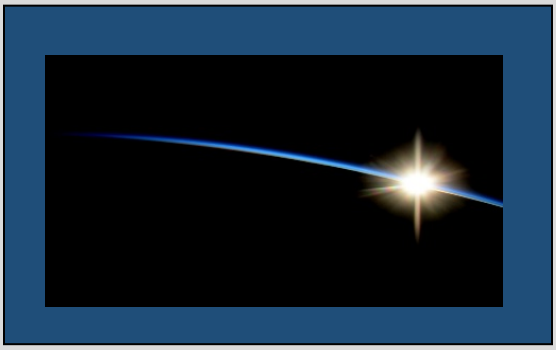
Critical Knowledge Gateway



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Executive Summary

The ultimate goal of the Chief Knowledge Officer (CKO) is to provide the NASA Technical Workforce ways to find and use the critical knowledge required now and in the future to achieve mission success in a highly complex and unforgiving environment.

The overall importance of Knowledge Services (KS) mission has been articulated in recent recommendations to the NASA Administrator by the Aerospace Safety Advisory Panel (ASAP) and has been specifically identified in NASA authorization legislation.

This compendium is an element in the Agency response to the KS challenge and is based on a new Agency Knowledge model that has been developed as a result of the revised Agency knowledge policy that supersedes NPR 7120.6 NASA Knowledge Policy for Programs and Projects. The primary purpose of NASA's knowledge policy is to ensure that NASA manages its knowledge resources in a way that enables the agency to execute its programs, projects, and missions with the highest likelihood of mission success, emphasizing a more integrated approach to lessons learned and knowledge management. Specifically, the policy defines the roles and responsibilities for Chief Knowledge Officers at the Centers and Mission Directorates and well as NASA staff members. The policy identifies six categories of knowledge activities and services currently being used across NASA (online tools, search/tag/taxonomy tools, case studies/publications, lessons learned/knowledge processes, knowledge networks and face-to-face). The policy requires that each Center and Mission Directorate CKO shall develop a knowledge strategy that considers the six approaches above and share the strategy annually at a meeting convened by the NASA CKO for purposes of sharing best practices and promoting greater integration and collaboration.

The current Critical Knowledge task has been undertaken to identify and make available video-based, multi-media CK resources to the greater NASA community including programs, projects, technical authorities, functional managers, contractors, partners, and external stakeholders. For the purposes of this task, Critical Knowledge is defined as broadly applicable lessons learned that enable mission success, stimulate critical thinking and help raise questions that need to be addressed at various phases in a project life-cycle. Many of the videos indexed in this compendium address challenges, risks and the way in which specific challenges and risks have been addressed.

Video resources referenced in this first edition of the compendium were developed by the Exploration Systems Mission Directorate and the Human Exploration and Operations Mission Directorate (HEOMD) during the 2006-2014 timeframe. Over 250 CK video segments have been indexed employing a simple intuitive framework that combines a notional, 4-phase project life-cycle (Early-on, Development, Operations, Close-out) with People, Process, and Technical sub-elements for each phase. Future indexing activities will include the CKO "Masters with Masters"

series of video resources featuring Agency subject matter experts and senior managers in focused panel discussions.

This compendium and its publically accessible, companion web site will be updated on a semi-annual basis as new material is incorporated. In addition, the CK Gateway web site will be tabbed and linked directly from the CKO Knowledge Map and will be searchable and findable through the use of modern digital tools as the Agency efforts in using knowledge to enable discovery and creation continue to mature.

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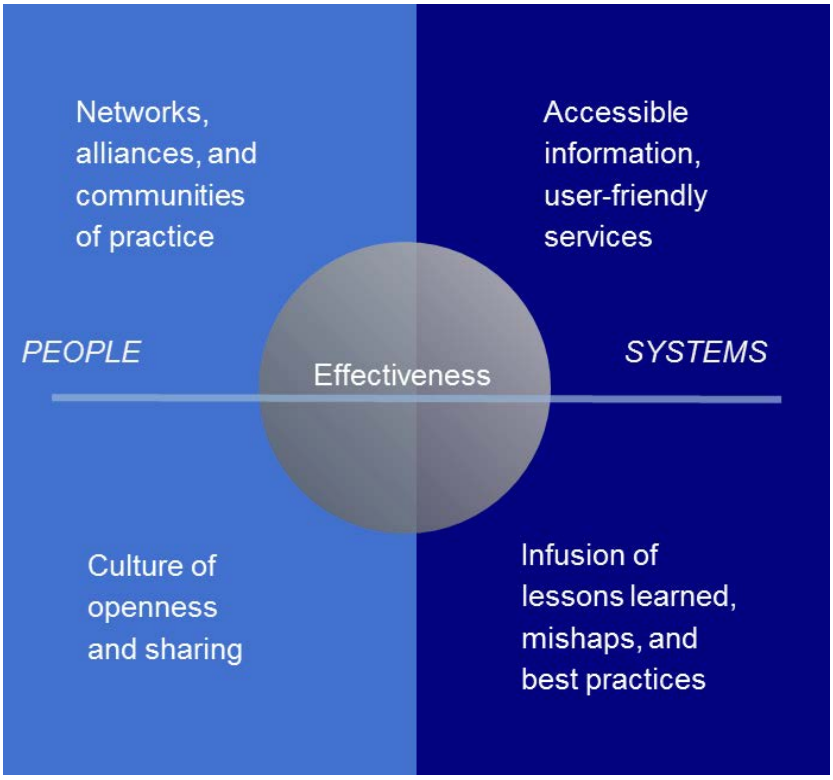
I. Introduction

NASA recognizes the importance and necessity of capturing and retaining, sharing and applying, critical knowledge derived from program success and failures. Future mission success builds upon an understanding of lessons from past failures as well as an acknowledgment of processes and practices that contributed to past success.

Recently, the ASAP review team asked NASA project personnel, "What is being done to ensure these lessons are being formally and systematically captured and made accessible across the whole organization?" The responses indicated there was no system that effectively captured, shared and allowed other projects to find these critical lessons. The issues of searchability, findability, and applicability of knowledge continue to be a great challenge. Projects are committed to identifying and sharing critical knowledge and lessons within a team, but it is rare to find knowledge across a system of systems and across project boundaries. In an increasingly complex and interconnected world, this integration can spell the difference between mission success and failure.

The Agency readily concurred with the CKO recommendation in 2011, focusing the Agency KS effort by appointing an Agency CKO within the Office of the Chief Engineer (OCE) and designating CKO positions across Centers, Mission Directorates, and Functional offices. The OCE has evolved as an enterprise-wide Project Management Office (PMO) responsible for developing and implementing the strategy, policy, standards, workforce development, advanced concepts, mission architecture, and integration across program and mission boundaries. In addition the OCE provides program assessment for overall technical workforce development that supports project and program success at an enterprise level.



Any NASA knowledge management approach needs to be adaptable and flexible to accommodate the varied requirements and cultural characteristics of each Center, Mission Directorate and Functional office. A federated model was the best fit for

Figure 1: NASA Knowledge Services Strategic Framework

the Agency, defining the NASA CKOs as facilitators and champions for Agency KS, not to serve as an overseer and direct manager. The governance document for NASA Knowledge, NPD 7120, NASA Knowledge Policy for Programs and Projects, was collaboratively rewritten because NASA had greatly expanded its knowledge activities over the past several years to include a wider array of services than simply capturing and retaining lessons-learned. The new policy ensured that NASA manages knowledge resources in a way that enables the Agency to execute programs, projects, and missions with the highest likelihood of mission success, emphasizing a KS integrated strategic framework. It also defined the roles and responsibilities for CKOs at the Centers, Mission Directorates, and Functional offices. The new policy addressed a set of KS priorities that clarified NASA objectives for project knowledge and emphasized the development and implementation of future knowledge initiatives, measures, and metrics (Figure 1).

KS goals include:

- People
    - Sustain and expand the use of the agency's intellectual capital across NASA's enterprises and generations through better networks, alliances, and communities of practice.
    - Increase collaboration across organizational barriers through promotion of a culture of openness.
- Systems
    - Support the technical workforce in executing NASA's missions efficiently and effectively through lessons learned, mishap reports, and promulgation of best practices.
    - Create an integrated infrastructure of knowledge that identifies the value of information and aligns practitioner and organizational imperatives through accessible information and user-friendly services.

One of the most striking things that the Agency's knowledge community discovered was the sheer depth and breadth of activity underway across the Agency. Some was found through self-service, such as typing a query in a search box and getting answers that point in the right direction, involving one person at a time, and works best with explicit knowledge that does not require a lot of context or personal judgment. At the other extreme, tacit knowledge that was dependent on context and personal judgment was transmitted through social interaction at meetings and storytelling.

Given this range of knowledge activities, the NASA knowledge community identified an initial set of knowledge categories that addressed most of the activities taking place across NASA that could be populated on the first-ever Agency Knowledge Map (Figure 2). The Knowledge Map web site provides access to:

- Online Tools - Include but are not limited to: portals; document repositories; collaboration and sharing sites; video libraries.
- Search/Tag/Taxonomy Tools - Dedicated search engine for knowledge (e.g., Google Search Appliance) and any initiatives related to meta-tagging or taxonomy.
- Case Studies/Publications - Original documents or multimedia case studies that capture project stories and associated lessons learned or best practices.

Figure 2: NASA Knowledge Map and Legend

- Lessons Learned/Knowledge Processes - Any defined process that an organization uses to identify or capture knowledge, lessons learned, or best practices, including: Lessons Learned Information System vetting process; organization-specific lessons learned processes; benchmarking; cases; knowledge sharing recognition programs; knowledge product validation processes; communications about expectations related to knowledge sharing.
- Knowledge Networks - Any defined knowledge network, such as: a community of practice; expert locator; mass collaboration activity; workspaces specifically designed to enable exchanges and collaboration.
- Social Exchanges - Any activities that bring people together in person to share knowledge (e.g., forums, workshops, Lunch and Learn/Pause and Learn, etc.). The reach of these activities can be multiplied through online tools such as videos and virtual dialogues.

The Agency is now linking all identified products and series to the map and creating active links to the resources, to include the Critical Knowledge task covered in this compendium. The categories are not a perfect fit for every type of knowledge activity across diverse organizations and multiple disciplines, but the hurdle cleared was the awareness that the perfect is the

enemy of the good. The knowledge community used these categories as an initial starting point that could be institutionalized, modified, and clarified during subsequent iterative reviews.

The NASA CKO Office developed the Rapid Engagement through Accelerated Learning (REAL) Knowledge model (Figure 3) to promote the capabilities of more comprehensively and accurately define a problem; to encourage a pragmatic orientation that informs better decision-making; and to help to address the issues of bias, ego, special interests, and personal agendas. At the core of the REAL Knowledge model is the operational KM cycle activities of capture, share, and discover, but with an effectiveness measure paired with the knowledge activity. For example: capturing knowledge is the action and retaining is the measure; sharing knowledge is the action and applying is the measure; and discovering is the action and creating outcomes is the measure. Surrounding the REAL Knowledge core activities are the Individual/ Team Knowledge factors and the Organizational/Societal Expectations that mitigate the journey of the Challenge/Opportunity from inception through the knowledge cycle to successful project outcomes. Note that the process arrows are bi-directional in terms of influence and input.

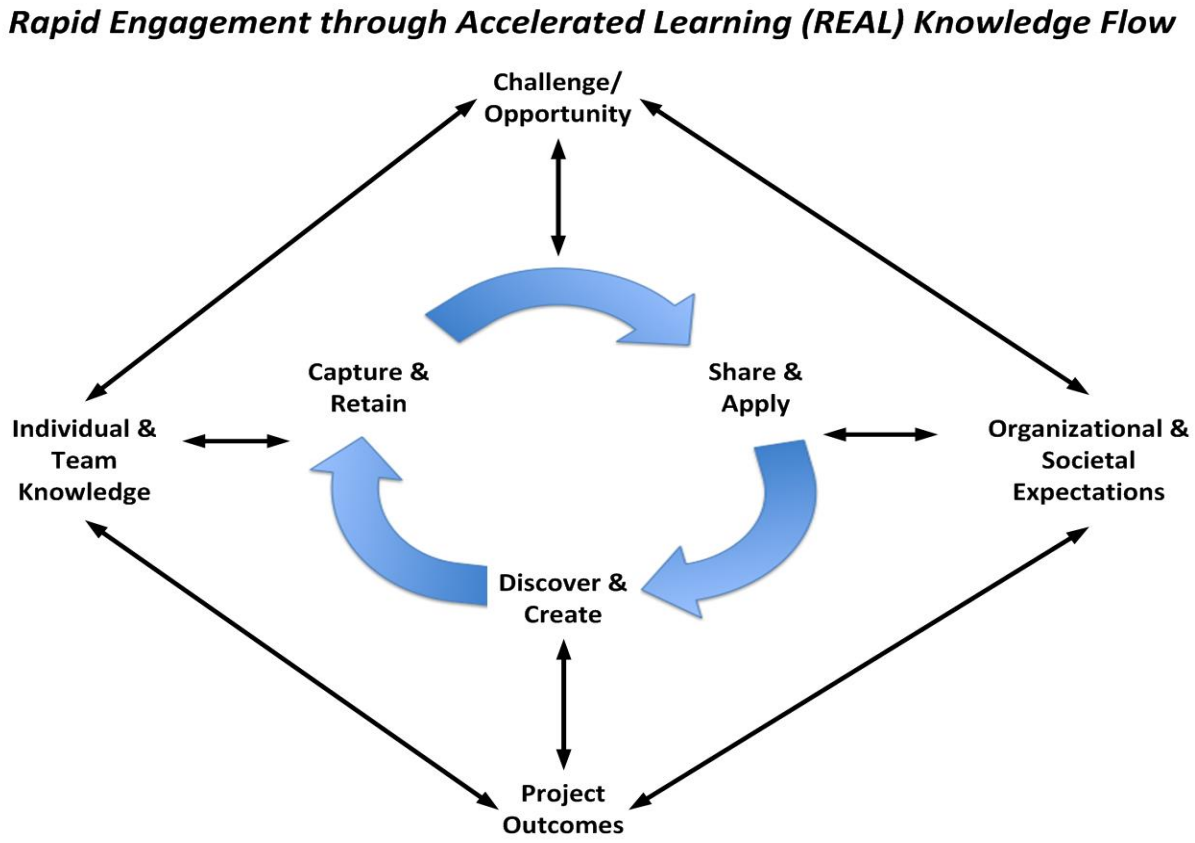


Figure 3: The NASA REAL Knowledge Model

This compendium is an element in the Agency response to the CK challenge and directly addresses the challenge of knowledge capture and retention for HEMOD. The current task has been undertaken to identify and make available video-based, multi-media CK resources to the

greater NASA community including programs, projects, technical authorities, functional managers, contractors, partners, and external stakeholders.

Video resources referenced in this first edition of the compendium were developed by the Exploration Systems Mission Directorate and the Human Exploration and Operations Mission Directorate (HEOMD) during the 2006-2014 timeframe. HEOMD resources were designed to ensure future public access by specifically avoiding material or interviews that could be considered restricted by either ITAR or Export Control regulations. Prior to publication in the nasa.gov domain all KCT resources underwent an extensive independent vetting process to verify that no ITAR or Export Control issues exist.

II. Critical Knowledge (CK)

For the purpose of this project, CK is defined as cross-cutting or broadly applicable lessons learned strongly related to accomplishing successful missions.

The editors recognize the difficulty in selecting "critical knowledge," which is often process dependent. Nonetheless the editors have endeavored to draw on their extensive NASA and project management experience to cull a select set of over 250 video clips deemed to be broadly applicable and of potential benefit to current or future NASA programs and projects.

III. CK Gateway

This compendium is a hard-copy companion to the CK Gateway web-site: http://km.nasa.gov/critical-knowledge-gateway/. It should be noted that while this compendium serves as a guide to specific CK video resources, it also serves as a gateway to a world of additional outstanding video and non-video lessons learned resources. Many of the CK items discussed within this compendium are located within a video dashboard "module" consisting of many subject matter experts addressing various aspects of a given program, project, or activity. In addition, each video "module" typically contains scores of related documents (in a variety of formats – pdf, pdf, doc, docx, etc.) as well as a synoptic lessons learned report (pdf). It is anticipated that any visit to a CK resource will prompt further exploration of the entire lessons learned module.

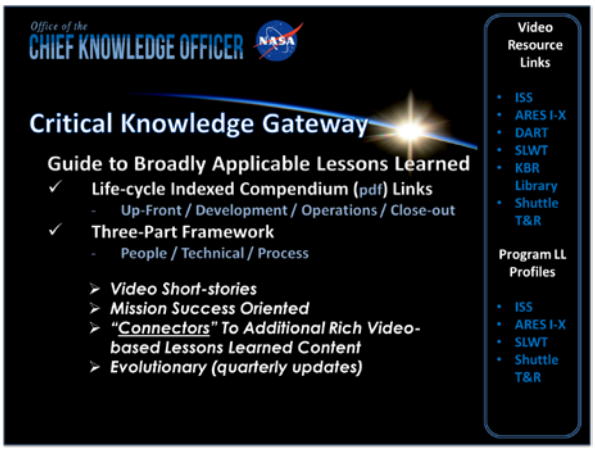


Figure 4: Notional Gateway web layout

Updates: Future updates will incorporate video content from CKO forums conducted over the past three years, as well as additional video content from HEOMD Knowledge Sharing Forums.

Public Access: Consolidating NASA knowledge resources into a publicly accessible web domain

is an important goal of the CKO and was specifically cited in the recent Senate authorization bill for NASA. It is anticipated that the consolidation of resources will be accomplished in CY 2015.

This compendium will be available on the companion CK Gateway web site (in development). The CK Gateway will be prominently tabbed on km.nasa.gov and linked directly from the existing CKO Knowledge Map on that same web site.

IV. Organization of Resources

A two-part classification approach has been employed, consisting of: 1) a notional simplified project timeline and, 2) high-level topical themes. While imperfect (as all frameworks tend to be), this structure provides a simple but effective framework for organizing, indexing, and browsing material. The organization approach is shown below in matrix format.

Table 1. CK Resource Organization and Tag Framework

INDEX MATRIX		*Nominal Project Timeline ---------->			
		1	2	3	4
	Themes	Early-on	Design/Build	Operate	Close-out
1	People	11	21	31	41
2	Process	12	22	32	42
3	Technical	13	23	33	43

The timeline elements include:

- (1) Early-on (e.g., architecture studies, forming the project team, defining roles & responsibilities, systems requirements definition, earliest milestones)
- (2) Design/Build (e.g. from PDR onward through CDR and into manufacturing phases)
- (3) Operate (e.g. ground processing, launch, and on-orbit operations of a space system)
- (4) Close-out (e.g. deorbit, program/project termination, facility closure, human resource management, close out of records, historical recordation, environmental cleanup)

Thematic elements include:

- (1) People (e.g., communication, leadership, organization, decision making)
- (2) Process (e.g., engineering, management, systems engineering, safety & mission assurance, business (cost and schedule), operational management)
- (3) Technical (e.g. modeling, verification testing, analysis, integration, technology, materials)

Using the structure defined above, each CK item is indexed with a 2-digit identifier such as "41" for a discussion of critical skill workforce retention during the fly-out of the Space Shuttle Program. In this case, 4 indicates the Close-out phase and the 1 indicates the People theme. On the other hand, the discussion of the Mission Management Team communication dynamics would be indexed as "31" for Operations/People.

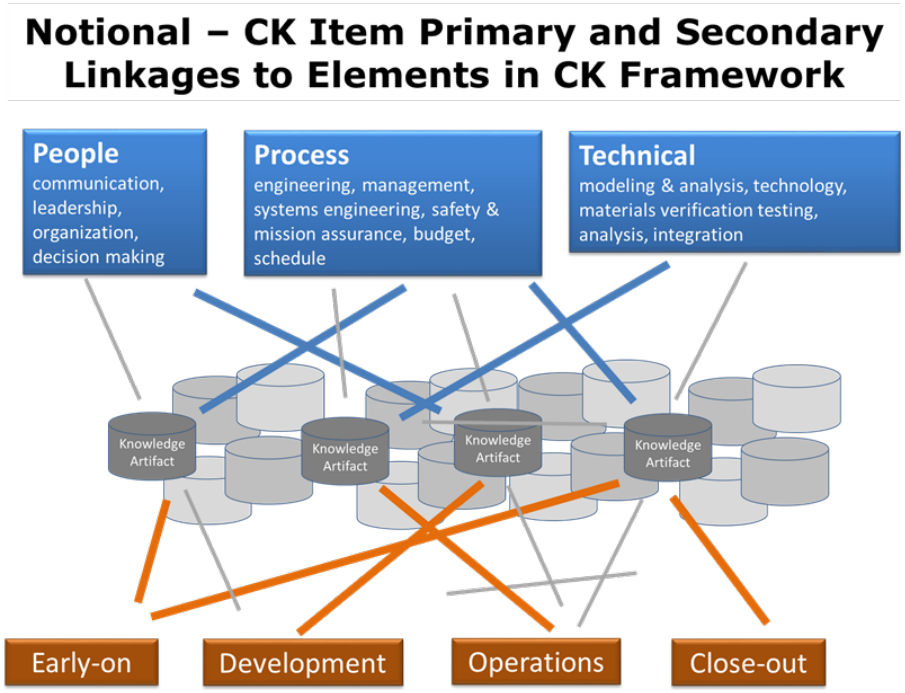


Figure 5: Indexing Challenge

As shown in the adjacent graphic, any individual CK item could be indexed multiple ways. The authors have endeavored to identify the primary linkages in each case while acknowledging the potential and encouraging the reader to make additional connections.

V. Index Field Structure

The CK resource index field structure has evolved with the goal of providing the user with the ability to rapidly browse (left to right) – first on a verb-lead tagline, secondly on theme, then presenter, followed by an excerpt, then where to locate the resource, and finally a timeline/thematic index used to sort CK records.

CK items are presented in a tabular format organized in the appendices of this document. Each CK item includes the following fields and content:

- Tagline – typically a short synopsis of the key point(s) or verb-leading declarative (e.g., "Put people first")
- Theme(s) – major and minor thematic elements as well as timeline indication
- Presenter – the video presenter
- Excerpt – typically 120 word or less excerpt from the video transcript
- Find it Here! – direction to the resource and/or web link to available CK items in the nasa.gov domain
- Index – the timeline/thematic index discussed in the previous section

Table 2. CK Compendium Index Layout Example

Tagline	Theme & Tags	Presenter	Abstract	Find It Here	Index
Put people first!	Program Transition Workforce Retention Closeout, People, 41	John Shannon	We put a huge premium with the contractor workforce and on the civil servant side with being extremely honest about what we were doing and why, and making sure that the people knew that even though we had budget problems and schedule problems and technical issues, that they came first and that we were as best we could within the constraints we had, both legally and just from a budget standpoint, that we were going to take care of them. That care was not just monetarily. It was communication; let them be able to have the opportunity to plan their life.	KBR 11797 – Civil Servant and Contractor Workforce Retention for Mission Execution Clip: Identification of Risk; Time marker: 04:30	41

VI. Sources

For this initial effort (Compendium 1.1), the CKO team conducted a detailed review and analysis of knowledge capture-transfer (KCT) resources developed by the Exploration Systems Mission Directorate (ESMD) (2006-2011) and the follow-on Human Exploration and Operations Mission Directorate (HEOMD) (2011-2014) identifying candidate CK content.

❖ Knowledge Based Risks

The NASA Knowledge-Based Risk (KBR) Library contains over 80 individual KBRs, each a comprised of subject-matter expert video interviews, white papers, articles, and presentations related to a specific management and/or technical issue. The KBR Library is an important Agency critical knowledge resource providing effective strategies for mitigating risks in terms of cost, schedule, and technical performance. KBRs are designed with a structured storytelling narrative format, describing the risk, providing context, expanding on how the risk was mitigated and summarizing lessons learned.

Figure 6: Knowledge Based Risks

While all KBRs are valuable and important, resources not all can be considered cross-cutting and broadly applicable. Accordingly, only a subset of available KBRs have been indexed in this compendium. CK, broadly applicable examples include: 1) composite overwrap pressure vessels (lightweight storage vessels that require careful handling and are a potential hazard); 2) tin whiskers (metallic crystal growth on circuit boards); 3) and Mission Management Team (communication dynamics and protocol for safety/mission critical decision forums).

❖ Demo of Autonomous Rendezvous Technology (DART) Case Study

The multi-media case explores program/project management and change management challenges during the DART life-cycle. Evolving requirements, three different NASA Administrators, the Columbia accident, limited resources, changing risk posture and time pressures create a rich case. Video vignettes featuring key DART program participants set the stage for group exercises.

Figure 7: DART Case Study

CK themes includerequirements management, technology development and infusion into new projects, limited staff, limited funding, minimal oversight and

limited systems engineering control processes. DART provides CK mission success insights for program and project managers, HQ Mission Directorate senior managers as well as engineering and safety & mission assurance technical authorities.

❖ Super Lightweight Tank Case Study

This multi-media case study focuses on the development of the Space Shuttle, Super Light Weight Tank (SLWT) – a technological innovation critical to development of the International Space Station. Key participant video vignettes provide a multi-dimensional look at the SLWT design, development, test, and evaluation process. Multiple risk issues abound including material property characterization, manufacturing process development, welding, weld repair, and system-level verification.

Figure 8: SLWT Case Study

Readers can examine the process of identifying and evaluating the risks and challenges that threatened the success of the project, and then compare their answers to those of the actual SLWT project team. Six case study exercises challenge users to identify and develop mitigation strategies for risks actually encountered by the SLWT project team. CK thematic content is very strong for planning and development phases with emphasis on technology and process.

❖ ARES I-X Flight Test

The ARES I-X module (video dashboard, documents, report, links) contains lessons learned video vignettes featuring 20 different key program participants from project management, integrated product team (IPT) leads and members; Mission Management Office; System Engineering and Integration (SE&I); Engineering and Safety & Mission Assurance technical authorities. Participants hailed from multiple Centers including: Glenn Research Center (GRC), Johnson Space Center (JSC) Kennedy Space Center (KSC), Langley Research Center (LaRC), and Marshall Space Flight Center (MSFC). CK capture topics addressed includeengineering management, technical authority (S&MA and engineering), systems

Figure 9: ARES I-X Video Dashboard

engineering, schedule, requirements management, design, organization, manufacturing, test and verification, communication, and resources.

❖ Columbia Accident Investigation Board

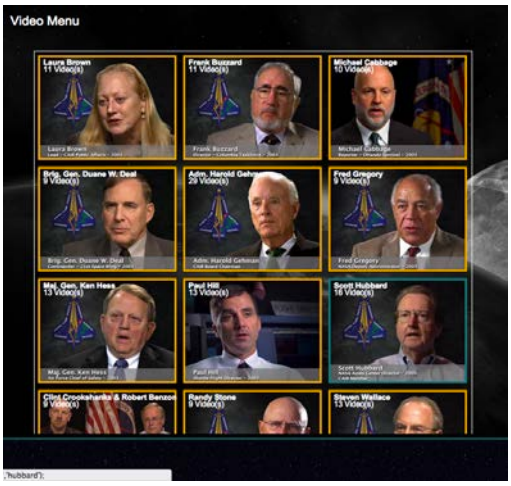


Figure 10: CAIB Video Dashboard

The CAIB module (video dashboard, documents, report, links) presents lessons learned in conducting the investigation of the 2003, STS-107 Columbia accident. CAIB members speak on lessons learned, do's, don't's and success factors in conducting investigations on the scale of Columbia. The CK content within the module provides an opportunity to review the preparedness and procedures that NASA has in place for future accidents. The module documents vignettes and observations from many of the participants and stakeholders of the investigation for both posterity and insight for future leaders. As might be expected from events of this magnitude, there were issues and challenges in conducting the investigation. Individual opportunities were identified and organized using a seven-element framework to assist in collating and communicating the interview survey results. Framework elements included 1) Leadership and Independence, 2) Contingency Action Planning, 3) Preparation and Training, 4) Investigation and Recovery, 5) Legal, 6) Communications and 7) Administrative.

❖ International Space Station

Figure 11: ISS Lessons Learned Video Dashboard

The ISS module (video dashboard, report, documents, links) provides insights from the ISS design, development, assembly, and operations relevant for ongoing and future NASA deep space and commercial space exploration activities. ISS participant videos address a wide array of topics including **Policy and Partnerships:** Policy, International Partners, Commercial Partners; **Engineering and Management:** Systems Engineering, Budget / Schedule, Risk Management, Internal Communication, External Communications; **Design, Development, Test & Evaluation:** Mission Architecture, Engineering Design, Technology, Materials, COTS, Interfaces, Integration & Test; and **Operations:** Logistics, Maintenance, Operations & Utilization, Crew Capability & Training, Crew Operations, Crew Medical, Science Utilization.

The accompanying report and documents provide a longitudinal perspective (2005, 2009, and 2013) on key experiences, issues, approaches, strategies, do's, don'ts, and cautionary tales that will be relevant to the formulation and implementation of future space exploration initiatives.

❖ Space Shuttle Transition and Retirement (T&R)

This module (video dashboard, documents, report, links) features subject matter experts discussing lessons learned derived from the Space Shuttle Program (SSP) Transition and Retirement (T&R) effort. Speakers address important issue areas, including: overall management, planning, human capital, real property, personal property, environmental management, historical preservation, document management, and contract closeout. The report also chronicles unique lessons associated with decommissioning Space Shuttle Orbiters and transporting them to museums around the country. While the SSP T&R is unique in many respects (e.g., closing-out a program that spanned 30 years), the lessons learned are in most cases largely transferrable to programs, projects, or organizations in change - any kind of transition, merger, fly-out, program cancellation, or end-of-program scenario. At a minimum, the SSP T&R experience will assist organizations by providing a framework to successfully plan and implement change.

Figure 12: Space Shuttle T&R Video Dashboard

❖ Knowledge Sharing Forums (KSF)

KSF events are designed as live discussion forums – seeking, in particular, to engage emerging project leaders. In most cases, the events have been video-recorded and the content made available through various NASA portals. Each KSF is structured to showcase senior project leaders sharing insights on their personal project implementation successes and challenges. Events showcase alumni from Apollo, Space Shuttle, and various other programs within NASA, as well as contributors from the broader aerospace industry and academia. Topics have included engineering management and systems engineering approaches, risk management, critical decision-making, organizational issues, as well as cost and schedule challenges. Examples include the (NASA's) Exploration Systems Architecture Study

Figure 13: Knowledge Sharing Forum

(ESAS), Space Shuttle Lessons Learned presented by Bo Bejmuk, or Discussion on Cyber Security, Risk & Knowledge Management at CYBERCOM with CKO Paul Guevin.

VII. Public Accessibility Status

As of January 2015 all of the following are deployed in the publically accessible nasa.gov domain and are direct links from the CKO, Critical Knowledge Gateway website, http:// _ _ _ _ .

- Ares I-X: http://cmsdev.nasawestprime.com/externalflash/irkm-aixll/
- DART: http://cmsdev.nasawestprime.com/externalflash/dart/
- SLWT: http://www.nasa.gov/externalflash/irkm-slwt/
- KBR Library: http://www.nasa.gov/externalflash/kbrs/
- Shuttle T&R: http://www.nasa.gov/externalflash/shuttle-transition/
- CAIB: http://www.nasa.gov/externalflash/CAIB/
- ISS: www.nasa.gov/externalflash/iss-lessons-learned

To be deployed at nasa.gov in 2015

- ESAS video Knowledge Sharing Forum

VIII. Appendix Structure

This pdf document contains four appendices, each one reflecting an element (Early, Develop, Operate, Close-out) in the notional project timeline discussed above. Within each appendix resources are organized consistent with the thematic framework – People, Process, and Technical.

Appendix A: Early-on (People, Process, Technical) - consolidated 11, 12, 13

Appendix B: Development (People, Process, Technical) - consolidated 21, 22, 23

Appendix C: Operations (People, Process, Technical) - consolidated 31, 32, 33

Appendix D: Close-out (People, Process, Technical) - consolidated 41, 42, 43

Search Capability: All pdf documents are fully searchable using the Ctr-F (find) command.

IX. Web-site Structure

The web site provides links to this entire document as well as the following topical consolidations of content into individual pdf files.

Timeline organization

- Early-on (People, Process, Technical) - consolidated 11, 12, 13
- Development (People, Process, Technical) - consolidated 21, 22, 23
- Operations (People, Process, Technical) - consolidated 31,32, 33
- Close-out (People, Process, Technical) - consolidated 41, 42, 43

Thematic organization

- People (Early-on, Development, Operations, Close-out) - consolidated 11, 21, 31, 41
- Process (Early-on, Development, Operations, Close-out) - consolidated 12, 22, 32, 42
- Technical (Early-on, Development, Operations, Close-out) - consolidated 13, 23, 33, 43

Appendix A: Early-on (People, Process, Technical) - consolidated 11, 12, 13

Appendix A: Early-on (People, Process, Technical) - consolidated 11, 12, 13					
Tagline	**Theme & Tags**	**Presenter**	**Abstract**	**Find It Here**	**Index**
Recognize that architectural decisions have political consequences	System Architecture Analysis - Politics	Doug Stanley	It is a HQ function to have an ESAS-type team of experts that keep setting the agency's direction and program architecture, to get around the NASA centers' politics.	ESAS Video; Time marker: 11:00	11
Recognize and manage Center-Center politics / ensure program-level integration	System Architecture Analysis - Politics and Communication	Doug Stanley	In ESMD, center politics are getting in the way and they are not sharing data with each other. That is unacceptable. You need some top-down system that rewards people for cooperating and sharing data. This is a HQ function, maybe a Directorate Integration Office (DOI) function.	ESAS Video; Time marker: 35:30	11
Recognize and address Center-to-Center cultural and terminology differences	Ares 1-X Project Management - Teambuilding	Robert Ess	The hardest things was to take all these different people and all these different cultures, using all those words together and making sure we ended up on the same page. Do not underestimate the lingo that we use. I would suggest that we speak in examples so we talk about not terms and definitions and acronyms but actually go down two or three or four levels deeper than you think you need to at day one of the project.	Ares 1-X Lessons Learned: Clip: Culture Shock!	11

Appendix A: Early-on (People, Process, Technical) - consolidated 11, 12, 13					
Tagline	**Theme & Tags**	**Presenter**	**Abstract**	**Find It Here**	**Index**
Build relationships and trust right from the start on a multi-Center project team.	Ares 1-X Project Management - Teambuilding	Carol Scott	When you're bringing a team that comes together from multiple centers and multiple organizations you've got to start off with building relationships and trust. It takes a good year to eighteen months to get there.	Ares 1-X Clip: Culture Shock!!	11
Establish relationships upfront to enable information flow.	Ares 1-X Teambuilding	Jonathan Cruz	Communication was key. If there was important information that someone had that didn't get where it needed to, that impacted the striving schedule. So some face-to-face meetings, travel at least up front to meet the people, established a lot of those relationships where we were able to call up if you had a question or you had some information that you needed.	ARES 1-X Clip: Communicate, Communicate, Communicate!	11
Build relationships with face-to-face interaction opportunities	Ares 1-X Communication	Jim Bolton	Email is the illusion of inclusion. A mechanism to get people to talk, to really talk to each other, is important.	ARES 1-X Clip: Communicate, Communicate, Communicate!	11

Appendix A: Early-on (People, Process, Technical) - consolidated 11, 12, 13					
Tagline	**Theme & Tags**	**Presenter**	**Abstract**	**Find It Here**	**Index**
Get the right people "on the bus"	Ares 1-X Project Management - Organization	Marshall Smith	Get quality people and trust them, so you don't have to revisit their answers and look at yet another option. We're done. It's time to move on.	Ares 1-X Clip: Systems Engineering and Integration	11
Develop clearly defined training objectives up-front	Design / People / Training / Concept of Operations	Ginger Kerrick	For exploration, while it is a noble goal to have everything in place (the hardware, the software, the ops concepts) ready to go so that you can implement your training plan, in reality it is very difficult to achieve. So my advice to you would be to have very clearly defined training objectives and you may choose to meet those objectives differently for the first flight than you would once you have a better understanding of the operations and you’re at a more mature level, but you need to make sure to understand the objectives up front.	ISS Video Dashboard Ginger Kerrick Clip 5, 1:17	11
Take your time to select the right people for the right task at the start	Personality dynamicsRight skills for the job	Kathy Owen	Make sure you put the right people, with the right skills, and the right personality in the job, because even if they've got the right skills, and they don't have the right personality, it really can be a detriment.	11496 Integrated Vehicle Ground Vibration Testing last clip	11

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Involve hardware owners in the decision making process	Improved Communication, Problem solving	Alvaro Rodriguez	It is important to involve the hardware owners as part of the team structure. Having them involved in decision making decisions informed the team and helped to answer questions that came up quickly.	11934 - On-Orbit Reinforced Carbon-Carbon Repair - Organization and teamwork	11
Assume positive intent	People Success	Jonathan Krezel	Lesson number one is assume positive intent. Assume that everyone on that team, while their perspective may be different than yours, is ultimately committed to the success of the entire endeavor. When you're in a knock-down-drag-out fight with someone over an issue which you feel passionately about and which, obviously, this person on the other side of table feels passionately about its very easy to forget that they are as interested in success as you are. They just have a different take on success. You have to step back and really make a conscious effort to put yourself in their shoes. Assume positive intent.	Space Shuttle Transition and Retirement Lessons CLIP 8 Top Three Takeaways: Time Marker 5:03	11
Communicate with increased frequency the harder the project	People, Communication	Joel Kerns	We found it was really important in such a complex task that affected so many different organizations that we had to communicate frequently about what we knew and what we didn't know, day-to-day, week-to-week and month-to-month.	Space Shuttle Transition and Retirement Lessons Learned; Clip: Time Marker 1:30	11

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Silence the rumors	People, Communication	Joel Kerns	Go out as the leadership and brief people on what it is we knew, what we thought was going to happen, what decisions we thought were coming up, or even what we didn't know, that rumors and uncertainty would creep into everyone's activities and just cause a lot of disruption.	Time Marker: 1:55	11
Co-location is key to rapid development of system architecture	System Architecture Analysis - Project Management	Doug Stanley	Co-locate people if you want a group of people to accomplish something in a short time period.	ESAS Knowledge Nuggets ESAS Video; Time marker: 0:10	12
Use an integrated risk management approach in assessing architectural options	System Architecture Analysis - Risk Management	Joe Fragola	You need an integrated risk management and mitigation approach, so that risk reduction in one segment doesn't increase the risk elsewhere and possibly to the overall architecture risk. Don't have pockets of risk mitigation in isolation. An integrated approach, using one tool with risk, cost and performance included is important.	ESAS Video; Time marker: 4:00	12

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Document and communicate assumptions embedded in trade analyses	System Architecture Analysis - Modeling and Analysis	Doug Stanley	Document your assumptions, so that you can do proper analysis and trade studies.	ESAS Video; Time marker: 5:00	12
Focus on managing the details of the program execution	System Architecture Analysis - Project Management	Bill Blaybaugh	Is well-organized system engineering needed? Anything (i.e. any management/process approach) can be made to work. The details are in the execution, not in the theory of management.	ESAS Video; Time marker: 12:00	12
Maintain a top-level, integrated understandfing of risk	System Architecture Analysis - Risk Management	Joe Fragola	Program managers should have a version of this integrated tool that integrates risks, costs and performance, to keep the engineers honest, since they may be driven by local optimization without considering global optimization.	ESAS Video; Time marker: 19:15	12

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Establish a baseline and track multiple performance metrics	System Architecture Analysis	Jay Falker	Use the technique of having multiple performance metrics to make decisions. EMSD should establish a baseline and then fully understand the impact any change has across all elements and aspects (cost, schedule, risk, performance).	ESAS Video; Time marker: 21:45	12
When necessary employ engineering judgment - informed intuition in considering options	System Architecture Analysis - Decision Making	Doug Stanley	Work with good models but also with informed intuition based on experience, since in space exploration we don't have vast amounts of empirical data. We need intelligent drivers/architects using these tools.	ESAS Video; Time marker: 26:45	12
Video-capture critical “know-how"	System Architecture Analysis - Knowledge Capture	Bill Claybaugh	Rockedyne recorded the know-how about the Saturn 5 by video-taping every single person who had worked on the F1 engine, talking about every detail of what they did. The know-how had all been documented and was available. And that is how you do it.	ESAS Video; Time marker: 31:00	12

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Articulate expectations - Orient partner organizations	Ares 1-X Project Management - Teambuilding	Jonathan Cruz	There was some culture shock once we arrived at Kennedy. It had been anticipated and they had actually held Kennedy 101 classes to try to educate other centers on what to expect	Ares 1-X Clip: Culture Shock!!	12
Develop a Program culture that transcends Center-to-Center cultural differences	Ares 1-X Project Management - Teambuilding	Marshall Smith	A center-focused mindset needs to be shed, and you're going to have to come with a system mindset, a system set of organizational goals and standards that you're going to follow as a system, regardless sometimes of your center's wants and needs.	Ares 1-X Clip: Culture Shock!!	12
Clearly define roles and responsibilities and interface details between project phases	Ares 1-X Project Management - Articulating Roles & Responsibilities	Trip Healey	There are differing level of assumptions when determining roles and responsibilities once the hardware actually arrived at the launch site at Kennedy. Design engineers wanted to be involved all the way to the end, but the launch site folks were operating in a culture in which hardware is turned over to them. And there was a level of disconnect between the drawings and the task of assembly.	Ares 1-X Culture Shock!	12

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Early in the project engage technical authorities at HQ and Centers and establish mutual expectations	Ares 1-X Working with Technical Authorities	Jon Cowart	The core team gets that better is the enemy the good enough, but the people back at the centers who aren't involved with us day to day, they're very worried, they see us, in their opinion, short-circuiting process and not following all the guidelines and all the standards and requirements.	Ares 1-X Clip: Better is the Enemy of Good Enough	12
Co-locate key people at the start of a project	Ares 1-X Project management - Co-location	Robert Ess	Co-locating some key people up front during the project formulation phase for 3 weeks to 2 months would have been good.	Ares 1-X Clip: The Importance of Co-location	12
Recognize communication challenges early-on and implement robust processes to address	Ares 1-X Communication	Ed Mango	Start early, get the team down, understand the issues with the team, understand how the team communicates and treat it like a team, not as a number of individuals. Badge-less is definitely the way to go.	ARES 1-X Clip: Communicate, Communicate, Communicate!	12

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Avoid surprises by effectively coordinating and communicating ahead of time	Ares 1-X Communication	Bruce Askins	Communication was the key so when we came up on our major reviews there were very few surprises. It was not like you were overturning rocks at the meetings.	ARES 1-X: Clip: Communicate, Communicate, Communicate!!	12
Develop, document, and communicate the project governance model	Ares 1-X Project Governance	Robert Ess	We at NASA tend to delegate responsibility and retain authority. I was delegated both. This worked well. People are smart and will figure out who the real decision maker is, and they'll concentrate their energies there. We relied on the NASA governance model (technical authority appeal route), which helped.	ARES 1-X Clip: Communicate, Communicate, Communicate!!	12
Establish S&MA requirements up-front	Ares 1-X SMA Technical Authority	Robert Ess	We were late getting the S&MA requirements for this flight test. People used 2 approaches: take the Shuttle requirements and cross off what doesn't apply, or start with a clean sheet and define what is needed. We spent days trying to marry those two approaches.	Ares 1-X Clip They are Guidelines, not Requirements	12

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Establish a clear, streamlined project governance board structure	Ares 1-X Preoject Governance	Chris Calfee	The systems requirements were controlled by the MMO but so was the next level of documents, the elements requirements documents. These latter documents were also contractually controlled documents so two boards were controlling this 2nd set of documents. Avoid that.	Ares 1-X Clip They are Guidelines, not Requirements	12
Start project elements on time, even if it is not perfect. Start finding problems early on	Ares 1-X Schedule-driven, risk informed Project Management	Robert Ess	Start when you have to start, schedule-wise, even if it is not perfect. Don't worry about it. The 80% solution is good enough. That way you will find your problems early and stay on track.	Ares 1-X Clip: Schedule Management	12
Consider advantages of a flat organizational structure	Ares 1-X Project Management - Organization	Robert Ess	Our organizational structure was as flat as you possibly could draw it. It made the lines of communication very clear. There was one control board. By structuring this way, our efficiency of communication, which is key to any project management, increased dramatically.	Ares 1-X Clip: Organizational Structure	12

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Delegate budget and schedule authority to lower-level project teams	Ares 1-X Project Management - Organization	Jeff Campbell	Each IPT had their own budget and schedule authority, and that seemed to make things run smoothly.	Ares 1-X Clip: Organizational Structure	12
Apply the Agency governance model with programmatic, technical and S&MA authority.	Ares 1-X Project Governance	Dan Mullane	The Mission Manager embraced the NASA governance model with a three-legged stool of authority: programmatic, technical and S&MA. All three authorities were part of all decisions.	Ares 1-X Clip: Safety and Mission Assurance	12
Recognize that hybrid, "one-shot" test projects may not need standardized rules	Ares 1-X Project Management - Requirements Management	Dan Mullane	Since ARES 1-X was a one-shot un-crewed flight, we made the maximum use of existing processes, allowing for maximum flexibility versus standardization between project segments. This puts the burden on the folks that had to do the integration function, but I think it was the right approach.	Ares 1-X Clip: Safety and Mission Assurance	12

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Finalize SMA requirements before awarding any contracts	Ares 1-X Safety and Risk Management	Dan Mullane	Do not award contracts before you have the right set of S&MA requirements. This was an afterthought in ARES 1-X.	Ares 1-X Clip: Safety and Mission Assurance	12
Tailor 7120 to your project needs and make sure senior management supports it	Ares 1-X Project Management - Requirements Management	Marshall Smith	Some people think that 7120 is something that actually holds you down, but it is extremely tailorable and people need to do that. Senior management needs to let go of their favorite requirement when it is not related to the mission goal. So, tailoring is a big thing that needs to be recognized and needs to be used and allowed to be used.	Ares 1-X Clip: Systems Engineering and Integration	12
Define clear organizational interfaces, roles and responsibilities up-front	Ares 1-X Project Management - Organization	Dan Dumbacher	When you're setting up a major project like this, spend a significant time up front on what the interfaces are, what the management scheme is, and what those relationships need to be. Minimize the interfaces, make sure that the management scheme and operation is clearly understood by everyone before you get too far down the road, and change the management scheme throughout the project life cycle, as needed.	Ares 1-X Clip: Senior Leadership Part Two	12

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Seek ways to innovate in how we accomplish space missions while managing risk	Ares 1-X	Dan Dumbacher	Most of our work force has been hired since Challenger and Columbia when, from a human space flight perspective, we got much more risk adverse. We have to help bring them along from that risk adverse posture into a posture that's willing to take a little bit more risk. We'll make some mistakes along the way, but I think we can find ways to operate more efficiently and ARES I-X gives us that big key data point to start the conversation.	Ares 1-X Clip:: Senior Leadership Part Two	12
Consider how Ares I-X lessons learned - and the culture battles - may be a precursor for the culture changes necessary to embrace commercial space	Ares 1-X Project Management - Oversight and Commercial Space	Dan Dumbacher	We can apply Ares I-X even to the commercial crew and commercial cargo operations. I think the culture question is the key in my mind and I'm honestly worried that we're not spending enough time really working through the culture of what needs to be done and what does not need to be done.	Ares 1-X Clip: Senior Leadership Part Two	12
Evaluate the applicability of ARES I-X streamlining and management approaches	Ares 1-X Project Management - Oversight and Commercial Space	Doug Cooke	ARES 1-X helps us to understand where we can streamline activities without sacrificing success.	Ares 1-X Clip: Senior Leadership Part Three	12

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Consider how ARES 1-X lessons learned with limited management insight and oversight informs commercial space oversight activities	Ares 1-X Project Management - Oversight and Commercial Space	Doug Cooke	For the commercial cargo and crew plans, we can't be over intrusive into the process or the cost will blow up on us. We can apply ARES 1-X lessons learned in limited management insight and oversight, and in streamlining.	Ares 1-X Clip: Senior Leadership Part Three	12
Have a discussion up-front with all stakeholders to baseline the risk management and technical authority oversight approach	Ares 1-X Project Management - Oversight and Commercial Space	Doug Cooke	If we're satisfied with less insight or oversight for commercial entities, then you have to ask yourself why isn't that good enough for the government developed vehicle. That's a big area of discussion. We have to have good models for implementing this. We have to concentrate on the high risk areas only, stop asking the "what if" questions as engineers, have management discipline, and education for everyone on the new way of operating. This is a culture change.	Ares 1-X Clip: Senior Leadership Part Three	12
Ensure that adequate staffing is in	Organizational Priority	Chris Calfee	DART was proposed as low risk—I'm sorry—high risk, low cost project, so that theme was carried over to the government side as well. So we started. I had no business office. I had no business manager. I had some support but no dedication there. No schedule, scheduler; I had schedule support, but not day-to-day.	Demonstration of Autonomous Rendezvous Technology (DART) Video Case Study: Page 8. Time: 3:31 Dart Overview	12

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Ensure balance between risk acceptance, staffing and budget.	Systems architecture	Mark Krome	MSFC, being a manned space flight center we have a high emphasis on reliability, on safety, on system redundancy and an important aspect of that is to verify that you've met system requirements. On DART, however, there were some initial differences in terms of the project expectations for how this would be done, among the things that would make it a high risk project, were the fact that it was to be largely single string, it was to be low cost.	DART Video Case Study: Page 21, Section: Risk Posture and Verification P2 Time 0:27	12
Drive to closure	Retiring tasks early buy schedule		You need to drive things to closure faster and that will pay off later. You need that time. And I learned that in this mission and there were people already on the mission who knew this—I had people pressuring me that we need to close this trade	KBR -11397 Project Lessons Learned	12
Expand QD limitations with a maximum credible event approach	Hazardous material storage, Overcoming manufacturing limitations and logistics issues	Steve Stover	Limitations of the VAB regarding the amount of allowed hazardous materials and the associated quantitative distance limitations were going to cause assembly and scheduling issues for programs after the shuttle. Using an approach previously developed by the DoD called Maximum Credible Event (MCE), a revised hazardous materials limit was determined for the VAB that could accommodate requirements for future launch vehicles.	2589 Quantity Distance Limitations	12

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Identify long lead items early, including supporting test and launch hardware	Long lead materials Scheduling	Larry Schultz	It is critical for the program to identify all the long lead items early. In this case umbilical plate assemblies were not acquired early enough in the program to support the test and integration schedules. Each team needs to be able to raise awareness within the program of their long lead items early on. Had the issues been raised early the funding would have been available and the time to negotiate acceptable delivery dates for the hardware would have been adequate.	4133 Umbilical Plate Assembly Deliveries	12
Characterize testing facilities and plan with them ahead of time	Planning Test environments	Alvaro Rodriguez	Too often during the project we would run into scheduling, cost, or technical issues with a facility and then have to redirect our focus to another facility. If we had fully characterized our environments and defined our testing needs early many of these challenges would have been reduced or eliminated.	11934 – on orbit RCC repair – Verification planning: facilities	12
Set realistic schedules	Schedule, requirements determination, program set up	Mike Fowler	Instead of putting a more realistic schedule for the first return to flight, we were always pushing the flight back about three months from the previous date. So every time that it got pushed back three months, we were back in that same situation of still not being able to change the hardware, still not being able to change the material, and it was just an endless loop of not being able to change anything and being stuck with a design that really didn't make sense from the initial	KBR 11938 Clip: Context; Lessons Learned -Schedule - Time marker: 0:00	12

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			requirements that were setup.		
Codify your WBS early	WBS Process	Karen Lucht	So I would say early on understanding and codifying that WBS, whatever the architecture is you decide to use, by codifying that early, using that again, that starts to establish how you manage and report expectations to stakeholders, and then it allows you to help manage what they want later in terms of information, level of detail. By having that established early, you can use it as always again reiterating this is the level of detail we have, we established it earlier so we were able to leverage that and keep that consistency all the way through the closeout of the program.	Space Shuttle Transition and Retirement Lessons CLIP 9 Top Three Lessons Learned : Time Marker 0:46	12

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Define your own playbook	Process Program Plan	Karen Lucht	So, in lieu of a playbook, develop your own playbook. Understand, again, once you know the scope, let's talk about what we have to accomplish, the timeline we have to accomplish it in, and let's develop the plays in order to get there, recognizing that it's adaptable as you go through there. So, you can't wait. That decision paralysis of waiting for decisions to be made, the playbook will enable you to actually move, make progress, good timely progress, and then adapt it as you go.	Space Shuttle Transition and Retirement Lessons CLIP 9 Top Three Lessons Learned : Time Marker 2:32	12
Structure your risk program to your needs	Risk Management Structure	Jonathan Krezel	The challenge with a risk management system is how far do you take it? You always need one. It's simply a matter of the details of what kind you want to set up. So I think in guess the lesson learned, my take away from that, is acknowledge that you should handle risks whenever you start a new activity like retirement and give some thought as to what that risk management system should look like for you. The answer is you need some sort of system to manage risks. The issue is just what kind of details you're going to use to set it up, but make sure you think deeply about it.	Space Shuttle Transition and Retirement Lessons CLIP 6 Top Transition and Retirement Risks: Time Marker 3:13	12

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Develop capability to do apple-to-apple trade studies	System Architecture Analysis - Trade Studies	Doug Stanley	Have integrated analysis capabilities with apples-to-apples comparison, using the best methods available.	ESAS Video; Time marker: 1:30	13
Use simple over complex tools in system architecture development	System Architecture Analysis - Modeling and Analysis	ESAS Team	I rather have simple tools that everyone knows how to use, than complex tools and nobody knowing how inputs turn into outputs. I rather have a simple model now that gives me some type of top-down understanding of the overall system behavior, than spend two years developing a integrated platform, web-based, etc., and then be two years too late finding out what I needed to know.	ESAS Video; Time marker: 12:30	13
Use architecture-level risk modeling tools	System Architecture Analysis - Risk Management	Joe Fragola	The risks in the ESAS report are not real risks but coherent sets that allow us to discriminate between designs. We build the risk analysis modeling tool over time, module by module, as funds were available, based on the 1995 Shuttle PRA. If we would not have had this tool, we would not have been able to do this study.	ESAS Video; Time marker: 16:00	13

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Understand and communicated constraints imposed on the architecture	System Architecture Analysis - Constraint Requirements	Doug Stanley	We cut the new technology budget in half because the administrator wants to accelerate the CEV program and he likes the proven and the Keep It Simple Stupid (KISS) approach.	ESAS Video; Time marker: 20:15	13
A perfect model is the enemy of a good enough model	System Architecture Analysis - Modeling	Joe Fragola	The perfect is the worst enemy of the good-enough. ESAS was successful because we were willing to use models that were not perfect in giving us THE risks. They gave us enough discrimination between options to make decisions. Deep simulation models are not needed at this stage.	ESAS Video; Time marker: 23:15	13
Understand acceptable uncertainty in modeling	System Architecture Analysis - Modeling	Joe Fragola	There always is some uncertainty. We use the concept of Expected Value of Perfect Information, i.e. if you reduce the uncertainty, would it change your decision? In many cases it doesn't, so the investment is not useful. Let's not strive for better models just for the sake of having better models. The type of model you need to discriminate is different from the type of model you need for an actual design.	ESAS Video; Time marker: 24:00	13

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Pay attention to infrastructure required to support architecture	System Architecture Analysis - Infrastructure and Facilities	Bill Claybaugh	Give attention to infrastructure. Every building comes with people in it, and fixed overhead costs. You have to knock down buildings in order to have lower infrastructure costs.	ESAS Video; Time marker: 28:30	13
Develop a clear strategy for technology development and technology incorporation within each architectural option	System Architecture Analysis - Technology Management	Jay Falker	There is an issue in NASA of how to deal with technology, because there are two cultures. We have development & flight, and we have research & technology. There is mistrust and there are some barriers that need to be broken down. There are two kinds of research projects. One is on the critical path, and others are looking further out. We need communications on which type you are.	ESAS Video; Time marker: 32:00	13
Establish the acceptable level of mission risk up front.	Ares 1-X Risk Management	Stephan Davis	If you're going to do a flight test program, understand up front what the level of risk is that you're willing to accept in the mission. For example, would an 80% probability of meeting a mission objective be OK?	Ares 1-X Clip: Plan Then Do	13

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Define and communicate success criteria up-front to all stakeholders	Ares 1-X Project Management - Requirements - Success Criteria	Dan Dumbacher	We had to work through a culture change to define what success is for a development flight test. Initially there were many different views on the definition of success.	Ares 1-X Clip: Senior Leadership Part Two	13
Carefully consider redundancy, cross-strapping, and component reliability in deep space mission design	On-orbit matted interfaces and required EVA support	Gregg Baumer	That's one of the things that I think I've learned most about the Russians and the Russians' approach to hardware: we do a lot by analysis - they do a lot by test, mostly by test. They have redundancies. In one particular case, we were looking at a system and they only had an A Side and a B Side to do a particular function, and we said 'No, if this function is lost, it's catastrophic to this Station.' This was on their propulsion system. They said 'That's not an issue because the A Side is really single-failure tolerant and the B Side is single-failure tolerant; and not only that, the individual components within that ORU [Orbital Replaceable Unit] are cross-strapped; actually, we could probably withstand about seven failures on the A Side and about seven different failures on the B Side and still be fully functional.' Redundancy, cross-strapping, and reliability [are some things] that have to be stressed in a long-term vehicle that's interplanetary. That's beyond the two-failure tolerance requirements that we levied for ISS [International Space Station]	KBR 2650 Failures of On–Orbit Mated Interfaces last clip	13

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			safety - because there, they're not going to have the luxury of bringing up spares and fixing something, it's going to have to work and have to continue to work.		
Start early to develop test data and models to support design activities.	Composite Overwrap Pressure Vessels (COPVs) in service now (SSP, ISS, spacecraft, EELVs) and will be used in future space systems (CxP, Lunar)	Multiple Subject Matter Experts	The most important thing that we have learned from this test, analysis and risk assessment program is to generate your data set and your models early in the planning phase for risk assessment. We have really been challenged in this program because we are developing our models for risk assessment after the programs have already selected vessels and are already buying components. It has been very difficult for us provide decision makers an accurate assessment of what the risks are.	KBR 7084 Last Clip : Lessons Learned	13
Set a baseline of mission objectives	Defining spacecraft objections	Chris Calfee	One of the other issues early-on as proposed was really a limited set of mission objectives. We were trying to accomplish in the 'prox ops' phase—in other words, as the DART spacecraft approached the target—what kind of operations were we going to demonstrate?	DART Video Case Study:	13

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Implement logistics, maintenance, reliability trades up-front	Design / Logistics / Reliability	Anthony Butina	We really didn't come on board until the CD phase. By that time, the design had solidified enough that any ability to influence it for maintenance and for repair was gone... you need to be up there early in the program and considered from the first time a piece of paper hits a pencil ... it takes that engineer to have that in the back of his head as he designs it so that we can get to these things and get them repaired as fast as we can	ISS Video Dashboard Anthony Butina Clip 1	13
Prioritize!	People, Communication	Jonathan Krezel	The great thing about priorities is, even if you're last on the priority list, it's better to know that you're at the bottom than to have any ambiguity about where you stand.	Space Shuttle Transition and Retirement Lessons Clip: 2 Start Up Transients: Time Marker 5:23	13

Appendix B: Development (People, Process, Technical) - consolidated 21, 22, 23

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Design ways to communicate efficiently in a complex matrix test program	Ares 1-X Communication	Robert Ess	The fact is that you can't educate everyone on your team because your team within NASA is never just a team of people that you see. There also is the matrix support team back at the institutions and directorates. Those are the ones that are really going to have a lot of influence on what happens and so it's a challenge, it's a daily challenge, every day.	Ares 1-X Clip: Better is the Enemy of Good Enough	21
Realize the challenges with virtual teaming	Ares 1-X Virtual team dynamics	Vince Bilardo	Operating with those five centers in that virtual project environment was very much a challenge.	Ares 1-X Clip: The Importance of Co-location	21

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The project manager must be present at the center of gravity	Ares 1-X Project management - Co-location	Robert Ess	As project managers consider where the center gravity of the project is at any stage and find a way to get close to that. Forge relationships with those people and I think you'll have a much better understanding of what's really happening with your project if you do it that way.	Ares 1-X: Clip: The Importance of Co-location	21
Co-locate design engineering in launch-site integration	Ares 1-X Project management - Co-location	Stephan Davis	Most of us moved to the Cape for the last eight or nine months. That made a huge difference as we stepped through the integration and testing	Ares 1-X Clip: The Importance of Co-location	21
Keep work and family life in a healthy balance in these fast-paced projects.	Ares 1-X Workforce Stress & Health	Carol Scott	We tend to jump into these special projects and run them at a sprint race. Don't forget about your family and friends.	Ares 1-X Clip: The Human Element	21

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Pay attention to your employees in fast-paced projects and watch for stress buildup.	Ares 1-X Workforce Stress & Health	Jon Cowart	As managers in particular you have to look and see how folks are doing and pay particular attention to them during stressful times.	Ares 1-X Clip: The Human Element	21
Change people out in demanding programs to avoid over-pushing people.	Ares 1-X Workforce Stress & Health	Jonathan Cruz	With such a fast-paced, demanding program it's important not to over-push people and to be able to be flexible enough to change out people even just temporarily when needed.	Ares 1-X Clip: The Human Element	21
Communicate and discuss changes in standard roles and responsibilities with all stakeholders, especially external ones	Ares 1-X Organizational roles and responsibilities	Ed Mango	If you're going to have different, non-standard roles and responsibilities for major decision-makers, such as the launch director, start discussing that early on, especially with external stakeholders such as the engineering and safety tech authority.	Ares 1-X Clip: Roles and Responsibilities	21

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Staff the SE&I function fully	Ares 1-X Systems Engineering	Jon Cowart	System Engineering & Integration (SE&I) has a huge role. They have to be a real technical authority on the whole rocket. Staff them properly and give them a little more resources than they think they need.	Ares 1-X Clip: Roles and Responsibilities	21
Function as a single integrated team	Ares 1-X Project Management - Organization	Robert Ess	We banned the use of phrases like level 2, level 3, level 4. We were all part of an integrated team.	Ares 1-X Clip: Organizational Structure	21
Maintain a focus on communication and information sharing	Ares 1-X Project Management - Communication	Dan Mullane	The Mission Manager always stressed that we were one team, breaking down barriers and silos of information that can exist between levels and centers. If you want to move fast in an efficient way, communication flow and the sharing of information is extremely important and while Ares I-X wasn't perfect, I thought it was the best example that I have experienced in my 20 year NASA career.	Ares 1-X Clip: Safety and Mission Assurance	21

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Recognize the team building and team training dimension of flight test projects	Ares 1-X Project Management - Teambuilding	Dan Dumbacher	One of the main take-ways was that the analyst, designers, system integrators and the operators all learned what needed to be done on this flight test, and what didn't need to be done, in addition to the technical take-away by getting the data we needed to inform the development program for Ares and Constellation.	Ares 1-X Clip: Senior Leadership Part Two	21
Don't glance over minority opinions, lean on experts	Minority opinion, expert knowledge	Mike Fowler	And so my lesson learned from that is that while you should be listening to all of the minority opinions, you should also respect the expert's opinions on what is and isn't a valid concern. So I think that it's good to listen to other people. It's good to listen to, you know often times there's negative information or questions that are asked that are good to, that no one had thought about. But there are also times that there are things that should not be pursued as vigorously or spending as much time trying to pursue	KBR 11938 Clip: Context; Minority Opinion-Time marker: 0:00	21
Build confidence through technical conversations	People, Trust and Confidence	Alvaro Rodriguez	One of the big lessons I learned through going through the repair project and seeing it to success, was the value we had in the team members and learning how to divvy up the roles. We had to learn to, especially for mission support, how do we work with each other and how do we trust and rely on each other to all come together to ultimately make a recommendation to the project. A lot	KBR 11934 Clip Context; On-Orbit Reinforced Carbon-Carbon Repair	21

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			of that was building trust with each other in terms of our technical discussions. Even personal relationships that we had built up; those were invaluable.		
Design interfaces as common as possible	Personnel training Smart simple design = reduced failure opportunities in use	Scott Parazynski	Crew training is critical when you have new tasks that require new tools or processes that are outside the normal training requirements. Overall the less design complexity and process complexity is involved the fewer opportunities for failure will be down the road during operation.	11934 – on orbit RCC repair – crew training	21
Assess organizational leadership and staffing risk as well as technical, cost, and schedule	SLWT Project - Risk Management	Bryan O'Conner	There is a lot of risk talk you can do on the technical matters and on the performance versus safety, but the organizational approach is equally important. There is a human side to this. Is this going to be too much for this project manager to handle? Does this project manager have access to the right support from his host center.	Super Lightweight Tank (SLWT) Case Study Exercise 1: Risk Identification; video clip/transcript	22

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Value independent assessment and peer review	SLWT Project - Reviews and Independent Assessment	Bryan O'Conner	My memory says we had 50 or 60 if you add them all up from start to finish, independent and peer reviews of one sort or another throughout this project. This team was not embarrassed to talk about their issues, claim their lack of understanding and asks for help. I think that is pretty key to success in a project.	SLWT Exercise 1: Risk Identification; video clip/transcript	22
Take no shortcuts in development testing	SLWT Project - Verification testing	Mike Pessin	When you start a program, you need to do your due diligence and understand what you're getting into - do the the advanced technology development. Give the people the right test hardware, give them a chance to do the proper testing. If you try and do that on a shoe string, it's going to come back and bite you!	SLWT Exercise 2: Materials - Risk Mitigation; video clip/transcript	22
Establish and maintain a documented, controlled project baseline	SLWT Project - Project management	Brewster Shaw	I highly recommend that we have an equivalent to 07700 to tell you how to execute the program and it talks about risk management specifically, having that to fall back on was an excellent way to manage a big, complex, high-risk program like Space Shuttle	SLWT Exercise 4: Design Verification Risks; video clip/transcript	22

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Defend against requirements creep	SLWT Project - Project Management - requirements management	Brewster Shaw	Requirements management, baseline configuration management, are extremely important. Requirements creep is a living thing in our programs and if you don't keep it under control, it'll ruin your program.	SLWT Exercise 4: Design Verification Risks; video clip/transcript	22
Plan and manage, to the extent possible, with margin	SLWT Project - Project management	Parker Counts	We set an internal goal of 8,000 pounds – so we were striving to do 8,000. Now we succeeded with 7,500 plus; but at least we started with some margins, so we had some ability to redirect in some areas.	SLWT Exercise 6: S&MA Risk Mitigation Planning; video clip/transcript	22
Build-in budget reserves	SLWT Project - Project management	Parker Counts	We had a development budget of about $132 million. We were able to complete the project and still have $20 million in reserve.	SLWT Exercise 6: S&MA Risk Mitigation Planning; video clip/transcript	22

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Secure dual suppliers for critical elements/material	SLWT Project - Supply Chain management	N/A; Report	Reynolds Aluminum was the sole supplier of Al-Li 2195 but was not the original inventor, and initially was not able to reproduce the material. The project qualified Alcoa as another qualified supplier of Al-Li 2195	SLWT Lessons Learned (3 of 4); PPT	22
Apply the mantra that better is the enemy of good enough on a test project	Ares 1-X Design test and analysis	Robert Ess	If you can do another analysis or if you can do another test, we typically try and do that. That's our culture. But for a flight test and its okay if there's a possibility that it won't work, so better is the enemy of good enough really was the mantra that we tried to instill upon the managers and the lower level managers	Ares 1-X Clip: Better is the Enemy of Good Enough	22
Tailor risk management processes consistent with a flight test project	Ares 1-X Risk Management	Bruce Askins	As far as actual risk for our project, we kept the scoring approach the same as regular programs. So a lot of our risk ended up scoring higher than what you probably would expect for just a test, project.	Ares 1-X Clip: Better is the Enemy of Good Enough	22

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Incorporate design engineering in launch-site integration	Ares 1-X Project management - Co-location	Vince Bilardo	From an engineering perspective, there is just no shortcut for having a presence at the launch site, being close to the hardware and having the ability to inspect it with your very own eyes and with the team, the stakeholders who are involved in trying to resolve that issue	Ares 1-X: Clip: The Importance of Co-location	22
Select common electronic tools (Requirements, RM, CM, EVM, schedule)	Ares 1-X Project Management tools	Bruce Askins	Carefully select the proper configuration management tool and include some good training for everyone upfront.	Ares 1-X Clip: Information Technology	22
Move toward paperless processing of hardware.	Ares 1-X Project Management tools	Jeff Campbell	Paperless processing of hardware provides for a quicker way to change, close out and process control procedures.	Ares 1-X Clip: Information Technology	22

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Manage scope and requirements creep.	Ares 1-X Project Management	Vince Bilardo	Two-thirds of our cost growth was driven externally by the increase in scope and the creep in requirements. It's not easy and it takes a lot of very disciplined and focused attentive work and appropriate systems and processes to very carefully define your configuration and then to hold it.	Ares 1-X Clip: Plan Then Do	22
Maintain contractual responsibility, even though you operate as a badge-less team.	Ares 1-X Contract Management	Ron Unger	It's nice to all say you're going to throw your badges on the table when you walk in and you're all one big happy family, but you still have to maintain that level of contractual responsibility as well	Ares 1-X Clip: Roles and Responsibilities	22
Recognize that NASA Standards are guidelines - tailor them appropriately for a given project	Ares 1-X Requirements Management	Jon Cowart	All those NASA standards out there, they are guidelines. If they don't make sense, talk about them and agree to not do them. I don't care what size your project is, don't feel like you have to follow those rules/standards. Be smart.	Ares 1-X Clip They are Guidelines, not Requirements	22

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Consider concurrent engineering when facing a compressed schedule project	Ares 1-X Design, Development, Test & Integration	Ron Unger	Build a mindset early on within the project team that given the compressed schedule, we are going to do concurrent engineering (requirements development, design, fabrication, stacking, testing).	Ares 1-X Clip: Schedule Management	22
Manage to schedule when schedule is "King"	Ares 1-X Schedule-driven, risk informed Project Management	Robert Ess	We made decisions to stay on schedule. After a while that's infectious and people realize that we're doing this. It not when we get around to it or when the analysis is done, but it's like, we're really doing this.	Ares 1-X Clip: Schedule Management	22
Stay on schedule by making timely risk-informed decisions	Ares 1-X Schedule-driven, risk informed Project Management	Jon Cowart	When we were "not ready" for a decision that had to be made to stay on schedule, we would talk about the situation very openly so that we could identify the real problems and the project manager can make a risk-informed decision.	Ares 1-X Clip: Schedule Management	22

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Empower the SE&I function with overall budget and schedule authority	Ares 1-X Project Management - Organization	Jeff Campbell	We had a flat org structure and delegation to the IPTs, you have to have a strong SE&I function up front, and this function needs to have the authority to maintain the overall project schedule and budget, what in a traditional program is called level 2.	Ares 1-X Clip: Organizational Structure	22
Minimize your number of control boards	Ares 1-X Project Management - Organization	Robert Ess	We decided to operate with one control board for most of the project, since most of the same people would be at any subordinate boards anyway. At the end we only created subordinate boards for instrumentation and floor processing to handle day-to-day near real time decision making.	Ares 1-X Clip: Organizational Structure	22
Empower the SE&I managers to manage	Ares 1-X Project Management - Organization	Robert Ess	A flat org chart becomes wide, and you have to deal with many interfaces. SE&I managed those interfaces, not as integrators, facilitators or coordinators, but as empowered managers. Don't just make them book managers. These are mini-project managers.	Ares 1-X Clip: Organizational Structure	22

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Select one schedule tool and make sure everyone is using it	Ares 1-X Project Management tools	John Howell	On this project the schedule was king. Take time initially to pick a good scheduling tool and mandate that everyone use it. We used Primavera.	Ares 1-X Clip: Business Operations	22
Control cost by managing the schedule	Ares 1-X Project Management tools	John Howell	Schedule is money. Provide training to technical managers to understand that and give them the tools to manage cost and schedule.	Ares 1-X Clip: Business Operations	22
Use top-down and bottoms-up risk identification methods.	Ares 1-X Safety and Risk Management	Dan Mullane	Our systematic identifying of safety and mission success risks consisted of a top-down fault tree analysis and a bottoms-up FMEA/CIL study. That worked well.	Ares 1-X Clip: Safety and Mission Assurance	22

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Employ multiple, mutually supportive risk management approaches	Ares 1-X Safety and Risk Management	Dan Mullane	We used the risk management system, in addition to the fault trees, hazards and FMEA/CILS for risks for which it is not clear yet how we will manage them. We can't write things in a hazard report that are not defined yet.	Ares 1-X Clip: Safety and Mission Assurance	22
Make no compromises on integrated test and verification	Ares 1-X Safety and Risk Management	Dan Mullane	Towards the end there was some pressure to forego some verification activities in order to keep the launch date. We had some spirited discussions. We ended up completing all verifications without slipping the launch date. This meant that many folks worked long hours. We got the job done and I think that helped pave the way to success.	Ares 1-X Clip: Safety and Mission Assurance	22
Implement rigorous risk management and quality assurance processes	Ares 1-X Safety and Risk Management	Dan Mullane	I always go back to two basic areas—you have to make sure you have a strong analytical function to make sure that you are being very systematic in identifying sources of risk. The other function that I think you have to have is a very good quality assurance program to make sure that all of the analyses that you are doing are valid because the hardware that we are going to fly is actually the same as the design that you analyze. And whenever it's not, make sure it's understood and get a proper engineering assessment.	Ares 1-X Clip: Safety and Mission Assurance	22

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Centralize the SE&I function and give it a project-wide scope	Ares 1-X Project Management - Organization	Marshall Smith	We reformulated the project after one year and put SE&I in a single place with more of a project focus rather than a vehicle or ground focus. This helped the project along.	Ares 1-X Clip: Systems Engineering and Integration	22
Implement a "Lean" approach to rapid early development flight test activities	Ares 1-X Project Management - Organization	Jeff Hanley	We understood that we needed to really be successful with I-X, we needed to stand up a leaner, small team, much smaller than the full program team to really work in parallel so that we could really make this early flight test happen, but yet not have it sideline or derail the main line activity of formulating Ares I and Orion.	Ares 1-X Clip: Senior Leadership Part One	22
Utilize available "Lean" training to prepare rapid development teams	Ares 1-X Project Management - Organization	Jeff Hanley	I had asked the, at the time, deputy project manager for Ares, Dan Dumbacher, to do a lean event, if you will, a lean six sigma activity, to look at how we were working together to make Ares I-X happen.	Ares 1-X Clip:: Senior Leadership Part One	22

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Empower rapid prototype development team management	Ares 1-X Project Management - Organization	Jeff Hanley	It became pretty clear that we needed to establish a truly independent team and that I needed to give them the freedom to move as rapidly as they possibly could. In other words, putting Bob Ess in the leadership position and empowering him to make decisions at his level without a tremendous amount of care and feeding, if you will, of the main line program.	Ares 1-X Clip: Senior Leadership Part One	22
Expect rapid prototype development to place schedule first	Ares 1-X Project Management - Schedule	Jeff Hanley	A lean team that is focused on staying on schedule needs to make decisions to moving. You can't dither and get into analysis paralysis. It means that the senior leaders on the team need to make tough choices and they're not going to have a warm tummy feeling with every choice that they make.	Ares 1-X Clip: Senior Leadership Part One	22
Recognize the advantages of rapid prototype development to complement traditional human space flight DDT&E	Ares 1-X Project Management - Organization	Jeff Hanley	A development program can go down two paths What we've been used to in human space flight is a path of doing rigorous ground testing before we commit to a flight test, and that is the way much of the Constellation plan had been formulated. What Ares I-X showed us is that there is another strategic path of incremental flight testing, or incremental build-up in capability, through flight testing as an alternative means to reach certification.	Ares 1-X Clip: Senior Leadership Part One	22

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Consider advantages of a flat organization in DDT&E activities	Ares 1-X Project Management - Organization	Jeff Hanley	Whenever you have a vertically oriented organization with many levels to it, there's a tax you pay in what would be a fixed cost that is going to stay with you. A flat organization avoids those costs.	Ares 1-X Clip: Senior Leadership Part One	22
Recognize that project organizational structure should be re-evaluated at each life-cycle phase.	Ares 1-X Project Management - Organization	Jeff Hanley	One of the conversations senior management should have with the project manager and program manager and that the program manager should have with his project managers and so forth is whether we organized properly for the next phase? E.g., design integration in phase B is very different in nature than conceptual work in early phase A.	Ares 1-X Clip: Senior Leadership Part One	22
Consider ways in which ARES I-X project demonstrated new approaches for hardware development	Ares 1-X Project Management - Organization	Dan Dumbacher	One of the big reasons for doing Ares I-X was to be able to get a development flight test off, get some data into the design process quickly, but it also had the secondary benefit of demonstrating to a large part of our work force that not everything had to be operated like shuttle, like a human space-flight program.	Ares 1-X Clip: Senior Leadership Part Two	22

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Limit the amount of contract change activity	Contract changes effecting Program overall objectives	Chris Calfee	The proposed cost for the DART project—and Orbital Sciences was the prime contractor—was approximately 50 million. Half of that cost was for the launch services, and that was essentially a fixed cost for the Pegasus launch vehicle. The other 25 million was for the design, development, test of the spacecraft itself which had the key sensors to provide the navigational technology to get to Mobilecom, which was our target spacecraft. At the end of the day, the total cost of the DART project ended up about 110 million, and there were various reasons why we ended up there.	DART Video Case Study: Page 18. 0:00 Cost Section	22
Establish reasonable milestones that will support adequate testing	Schedule pressures and reasonable targets	Chris Calfee	Schedule pressure is going to be a part of every project that we do at NASA. It's been a part of every project I've ever worked on, and I expect it will be a part of every project I ever work on at NASA. There was one difference for DART: we had a target spacecraft called Mobilecom. It was a retired Department of Defense satellite that was basically given to Orbital. It had completed its mission; it obviously had a limited life. The original target launch date was April 2004. That had slipped a little bit, we were in the fall of 2004, and we were worried about Mobilecom even being there.	DART Video Case Study: Page 19 TIME 0:00 Schedule Section	22

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Ensure adequate staffing and increase as necessary with changes in baseline	Organizational Priority	Chris Calfee	Push back a little bit more early-on.. I was told, or directed, that I was to have a fixed amount of project office personal, and it was four.	DART Video Case Study: Page 20 Section: Other constraints Time 0:51	22
Set a verification baseline in line with risk posture early on	Systems Engineering Design Verification	Jim Snoody	In the beginning the verification approach was using a very similarity approach very heavily weighted toward similarity and analysis with not a full recognition of in space environments, a launch vehicle and the complication of the technology being very low with very little hardware in the loop, system-type test, so as we evolved out of the CDR.	DART Video Case Study: Page 21, Section Risk Posture and Verification Approach Time: 1:37	22
Engineer upfront	Peer review disposition of risk	Jim Snoody	DART ended up with 300 plus related to critical design review, ended up with six components that were failed and ended up in a band aid approach of trying to do system engineering so you spent all your time on DART trying to fix all the system engineering adequacies and you really didn't have time to think about the broader context and actually trying to figure out how to make it better, it was more one band aid after another.	DART Video Case Study: Section: Risk Posture and Verification P2 0:00	22

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Test Like you fly	Systems Engineering Design Verification	Jim Lomas	The SURI GPS receiver when it got on orbit for the first time in the DART mission it saw more satellites than it had ever seen before in any terrestrial application or any testing. The software inside the SURI didn't really know how to handle this very well and it caused a slight hiccup in the navigation state that the SURI was putting out. This caused a navigation state error which was the original cause for the filter, the GN&C navigation filter to reset. When that happens we take the solution from the SURI and use it as a starting point and then start trying to navigate.	DART Video Case Study: Page 32, Section: Rendez 0:08	22
Set up regular communication channels between design teams	Dispositioning all non-conformances	Jim Lomas	The second problem that the SURI had was an embedded velocity bias which was documented by the company, but not very well communicated between the various design teams.	DART Video Case Study: Page 32, Section: Rendez 0:48	22
Divide productions teams from enhancement teams	Organizing by project phase	Parker Counts	It was ideal to separate the production team (which was allowed to focus on supplying the LWT for continuing SSP operations) from the development team (which could then concentrate on SLWT) under one ET Project Manager, so that each team was not competing for the same resources.	SLWT Clip: Lessons Learned (4 of 4)	22

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Go back and review risks and assess how risks may have changed with time	Risk Management / ECLSS	Kirk Shireman	The key is continually going back and looking at those risks, even the ones that are not your number one risk to see if did I understand them correctly, have they grown over time, is our understanding of those changed, has other factors in the environment changed that would change my overall risk assessment, and where I would deploy my resources?	ISS Video Dashboard Shireman Clip 3, 44:40 - end	22
Test, Test, and Test	Design / ECLSS	Robyn Gatens	we learned things on orbit that maybe if we had tested more on the ground we would of uncovered on the ground. So test, test, test – I know I'm not the only one that ever says that.	ISS Video Dashboard Robyn Gatens Clip 8	22
Discover and expose undocumented assumptions	People / Communication / Operations	Mark Geyer	So I think how that how you apply that to things like testing and even analysis is that we need to be real clear on assumptions, on input variables, for example on loads, and even on factors of safety, on conservatism, because we definitely come at that in different ways. We each have our own biases about what we have experienced in the past. It is important to penetrate to that next level to ensure that you are integrated—whether it is an integrated analysis or an integrated test—that there aren't hidden things or gap.	ISS Video Dashboard Mark Geyer Clip 4 (all - esp 5:30 - end)	22

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Fly as fast as you can	DD&T / Design / Test / Risk Management / People	Mark Geyer	So you make a choice: fly something early, it's not the perfect design yet but you're going to learn a ton about the design and you're going to be able to focus the team, you're going to actually learn a bunch about how to not just the design but about the processes, processes, and even the contract and everything else and it shows that you're moving forward.	ISS Video Dashboard Mark Geyer Clip 6 (all)	22
Locate the reliability, maintenance, and logistics function within the design organization	Design / Logistics / Reliability	Anthony Butina and William Robbins	The recommendation would be is to have your logistics people in that design organization and in the engineering organization as early as you can so that they can do the things that they need to do so we could maintain the station more effectively.	ISS Video Dashboard Anthony Butina Clip 2	22
Conduct an integrated logistics support analysis	Design / Logistics / Reliability	William Robbins - Anthony Butina	LSA, Logistics Supportability Analysis, is a body of activities aimed at identifying what the resources are going to be needed in order to support the hardware as well as identifying the basics of crew operator tasks, how to do it, the parts that will be needed, the tools that will be needed.	ISS Video Dashboard William Robbins Clip 3 also Anthony Butina Clip 3	22

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Design for maintainability - 100 screws! Are you kidding	Design / Logistics / Reliability / Operations	Anthony Butina	. So there's a treadmill and that treadmill base has 100 screws around it in order to get to a motor that is embedded inside. The time it takes for a crew member to get 100 screws off to get into that is overkill. You just don't need to have that. ..... that three pound motor took a couple of hours to replace, not just because of the screws, but how it was embedded inside of that treadmill.	Anthony Butina Clip 4	22
Design for storage and trash management	Design / Logistics / Reliability / Operations	William Robbins	You have to have a detailed operational concept that considers, not only everything that is coming up that the crew is using, but what is the crew going to be using. How much consumables are there? What volume do the consumables take up? And, do those trades of onboard stowage and transportation options	ISS Video Dashboard William Robbins Clip 4	22
Consider the trade-off between reliability, maintenance, and supportability	Design / Logistics / Reliability / Operations	William Robbins	The more reliable the hardware is, the less resources you would need in order to maintain the hardware. There's a cost tradeoff with that in the design phase in that in trying to make the hardware more reliable you're increasing cost during the design and development phase with the expectation that you'll be able to reduce support costs	ISS Video Dashboard William Robbins Clip 5	22

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Implement commonality to reduce spare inventory (mass and volume)	Design / Commonality / Logistics	William Robbins	Commonality can be a big payoff, but it's very difficult to get a design team or a project to accept commonality requirements because they feel that it restricts their designer's ability to be innovative and they've got a point, but the payoff with commonality is that if you have common fixtures, common fasteners, common connectors, common parts, you reduce your support resources.	ISS Video Dashboard William Robbins Clip 7	22
Use Common Specifications	Commonality reduces the potential for error	Warren Woodworth	There is potential for process escapes or process errors, using one application in the wrong situations, in other words using a specification for one vendor and an application for another vendor, so it promotes the opportunity for errors. Commonality will eliminate a lot of that.	KBR 5046 Commonality (Indentificaiton of Risk)Time marker: 02:00	22
Reduce cost with commonality	Use aerospace or commercial standards to limit cost	Warren Woodworth	One thing that drives cost is having a unique design, having unique hardware, unique specifications, multiple specifications, unique materials... All this drives cost and it drives schedule, so the thing to strive for is commonality.	KBR 5046 CommonalityClip: Indentificaiton of RiskTime marker: 0:11	22

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Match as-built to drawing Configuration	Reduce mismatched parts with current drawings	Ed Statham	It is really important that you maintain an as-built database that is accurate, and that your as-designed be verified against the as-built, and probably released via a change order before you actually incorporate it into the new design.	KBR 5048Clip: Identification of RiskTime marker: 04:11	22
Prevent assembly operations surprises	Verification of as designed to as-built prior to new enigneering	Ed Statham	By closely maintaining your as-built configuration, and by checking your as-designed against that as-built configuration before you include the new engineering into the planning, you will avoid unnecessary surprises, schedule delays, and cost, by understanding completely what is required to go do a job prior to beginning.	KBR 5048Clip: Mitigation of Risk Time marker: 01:47	22
Unburden your configuration management	Use of non critical parts should be tracked wisely	Ed Statham	be smart about what you choose to track in your configuration management system. Track the things that are important to track, but don't track things that are not critical and otherwise don't require tracking.	KBR 5049 Cumbersome Pedigree Maintenance Clip: Mitigation of Risk Time marker: 02:38	22

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Fully Qualify Large Mechnical Systems	Verification	David McCann	For a large complex mechanical system like this you've got to perform a major qualification of the hardware; test as you fly. SARJ was originally designed to be tested that way; over the years as the program developed and cost constraints came along the determination was we would perform proto-flight testing of the two SARJs and that there wouldn't be a major qualification test performed on the SARJ.	KBR - 11825 Solar Alpha Rotary Joint (SARJ) Vibrations Pose Risk to ISS Power and Operations	22
Verify each mate-demate for all electrical connection	Assembly and checkout procedures Quality assuranceElectrical connections	Ron Welch	Often on complex setups, after a connection mate is made, connectors will become covered by other connectors or equipment in future assembly steps. Each mate or demate should have a one-on-one verification and be documented by the QA individual who personally witnessed the activity. This is extremely important and has the highest consequence for final mates prior to launch.	1363 Unverified Mating/Demating of Flight Connectors	22
Consider commercial off the shelf equipment for cost effective short lead time parts	Cost savings	Ben Greene	As the requirements were defined more, we realized that we could actually use commercial off-the-shelf equipment as the dispensing mechanism. At first it made the engineers uncomfortable since they are not part of the development of the hardware but in the end it was a cost effective and inexpensive way of accomplishing the task.	11934 – on orbit RCC repair – COTS Hardware	22

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Balance the right amount of analysis and testing to verify a design	Design and Requirement verification	Ben Greene	Too much time was spent trying to analyze one of the design options when in fact it was easy to test. Testing ended up being the method we used to verify the design option as viable but we spent a lot of extra time and resources on analysis that wasn't necessary in the beginning.	11934 – on orbit RCC repair – Verification planning: analysis vs testing	22
Challenge requirements. Challenge requirements. Challenge requirements.	Requirements	Lora Bailey	One the most important take aways from this experience, is kind of a repeat of many of my other projects, is that you do not blindly accept requirements that are given. You challenge them to begin with and fight and argue over them and hash them out as early as possible but also you don't give up on challenging them over the course of the project because the requirements are what can either drive you into the ground or drive you to success.	KBR 11938 Clip: Context; Key Remarks for the Future-Time marker: 0:00	22
Increase design safety factors when there is higher technical uncertainty.	SLWT Project - Design	N/A; Report	Due to questions about the fidelity of analysis, the goodness of the modeling, synergistic effects and the applicability of component testing data, we increased the safety factor to 2.0 and required independent analysis.	SLWT Exercise 4: 4.1 Introduce Higher Design Safety Factors; PPT	23

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Consider a Skunk Works approach when facing technology challenges	SLWT Project - Design & Development	Mike Pessin	And we managed this like a Skunk Works. This technique gives you a certain amount of risk because you don't get the multiple levels of review, but it gives you a virtually immediate response; and if you have the right people – and you've got to make sure you get the right people involved – it gives you a very efficient and streamlined program.	SLWT Exercise 5: Production Verification Risks; video clip/transcript	23
Solicit manufacturing practitioners experience and knowledge in solving tough design problems	SLWT Project - Problem solving in design	Bryan O'Conner	The project manager and his senior folks did not limit their brainstorming to themselves. Invite enough people from enough levels to participate in that. Sometimes you get the best answer by going to the floor and talking to the folks with the wrench in their hand and the torch in their mitt that are actually doing the job.	SLWT Four Important Take-Aways; video clip/transcript	23
Expect that heritage hardware will require the same integration level of effort as new flight hardware	Ares 1-X Heritage Hardware	Robert Ess	With heritage hardware, the physical integration and technical integration is as much work as if you started off from scratch and sometimes it's more work.	ARES 1-X Clip: Caution! Heritage Systems	23

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Expect that heritage hardware will require the same system-level verification as new flight hardware	Ares 1-X Heritage Hardware	Jon Cowart	Heritage is great, I recommend you go use it, but make sure you plan up front that down the road it's going to require from you some extra verification and certification time.	ARES 1-X Clip: Caution! Heritage Systems	23
Check heritage hardware drawings in case something changed in the interim.	Ares 1-X Heritage Hardware	Mike Stelzer	Don't trust the drawings of heritage hardware. Do those additional surveys to verify that your drawings- your models- are accurate and up to date in case something changed in the interim.	ARES 1-X Clip: Caution! Heritage Systems	23
Evaluate the end-to-end (design to launch) impact of heritage hardware before deciding on the use.	Ares 1-X Heritage Hardware	Robert Ess	If you think through the integrated end to end from design all the way to launch day impacts of a heritage change then you can understand whether it's really a good trade for you or not.	ARES 1-X Clip: Caution! Heritage Systems	23

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Design with integration and operability in mind	Ares 1-X Design and Integration	Jim Bolton	Infusing operability early makes a huge difference later. Include design engineers visiting KSC and ground ops people visiting design centers.	Ares 1-X Clip: Operability is Not an Afterthought	23
Test integrated avionics and anomaly conditions in a flight-like simulator lab.	Ares 1-X Design verification testing	Kevin Flynn	Use an integrated avionics simulation lab that truly has flight-like hardware, meaning having the same form, fit, and function as the flight boxes, and test all the functions possible. Especially testing things like anomaly condition is worth its weight in gold.	Ares 1-X Clip: Test Like You Fly, Fly Like You Test	23
Except to run loads and environments analysis up to the time of launch	Ares 1-X Design, Development & Test	Marshall Smith	Any time you build a new vehicle you're going to be doing loads and environments until the time you launch and after. I'm very convinced that this is never going to get better. It's always going to be uncertain. People are always going to be running loads. You're always just going to be saying, well, what if we did this, what if we did that. You've got to understand it, you've got to accept, and you need to set people's expectations so they don't freak out about it.	Ares 1-X Clip: Systems Engineering and Integration	23

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Recognize that flight test project design verification may differ in complexity from other types of missions	Ares 1-X Design verification testing	Marshall Smith	Doing verification is different for a fast moving one-of-a-kind vehicle development program than for operational environments. The former includes product verification where you actually check each part, whereas the latter uses just spot checks. The ARES 1-X project had people from both those cultures. Some of us had to learn to trust the processes and people and to not check everything on this one-of-a-kind vehicle.	Ares 1-X Clip: Systems Engineering and Integration	23
Test, Test, and Test	Ares 1-X Design verification testing	Marshall Smith	A flight test does not only solves the problems you think you're going to have, but it tells you about a lot of unknowns. You find out things you didn't expect. I highly recommend that you set up a series of test programs, each building on the next, similar to what we did in the past on Mercury, Gemini and Apollo. They had it right and that's the right way to go.	Ares 1-X Clip: Systems Engineering and Integration	23
Employ the latest (ARES I-X) updated acoustical environment prediction models	Ares 1-X Design Modeling	Marshall Smith	This test showed that we under-predicted the vibro-accoustic sound pressure levels for some places by a factor of three or four. This is not ARES 1-X specific but geometry specific. This allowed us to update our models, which now can be used for other vehicles as well.	Ares 1-X Clip: Systems Engineering and Integration	23

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Recognize the need to address triboelectrifcation risks and requirements	Ares 1-X Requirements Management	Jeff Spaulding	ARES 1-X was not treated or tested for triboelectrification, so we could not fly through any clouds above the minus 10 degrees Celsius level. This was a cost tradeoff decision that ended up delaying the launch one day.	Ares 1-X Clip: Triboelectrification	23
Early flight test is important to program growth and stability	Ares 1-X Project Management - Stability	Jeff Hanley	Senior management saw the technical value of 1-X, but also from a team perspective it was good getting an early flight test success.	Ares 1-X Clip: Senior Leadership Part One	23
Early flight test experience will inform "main line" development project structure	Ares 1-X Project Management - Organization	Jeff Hanley	what Ares I-X taught us is that we could treat the main line program very differently once we got past PDR, we could organizationally lean it out, flatten it, and get the team focused on flight tests, i.e. be test-centric.	Ares 1-X Clip: Senior Leadership Part One	23

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Review and renew ones understanding of data underlying any critical design model.	Systems Engineering Design Verification	Robert Manning JPL	The validation process didn't go back far enough into the past to look to ensure that we did the right thing from the original data. We were shocked; and, well, the good news [is] we caught it in time for the MER project.	KBR 1599 Common Mode (Model error) Failures in Technology Clip: 3:47 + 1:42	23
Verify that your model is valid for the application scenario.	Systems Engineering Design Verification	Rodney Rocha	There's always the opportunity or mis-opportunity to misuse a critical math model and fall into a pitfall of misuse, a flawed recommendation, an inaccurate statement about the usage of such math models.	KBR 11939 Application of Models in Design Verification and Safety Critical Decision Making first & last clip	23
Identify assumptions and uncertainties in using any model and build in margin as necessary.	Uncertainty in the space environmental models	Robert Manning JPL	As a system engineer, you need to be cognizant of the uncertainties in the environment that is being specified for you by environmental specialists, and if you have the ability to do it, you can hedge your bets by adding complexity and systems to try to deal with unexpected environmental conditions or conditions that may be worse than the specified environment that the experts have predicted. Because it turns out you're asking them a very difficult question, and when they give you an answer, you have to be aware of the fact that they may not be certain that that answer is correct.	KBR 1339 High Level of Uncertainty (Environmental Model)second clip	23

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Always perform an integrated test for critical systems - always.	ISS integration testing in a cost constrained environment	Stephanie Sowards	Using risk-based analysis to determine if we should conduct integrated test is a nice idea and it looks good on paper. However, given the complexity and the tightly coupled configurations of elements that span geographical and international boundaries that could result in catastrophic outcomes, the right thing to do is to always perform the actual integrated test. MEIT was designed to test mechanical, data, electrical, fluids every subsystem across those elements.	KBR 10440 ISS: Multi-Element Integration Testing (MEIT)second clip	23
Always perform an integrated test - known unknowns will emerge.	ISS integration testing in a cost constrained environment	Timothy R. Honeycutt	So these types of problems, we learned from them as far as finding them on the ground, resolving them prior to launching into orbit. If we would have had these types of problems on orbit, we would have had major cost and schedule delays. It would have caused increased safety issues for the crew. We could have had a loss of mission objectives and loss of flight hardware. It would have driven unplanned EVAs. So for future programs I would take all of this information under consideration from what we learned from MEIT not only that we need to look at what type of integrated testing we need at the launch site but also the planning that it takes to put one of these tests together providing all the correct GSE, the right personnel, the right involvement of other organizations and companies, down to the manufacturers level. To plan that up front is a great cost savings as well as to catch these problems that we find and resolve on the ground prior to getting in orbit. So some specific lessons from MEIT,	KBR 10440 ISS: Multi-Element Integration Testing (MEIT)last clip	23

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			one is the fact that we do know that we will come across unknowns when we integrate hardware together. There is no way of understanding all of the scenarios involved with large-scale integration of space hardware until you put the actual hardware together. You can simulate that, you can emulate that to the best that you can but there are some unknowns that you will come across when you actually perform that final integration.		
We must understand COPV failure modes.	Composite Overwrap Pressure Vessels (COPVs) in service now (SSP, ISS, spacecraft, EELVs) and will be used in future space systems (CxP, Lunar)	Multiple Subject Matter Experts	They are integrated throughout all of our vehicles. They are also integrated throughout our international partner's vehicles. Right now we are getting ready to inspect the AMS vessels which we have in our international partner's vehicles and also our payloads. Anything that is trying to save weight, we will put a composite pressure vessel in that application. We must understand the failure modes and be able to mitigate the failure causes so that we have a safe and reliable vessel.	KBR 7084 Composite Overwrap Pressure Vessel Safety Hazards First clip: Intro & background	23
Start and end with the same risk posture	Categorizing risk posture for program classification	Chris Calfee	DART was proposed and accepted as a high risk, low cost project. What came with that should have been a high threshold for risk and a reasonable amount of acceptance that there could be a failure here—it was a flight demonstration. So decisions were made early-on with that in mind, with those assumptions firmly in place and thought to be understood by management. As time evolved—and really it wasn't an evolution that it changed, it was like it flipped overnight—	DART Video Case Study: Page 21, Risk Posture and Verification 0:06	23

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			DART suddenly went from a 'high risk, low cost' to a 'can't fail, low cost' project.		
Reduce Margins Carefully	Margin reductions represent increased risk	Mike Pessin	There are often places were margins can be reduced while maintaining the required FoS. There always represent areas of optimization, built is should be remembered that any form of margin reduction increases overall risk	SLWT Clip: Lessons Learned (4 of 4)	23
Be Flexible	TRL Levels may need back up plans	William Yuknis	I think the number one thing when encountering new technology, especially with a great unknown, the best thing that you can do in my opinion, is to be flexible. In other words be prepared to change the course and have a backup plan ready to go. In others word, we call it the "Plan B".	KBR 11397Parallel Pathways to Mission Success Command & Data Handling,(C&DH) Lessons Learned	23

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Conduct end-to-end testing - absolutely essential	Integration testing and verification ECLSS	Robyn Gatens	It is important to note that this end to end testing is absolutely critical before we fly future exploration missions. Not only was it the first time in some cases that the flight hardware met the flight software but just everything integrated together is critical before you fly that element.	ISS Video Dashboard Robyn Gatens Clip 2 (all - especially 5:20)	23
"Unexpected things are going to happen"	Design robustness / ECLSS	Robyn Gatens	We learned some things once we launched our ECLSS system to the space station on orbit that we didn't anticipate when we designed it.	ISS Video Dashboard Robyn Gatens Clip 3 (all - esp 2:40)	23
Balance safety v complexity	Safe Design - complexity / ECLSS	Robyn Gatens	So I think as we go forward, yes safety is very critical but we need to find a balance between making something so safe that it is too complex and therefore not as reliable and where is that balance.	Robyn Gatens Clip 5	23

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Leverage technology - employ RFID for inventory control	Operations / Storage	William Robbins	Leverage technology and get the human out of the loop as much as possible .... using RFI de-tags, ... automated readers that are mounted in various places in your living space such that if an item moves you automatically know about it ... (freeing the crew) to operate the vehicle and do science and explore and do those things rather than being an inventory checker.	ISS Video Dashboard William Robbins Clip 8	23
Be weary of obvious answers	Risk Management	Richard Williams	just because a part has been reliable and something that we have used for a very long time here, doesn't necessarily mean that it doesn't have an inherent flaw within it and don't just accept that part the way it is.	KBR 11365- Lunar Reconnaissance Orbiter Project (LRO) - Defect in Socket Contacts (Lessons Learned)	23
Carefully Evaluate Heritage parts with used in extreme thermal environments	Thermal	Charles Baker	The word heritage only applies to thermal if the actual environment that the instrument was used in last was more severe than the environment that it's being base-lined for. If it is less severe than there needs to be resources put in to and early model exchanges and early technical exchanges to help develop the thermal subsystems so that it can handle the more severe environment.	KBR 11377 - LRO Heritage Instruments Still Require Significant Design Efforts (Lessons Learned)	23

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Integrate final hardware together before launch to uncover unplanned problems	MEIT - Component Testing and Verification	Tim Honeycutt	There is no way of understanding all of the scenarios involved with large-scale integration of space hardware until you put the actual hardware together. You can simulate that, you can emulate that to the best that you can but there are some unknowns that you will come across when you actually perform that final integration.	KBR 10440	23
Scale tests to fit the purpose	Test objectives, test cost, testing	Warren Woodworth	The basic guideline is to do the right test and do the test right. Document the test properly and clearly state the objectives and intended purpose of the test. Conducting a test that does more than is necessary or overly complex for the purpose or objective will add increased cost and schedule.	5045 Orbiter Program	23
Plan for success in multiple ways	Parrallel path, mitigation strategies	Lora Bailey	As a project manager I typically always have at least three parallel paths in mind. That is I have a primary path, so that's plan A, and not only do I always have a plan B in my hip pocket but I have a plan C because I want to have at least two layers of redundancies of places to go to in the event that I have a failure with plan A. That's just how I do business and I believe that it the right way to do business, to have at least two backup plans.	KBR 11938 Clip: Context; Parrel path- Time marker: 0:00	23

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Develop an inclusive decision making culture	MMT Process Improvement - Decision Making	Wayne Hale	Clearly, The Mission Management Team (MMT) was a place where senior managers and NASA could come together and review the progress of the mission, but the decisions were all made by the chair.	11937 - Mission Management Team Changes Post Columbia Clip: Context; Time marker: 00:45	31
Recognize and critically assess the dynamics in mission critical decision forums - Little Give and Take	MMT Process Improvement - Decision Making	Wayne Hale	In fact, the Mission Management Team is almost exactly the same team that participates in the flight readiness reviews and the other pre-launch reviews the ET, SRB made and the orbiter made reviews that lead up to the flight readiness review. Effectively the same people doing effectively the same things, and those processes I had known for some time, and anybody who participated, knew for some time that they were troublesome. There was a lack of "give and take" in those meetings.	KBR 11937 Clip: Context; Time marker: 02:00	31

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Recognize and critically assess the dynamics in mission critical decion forums - Intimidating Forum?	MMT Process Improvement - Decision forum dynamics	Wayne Hale	They were typically large meetings held in a big room and the culture was if you are not an expert in the particular topic that was being discussed, you didn't participate; you didn't speak up, you didn't ask questions.	KBR 11937 Clip: Context; Time marker: 02:20	31
Recognize and critically assess the dynamics in mission critical decion forums - Stilted? / Heirarchal?	MMT Process Improvement - Decision forum dynamics	Wayne Hale	It was a very strange and stilted culture that was going on, very hierarchical; not much discussion. It clearly did not allow for input of many, what we would call dissenting points of view. There were other avenues and certainly people use the social network and those sorts of things to talk about these issues outside the meeting, but the meetings were stilted and formal and hierarchical.	KBR 11937 Clip: Context; Time marker: 03:15	31
"We knew we had to change the culture"	MMT Process Improvement - Decision forum culture	Wayne Hale	We had a number of senior managers that had been brought up through the NASA human space flight system that had very hierarchical points of view and we knew that we needed to change that culture.	KBR 11937 Clip: Mitigation; Time marker: 00:40	31

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Implement training in interpersonal interaction - II	MMT Process Improvement - Decision forum participant training	Wayne Hale	We had a Behavioral Sciences organization come in and sit in our meetings and watch our behaviors and then give us feedback. You had to say "please and thank you" and be polite. Some of the old-line managers had a real problem with that attitude change because coming from an almost military, hierarchical, we're "all about the facts" and "we don't suffer fools gladly" type of organization, it was difficult to sit and listen.	KBR 11937 Clip: Mitigation; Time marker: 04:10	31
Implement training in interpersonal interaction - III	MMT Process Improvement - Decision forum participant training	Wayne Hale	We developed a plan to train people [to be on the MMT] where they had to actually read some material, they had to observe some MMT's doing what we call "on-the-job training", they had to take some class work to be prepared and then they had to be formally certified.	KBR 11937 Clip: Mitigation; Time marker: 05:30	31
Implement training in interpersonal interaction - IV	MMT Process Improvement - Decision forum participant training	Wayne Hale	Part of the training was this culture change and that we're going to speak up; we're going to poll everybody. We're not going to throw people out of the room.	KBR 11937 Clip: Mitigation; Time marker: 06:00	31

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Recognize social dynamics within the decision forum	MMT Process Improvement - Social Dynamics	Wayne Hale	As a manager, a leader or whatever in an organization you need to understand social skills and you need to be proficient in them because they are equally important with the technical skills. You will not make good technical decisions if you are a poor people manager and you don't understand how to communicate and engage and motivate and really relate to people and hear what they're having to say.	KBR 11937 Clip: Lessons Learned - Culture Change; Time marker: 03:50	31
Take the time to communicate effectively.	MMT Process Improvement	Wayne Hale	Communication is the key element in that and it is a human, not a technical, it is a human interaction thing and you have to take the time to develop the networks and have the rapport and listen more than you talk to have good communication	KBR 11937 7th Clip: Communication	31
Recognize the developmental training embedded in flight test experience you test the hardware	Ares 1-X Training the team	Steve Davis	The flight test itself, beyond the fact that you learn so much about the vehicle, which is the reason why we really did it, just training the team and training the personnel was incredibly beneficial. That was as beneficial, in my mind, as actually learning about the systems.	Ares 1-X: Clip: The Importance of Flight Testing	31

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Select and train crews to have broad basic skill-sets then provide just-in-time training for specific tasks	Training / People / Skill-set	Don Pettit	First of all you have to have a good skill set. Maybe you don't know how to use a special microscope but you know how to use a standard microscope, you can take your knowledge and skills and apply it to the new event. You don't need to have a class on how to use the special microscope in order to figure out how to use it, but you do need just in time training – watch a video or read a background paper after that you can jump right in and use it. With good background skills and just in time training you can get it done expertly.	ISS Video Dashboard Don Petit Clip 3	31
Provide crew with hands-on electrical and mechanical skill development training	Training / People / Skill-set	Don Pettit	Something that occurred to me after my last mission is probably 80% of what we do on orbit could fall under the realm of mechanical or electrical skills for repair and maintenance .... so I would say that say that sending astronauts to emersion training on the T38 aircraft with a certified mechanic and spend a week in the avionics shop a week in the hydraulics and engine shops and then we will spend time on the hanger floor doing maintenance on the airplanes and then the three weeks of training you get more mechanical training than you would get for years of training for a ISS mission ...	ISS Video Dashboard Don Petit Clip 4	31

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Provide high fidelity training and simulation mockups	Training / People / Skill-set	Don Pettit	For the space shuttle,.... we had outstanding simulators and that was a well-oiled mechanism, but if you look at ISS in a six month period the configuration of ISS can change because rack and pipes and pluming can be changed – its ever changing which is good but it makes it hard for the simulators on the ground.	ISS Video Dashboard Don Petit Clip 5	31
Minimize crew training template. Cover the critical systems, then supplement with JIT	People / Just-in-time training / operations	Ginger Kerrick	We create dedicated packets of review information that we would send up to the crew prior to executing a specialist-type task. This would include PowerPoint presentations and videos and things of that nature as if you were sitting in a classroom environment down on the ground except they'd be performing that training on-orbit. So we call this "just in time" training and that is a concept that we are now looking at implementing and expanding the use of onboard ISS and we think it would be a very good starting base for training for exploration as well.	ISS Video Dashboard Ginger Kerrick Clip 4, 4:00	31
Form a strong bond between team members	Dedicated workersTeamwork	Ben Greene	By forming a cohesive team for the RCC repair task, even after some members left the team or moved on to other tasks, as repairs were required we always had members come back to help out with the repair when needed. This was a team across multiple disciplines in the community that worked well together and it showed in the high quality of the work.	11934 – on orbit RCC repair – Organization and teamwork	31

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Opinion overload may create impasse	Minority opinion, risk	Lora Bailey	I would say that our sensitivity to risk had in some ways actually hamstrung us from being able to proceed in a more aggressive approach or at a more aggressive rate schedule wise than we might otherwise have been able to do. Because we were operating in this environment where we wanted to make sure that everyone who had an input got to have their input and that we addressed every input. And so it was a little bit where the pendulum swung to one side and it was so far over that you nearly at an impasse to some degree.	KBR 11938 Clip: Context; Minority Opinion-Time marker: 1:41	31
Leverage external experts	People Success	Karen Lucht	The second really important piece is realizing that you don't have to do it all yourself. So about 6 months into it we started to realize hey there are experts out and I think it's a NASA Shuttle culture that we manage the program so we want to do it ourselves, but realizing there were many experts out there that we were able to leverage their knowledge that they already had there.	Space Shuttle Transition and Retirement Lessons CLIP 2 Roles and Responsibilities: Time Marker 3:31	31
Engage your people		John Olson	You've got to have the best people you can, engaged through that communication and through that plan. But you've got to put trust and responsibility and hold your people accountable, and then they will just amaze you.	Space Shuttle Transition and Retirement Lessons CLIP 9 Top Three Lessons Learned : Time Marker 1:21	31

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Brainstorm everything in assessing critical decision forum effectiveness	MMT Process Improvement - Decision forum evaluation	Wayne Hale	We literally brainstormed everything that we could think of that would improve the decision making, retrain the managers, and address the perception problem.	KBR 11937 Clip: Mitigation; Time marker: 01:50	32
Bring in outside opinions and consultants	MMT Process Improvement - Decision forum evaluation	Wayne Hale	We hired various consultants.	KBR 11937 Clip: Mitigation; Time marker: 02:00	32
Implement training in interpoersonal interaction - i	MMT Process Improvement - Decision forum participant training	Wayne Hale	We put all of our senior managers through what used to be called a "Cockpit resource management" which is a training that NASA developed with the FAA for airline pilots and air crews.	KBR 11937 Clip: Mitigation; Time marker: 02:10	32

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Rethink communication modalities and effectiveness	MMT Process Improvement - Risk communication	Wayne Hale	We had Dr. Tuffte come and do his course on presentation materials. It did point out that some of the things we were doing were pretty horrific in the way that presentations were put together. It encouraged people to do more "white-papers" than PowerPoint presentations.	KBR 11937 Clip: Mitigation; Time marker: 03:30	32
Listen for weak but important signals	MMT Process Improvement - Leadership	Wayne Hale	We specifically trained our leadership to try to listen for weak signals and to understand that just because someone is not presenting very coherently or articulately doesn't mean that there isn't a concern there that we need to address.	KBR 11937 Clip: Mitigation; Time marker: 06:45	32
Provide critical decision team participants with contingency response exercises	MMT Process Improvement - Decision forum participant training	Wayne Hale	We subjected the Mission Management Team to a number of integrated simulations, stressing problems that were related to TPS damage and those sorts of things but also including other unrelated problems. They were very effective; they made us think as a group, they educated the team on the entire operation, and folks that were not typically involved in the mission execution phase of the flight became very involved and actually, by virtue of being trained, smart, observant managers, provided really some key insights to the operations team from time-to-time on how to solve problems.	KBR 11937 Clip: Mission Simulations; Time marker: 02:00	32

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Ensure the critical decision forum is an inclusive, positive physical environment	MMT Process Improvement - Decision forum environment	Wayne Hale	We rebuilt the Mission Management Team room. We decided we needed a bigger room. We needed a video conference. I was particularly adamant that we needed a round table; I didn't want to have a head of the table.	KBR 11937 Clip: Mission Simulations; Time marker: 03:00	32
Be wary of embedded assumptions in a critical decision environment - such as "there is nothing we can do"	MMT Process Improvement - Embedded assumptions within the decision forum	Wayne Hale	At all levels, management shut down these kinds of "let's try something" discussions with this "Well, there's nothing we can do" phrase. After 107, we took that out of our vocabulary. We are going to try to do something. It empowered people that had ideas and had concerns to come forward and express them. So that little culture switch that got flipped right there was really very critical. There is always something we can do.	KBR 11937 Clip: Lessons Learned - Culture Change; Time marker: 03:00	32
Recognize the reality that an operational decision must be made - the least imperfect decision being the goal	MMT Process Improvement - Decision Making	Wayne Hale	We tried very hard to make people learn how to play nice together and in that way I think we over did it. There are some people that are never going to be satisfied. At some point you have to decide "Have we done good enough?" It is never going to be perfect. And that is the real heart of the whole thing.	KBR 11937 Clip: Lessons Learned - Culture Change; Time marker: 06:00	32

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Actively seek participant input in critical decision forums	MMT Process Improvement - Decision Making	Wayne Hale	The communications emphasis that we had on the MMT was that we called on everybody. So everyone was told that they were expected to participate in all discussions, every member of the MMT.	KBR 11937 Clip: Lessons Learned - Communications; Time marker: 01:10	32
Build in a break to enable informal reflection and discussion prior to a decision	MMT Process Improvement - Decision Making	Wayne Hale	If we're discussing a difficult situation that's going to have complex ramifications, after looking at all the details, we're going to take a break. After that we would have the chair propose a course of action and then say "Now let's take a break and everybody go think about that." Go poll your delegations, go out in the hall and see if you have any more questions. Let's walk around and talk about it. So you get out of this formal, stilted hierarchy where we're all sitting around the table looking very solemn.	KBR 11937 Clip: Lessons Learned - Communications; Time marker: 03:30	32
Demand cogent, clear, thorough presentation of safety critical information	MMT Process Improvement - Mission critical communication	Wayne Hale	It's not just PowerPoint or bullet charts but it's the mentality behind we have to cram very complex subjects into the fewest number of English words humanly possible. That's poor communication technique.	KBR 11937 Clip: Lessons Learned - Communications; Time marker: 08:20	32

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Engage independent engineering and SMA organizations in identifying and assessing risk	MMT Process Improvement - Risk Management	Wayne Hale	We used these independent technical authorities, like Safety and Mission Assurance organization, like engineering organization, to help us categorize the risk, not just in this technical sense, but in this likelihood versus consequence base, and try to deal with them in an appropriate manner.	KBR 11937 Clip: Lessons Learned - Assessing Risk; Time marker: 03:00	32
Remain vigilant - stay worried about what could go wrong.	MMT Process Improvement	Wayne Hale	It takes vigilance, and that's what I would like to pass along, probably as a parting word, is you have to be vigilant. You have to always suspect that you're not as smart as you think you are, that things aren't going as well as you think they're going. You have to be hungry and worried about what could be going wrong. Those are the real keys in a high risk, high reliability organization, is you have to always be worried about making a mistake, about having an accident. That leads you to stay on your toes, being hungry, being vigilant, and if anything, that will prevent the accident that you're worried about.	KBR 11937 Last Clip: Key Remarks for the Future 1:20	32
We can do it - but we should minimize on-orbit assembly	On-orbit assembly	Mark Geyer	So I think we learned a couple things, we learned we can do, we absolutely can do complex assembly. I think in my mind, we also learned that we should avoid it when we can. So I'm a big fan of the big rocket because we should minimize this assembly because it adds risk every time you do it. But even with the big rocket we're going to have some. And so when you do that you need to lay out your plans, you need to figure out	ISS Video Dashboard Mark Geyer Clip 8	32

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			whose the responsibilities are, then you got to figure out a reasonable test program on the ground to flush it out.		
Prepare for and remain flexible enough to reformulate research questions	Crew / people / training / skill-set / Frontiers	Don Pettit	for me a frontier is a place where your normal intuition no longer applies and the answers are no longer in the back of the book.... Here is the irony – you go into a frontier with a set of questions, you figure the answers out and after you look at the answers you say "we asked the wrong questions" and so now you formulate a whole new series of questions	ISS Video Dashboard Don Petit Clip 7	32
Change your plan	Planning Processes	Jonathan Krezel	Unanticipated consequences, your refinements and estimates are going to change. What are the processes you're going to leverage to make continual adjustments to your plan? Do you have to have rigorous documentation of those processes? Can they be handled more informally? That's going to change depending on the circumstance. Who do you have to interact with? Whose approval or consensus do you have to gather to make changes to that plan? How are you going to gather that consensus? So you have to think through your processes.	Space Shuttle Transition and Retirement Lessons CLIP 8 Top Three Takeaways: Time Marker 1:28	32

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Practice, Practice, Practice	Critical Lifting Operations (Orbiters)	Stephanie Stilson	So the key lessons that we gained from this task was how valuable and important it is to do a dry run to begin with and while you're doing that go back and look at those procedures to see if you need to make changes that make it more understandable for the current culture that's working on that… we had public affairs film our dry runs….	Space Shuttle T&R Practice, Practice, Practice (Stilson Clip 4)	32
Always have a Plan B and periodically reevaluate your Plan B	Operational contingency planning, risk management, ISS	Kirk Shireman	…the message here I think, or the thing to think about, is focus on the contingencies depending upon the phase of your program and know that they're going to evolve over time. So, when your program reaches another phase or about to enter another phase need to go back and reevaluate what are the contingencies	Space Shuttle T&R Shireman Clip 7	32
Challenge the requirements	Verification	David McCann	You got to challenge the requirements as you develop hardware. One early requirement that was levied on the SARJ was that we shouldn't have any liquid grease in the system. Many times in the development of the program there were suggestions that they move to a grease and that was always discounted because of this requirement they had to not use liquid greases. What it turned out to be was there was no hard written down requirement like that, it was just always believed that you shouldn't be using liquid lubricants.	KBR- 11825 SARJ Vibrations Pose Risk to ISS Power and Operations	33

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Put people first in transition management	Program Transition Workforce Retention Closeout, People, 41	John Shannon	We put a huge premium with the contractor workforce and on the civil servant side with being extremely honest about what we were doing and why, and making sure that the people knew that even though we had budget problems and schedule problems and technical issues, that they came first and that we were as best we could within the constraints we had, both legally and just from a budget standpoint, that we were going to take care of them. That care was not just monetarily. It was communication; let them be able to have the opportunity to plan their life.	KBR 11797 – Civil Servant and Contractor Workforce Retention for Mission Execution: Clip: Identification of Risk; Time marker: 04:30	41
Manage transition with retention incentives	Program Transition Workforce Retention Closeout, People, 41	Sue Leibert	That there's a sense of loss at the end of the program, and that we can't underestimate what that will do. And that there's a sense of distraction, and that things like monetary and support services are important in helping the workforce not feel so distracted.	KBR 11797: Clip: Identification of Risk; Time marker: 06:15	41

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Benchmark external organizations - develop credibility	Program Transition Workforce Retention Closeout, People, 41	Sue Leibert	I think just the fact that we did benchmarking helped us an awful lot with our internal customers and our external customers. It gave us a lot more credibility with people to be able to say "these are some things that Titan did that helped make them successful...or NAVAIR or NAVSEA, and this is why we want to do the same things.	KBR 11797: Clip: Identification of Risk; Time marker: 06:45	41
Communicate in multiple ways	Program Transition Workforce Retention Closeout, People, 41	John Shannon	One thing we did was surveys, to which we got a very good response back and it helped to point out areas of communication that we needed to focus on and make sure that the managers were talking to the team. You have to realize this was grief; this was a grieving process. People knew that something they loved was going to end and communication cannot be overstated; the importance of it and how you have to do that in many different ways. You can't just talk to people at a staff meeting; you also have to do emails, you have to websites, you have to make sure they have the ability to respond to surveys, that you're available for brown-bags and Q&A because not one thing will catch everybody. But if you do multiple, many different communications efforts then you're going to get most of the people and that was very important.	KBR 11797 Clip: Mitigation of Risk 1; Time marker: 11:40	41

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Communicate the details, Discuss the details, Build Trust	Program Transition Workforce Retention Closeout, People, 41	John Shannon	They needed assurance from me that we were on a plan, we were going to execute that plan, we all understood it, we understood when people would be let go, what the retention incentives were going to be. It was just a lot of discussion and we built a lot of trust between the civil servants and the contractor leadership to make sure that we had discussed that, the importance, and that they were really committed.	KBR 11797Clip: Mitigation of Risk 1; Time marker: 14:10	41
Communicate, Communicate, Communicate	Program Transition Workforce Retention Closeout, Process,41	Sue Leibert	What were the lessons learned? The big one was, I think, communication. We did that well, I think, in that we got the contractors and the civil servants and the agency and the program and the projects all together, and I would encourage whoever would do this in the future, to do that.	KBR 11797Clip: Lessons Learned; Time marker: 03:10	41
Focus on team skills, team capability and process streamlining	People, team skills and capability, planning	Dorthy Rasco	My big takeaways: …. maintaining the critical skills … reviewing processes and you need to streamline …. communication and picking you're right team	Space Shuttle T&R Rasco Clip 6	41

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During transition communicate aggressively using all available modalities	Planning / Communication / People	John Olson	…we used every tool underneath the sun. We used traditional mechanisms like PowerPoint and Word to capture things. We also used social media wikis, and we used our ICE, Integrated Collaborative Environment,… we used a variety of newsletters; we used regular communications; we spoke and did public speaking events regularly. We spoke not only in large groups but small groups, tailored employee groups, to the Union, and to so many different constituents and stakeholders, … having such a constant and pervasive and consistent level of communication that used all those modalities plus all the existing constructs and the new ones that we added in order to amp up this specific communication, we again tackled that "tell them what you know, tell them what you don't know, and how you're working to get that."	Space Shuttle T&R Olson Clip 4	41
Plan thoroughly, get the right people on the team and communicate continuously	Planning, communication. people	John Olson	First you got to have a plan. A rigorous, well thought out, well researched, flexible plan is vitally important. And this plan has got to be a systems engineering approach; It's got to be a risk-based plan,…Number two, you've got to have communication: communication up, down, in and out, vertically throughout the organization and all levels, leveraging all the tools available, traditional ones, new ones, … the third thing, and perhaps the absolute most important thing of the three, is you've got to have (the right) people.	Space Shuttle T&R Olson Clip 7	41

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Employ a structured risk management approach in transition	Program Transition Workforce Retention Closeout, Process,42	Sue Leibert	So the overarching risk mitigation plan was a combination of that program in conjunction with the projects, but it was around communication and partnerships, it's around retention tools, and it's around planning and helping people see future work. Of course as a piece of that you have to have your metrics and measures and assessments; how are you doing in that process.	KBR 11797 Clip: Mitigation of Risk 2; Time marker: 01:40	42
Benchmark internal organizations - share lessons learned	Program Transition Workforce Retention / Closeout, Process,42	Sue Leibert	We established some human capital working groups and human capital councils so that we could share best practices between what the contractors were doing and what the civil servants were doing.	KBR 11797 Clip: Mitigation of Risk 2; Time marker: 02:25	42
Leverage the support of subject matter experts in Human Resources	Program Transition Workforce Retention Closeout, Process,42	John Shannon	You're not alone. I learned very early in running the program that if I had something I didn't know, especially about a personnel issue or HR or just how to deal with the emotions, I had help. Just make sure you use your team. Don't try to solve everything by yourself.	KBR 11797 Clip: Lessons Learned; Time marker: 01:30	42

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Protect assets and documentation for the future.	Refurbishing Protecting Assets during close out	Kathy Owen and Jerry Oakley	Protect assets for future programs. Often test equipment is abandoned and not stored properly and may become damaged prior to use on a future program. So if at all possible, to preserve both the hardware and the documentations for potential future users. When starting a refurbishment activity, gather a lot of historical data. There was a variety of NASA archives were we went and got information, there was actually still some hard copy data that was stored in the test area, and we also had the great advantage that we could consult with two key people that were involved in the HDS activities previously. It was a great thing for us to be able to draw on those resources, as well as to have all of the documentation available that we were able to find.	11496 IVGVT last clip	42
Expect late changes in requirements – maintain margin & flexibility	Requirements Management / Change Management / Margin / Flexibility	Stephanie Stilson	…we thought we had defined all the requirements (what we needed to do, work we needed to do) to safe the vehicles and get them ready for delivery. Well then we found out that some new requirements were being generated. The Agency was wanting to see are there any components of these orbiters that we may want to retain for any studying, testing, potential future use, things that maybe we would like to gain and learn from these pieces of hardware.	Space Shuttle T&R Adjusting to Late Changes (Stilson Clip 5)	42

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Closeout with Priority	People, Communication	Jonathan Krezel	So I think the lesson learned there is, in any activity, but particularly when you're doing a large program shutdown, make sure you have your priorities straight and certainly for human spaceflight that priority was on safe flyout.	Space Shuttle Transition and Retirement Lessons Clip: 2 Start Up Transients: Time Marker 6:32	42
Don't try to reinvent … reach out and leverage existing knowledge and expertise	Early Transition Planning /	Dorthy Rasco	…reach out to those that have the knowledge in the area that you don't have. Don't try to reinvent. Leverage off of the policies and the processes and the people that are within the Agency that's already available to help you with all of the areas that you're not as familiar with.	Space Shuttle T&R Rasco Clip 2, Early Transition Planning	42
Keep core business management capability throughout program close-out	Contract closeout	Dorthy Rasco	…make sure you that you maintain those best folks on your team until the very end … legal, procurement, contracts	Space Shuttle T&R Rasco Clip 4	42

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Implement and use a risk management process	Closeout Risk Management	Dorthy Rasco	…one of the processes that is one of the most useful tools is the risk process. We used it so much, and it was one of our top priorities that we reviewed for the operations. And I kept it and continued using that same process for the Transition & Retirement,	Space Shuttle T&R Rasco Clip 5	42
Set a budget baseline for closeout	Closeout Cost Estimates	Jonathan Krezel	It's okay to scope out the entirety of your effort up front and to really put a corner case estimate out there of what do you think it would cost, but in no way should you pretend that that estimate is gospel. That's your starting point. That's the starting point to really, in detail, lay out your assumptions and then through your subsequent processes, through subsequent planning, in our case we used the budget process, attack each of those assumptions and really work each of them hard until you get to the absolute core things that you have to do. So, using the budget as a way to attack assumptions was a key lesson learned from this.	Space Shuttle Transition and Retirement LessonsClip: 3 Start Up Transients: Time Marker 3:35	42
Use a systems engineering approach to tackle complex challenges	Planning, and systems engineering process	John Olson	…transition from the Space Shuttle to the follow-on program, it's really a large systems engineering problem. And I would even go further; I'd call it a system of systems engineering challenge. Of course that requires and necessitates a rigorous systems engineering breakdown and methodical approach to tackling it.	Space Shuttle T&R Olson Clip 3	42