Lessons Learned and Knowledge Sharing

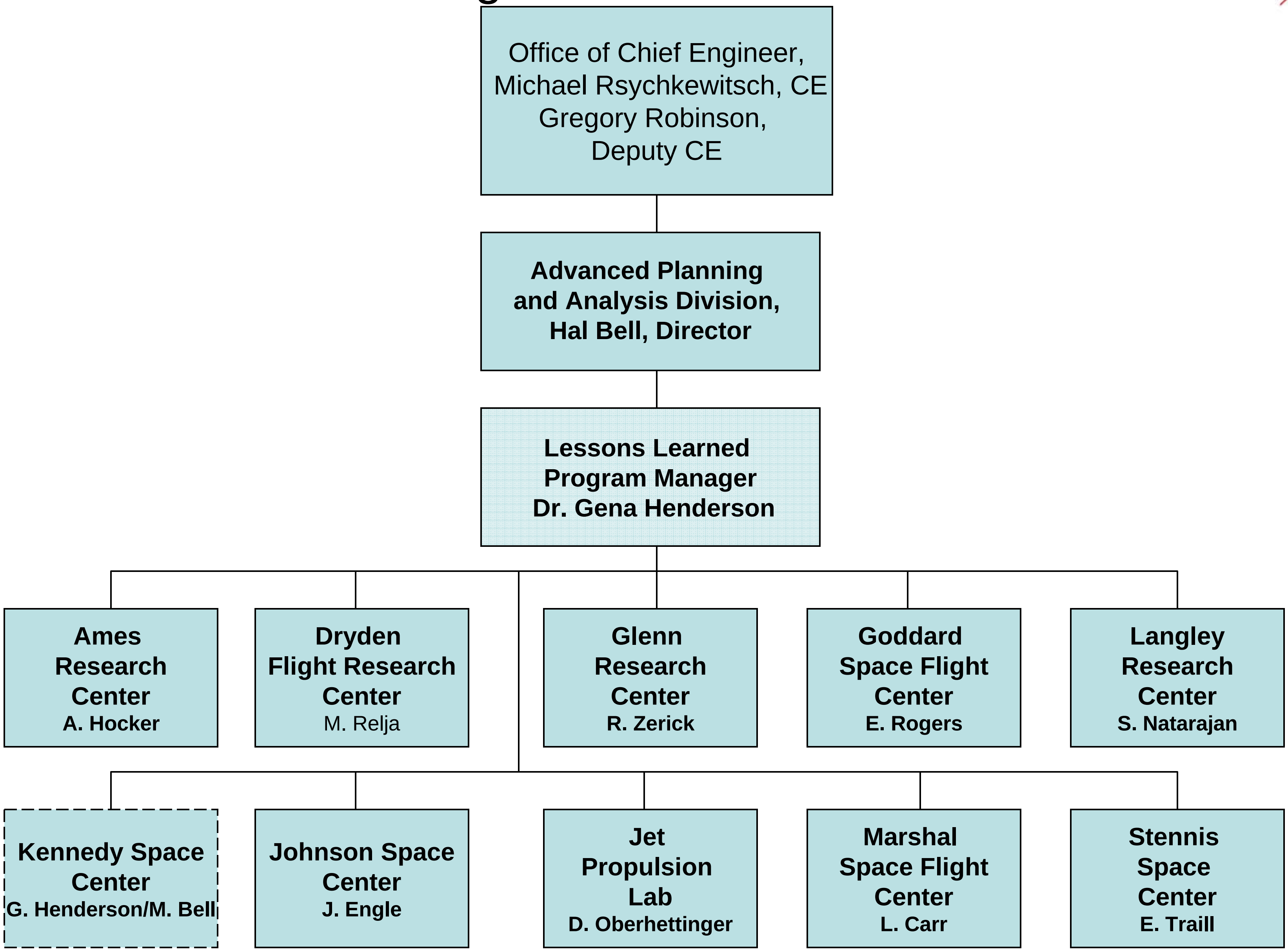
An Agency Initiative

Dr. Gena Henderson
Lessons Learned Program Manager
Advance Planning and Analysis Division
HQ Office of the Chief Engineer
February 26, 2008

AGENDA

- NASA Lessons Learned Organization
- Congressional Authority
- History
- Agency Lessons Learned and Knowledge Sharing Process
- Center Support
- Recognizing & Reporting LL throughout Lifecycle
- Q & A

Lessons Learned Organization



NASA LL Organization Overview

Office of Chief Engineer, Michael Rsychkewitsch, CE Gregory Robinson, Deputy CE

Advanced Planning and Analysis Division, Hal Bell, Director

Lessons Learned
Engineering Standards
Inventions and Contributions Board
NASA Engineering Network
Advance Planning and Technical Investment, Technical Excellence Initiatives
PA&E and OSMA Collaboration

Lessons Learned Program, Dr. Gena Henderson, Manager, HQ Data Manager (HDM)
Committed to providing an agency wide lesson learned system that infuse lessons into our policy, procedures, guidelines, technical standards, training, and education curricula. Through strategic partnerships with our customers and stakeholders, we are able to offer the best practices of lessons learned that contribute to mission success. Increase awareness so that all practitioners identify and share lessons learned resources at their centers and across the Agency.

Lessons Learned Steering Committee, CDMs from each center

CONGRESS

Provides Lessons Learned Authority

NASA Authorization Act 2005

- SEC. 107. LESSONS LEARNED AND BEST PRACTICES. (a) IN GENERAL.--The **Administrator shall transmit** to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate an **implementation plan describing NASA's approach for obtaining, implementing, and sharing lessons learned and best practices** for its major programs and projects not later than 180 days after the date of enactment of this Act. The implementation plan shall be updated and maintained to ensure that it is current and consistent with the burgeoning culture of learning and safety that is emerging at NASA. (b) REQUIRED CONTENT.--**The implementation plan shall contain at a minimum the lessons learned and best practices requirements for NASA**, the organizations or positions responsible for enforcement of the requirements, the reporting structure, and the objective performance measures indicating the effectiveness of the activity. (c) INCENTIVES.--The Administrator shall provide incentives to encourage sharing and implementation of lessons learned and best practices by employees, projects, and programs, **as well as penalties for programs and projects that are determined not to have demonstrated use of those resources.**

- Here is the link for the entire authorization act:

http://www.govtrack.us/congress/billtext.xpd?bill=s109-1281

LL Implementation

NASA Implementation Plan

The purpose of this document is to transmit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate an implementation plan describing NASA's approach for obtaining, implementing, and sharing lessons learned and best practices for NASA's major programs and projects.

- **NASA Integrated Action Team (NIAT**) December 2000
  - **NIAT-17 Action:** Promote the continuous capture, dissemination and utilization of knowledge and make checklists available to support project managers. [***AO***, FT, Q, AE,Center Directors; 6/01].
- **General Accounting Office (GAO) Report 2002**
  - GAO found that NASA's processes, procedures, and systems do not effectively capture and share lessons learned and therefore, NASA has no assurance that lessons are being applied towards future missions.
  - Respondents reported that they are unfamiliar with lessons generated by other centers and programs.

GAO-02-195 NASA Better Mechanisms Needed for Sharing Lessons Learned

NASA needs to strengthen its lessons learning in the context of its overall efforts to **develop and implement an effective knowledge management program.** Improvement of NASA's lessons learning processes and systems can help to ensure that knowledge is gained from past experiences and applied to future missions.

We recommend that the NASA administrator strengthen the agency's lessons learning processes and systems by:

- **articulating the relationship between lessons learning and knowledge management** through an implementation plan for knowledge management;
- **designating a lessons learned manager to lead and coordinate all agency lessons learning efforts;**
- **establishing functional and technical linkages among the various center-level and program-level lessons learning systems;**
- developing ways to **broaden and implement mentoring and "storytelling"** as additional mechanisms for lessons learning;
- identifying incentives to encourage more collection and sharing of lessons among employees and teams, such as **links to performance evaluations and awards;**
- **enhancing LLIS by coding** information and developing an **easier search capability** to allow users to identify relevant lessons, including **more positive lessons**, providing a means to disseminate key lessons to users; and **soliciting user input on an ongoing basis**; and
- **tracking** and reporting on the **effectiveness** of the agency's lessons learning efforts using objective **performance metrics.**

Function as a Learning Organization

"Shuttle management declined to have the crew inspect the Orbiter for damage, declined to request on-orbit imaging, and ultimately discounted the possibility of a burn-through."

"The Board views the failure to do so as an illustration of the lack of institutional memory in the Space Shuttle Program that supports the Board's claim… that NASA is not functioning as a learning organization."

CAIB Report (2003) Section 6.1, Page 127

- **CAIB**

Learned Information System: The Lessons Learned Information System database is a much simpler system to use, and it can assist with hazard identification and risk assessment. However, personnel familiar with the Lessons Learned Information System indicate that design engineers and mission assurance personnel use it only on an *ad hoc* basis, thereby limiting its utility. The Board is not the first to note such deficiencies. Numerous reports, including most recently a General Accounting Office 2002 report, highlighted fundamental weaknesses in the collection and sharing of lessons learned by program and project managers.

- Diaz Team Report
  - The seriousness of the *Columbia* accident and the CAIB Report, NASA leaders need to reflect upon and grow from the lessons learned.
  - The Diaz Team's actions contained in the Diaz Team Matrix require that everyone understand their responsibilities and are given the authority to perform their jobs, with the accountability for their individual and program's successes and failures, including lessons learned.
  - Mandate that current and new employees moving into management positions attend a lecture (sponsored by NASA) outlining historical lessons learned by NASA and comparable agencies.

GAO-06-1129T GOES Additional Action Needed to Incorporate Lessons Learned from Satellite Programs

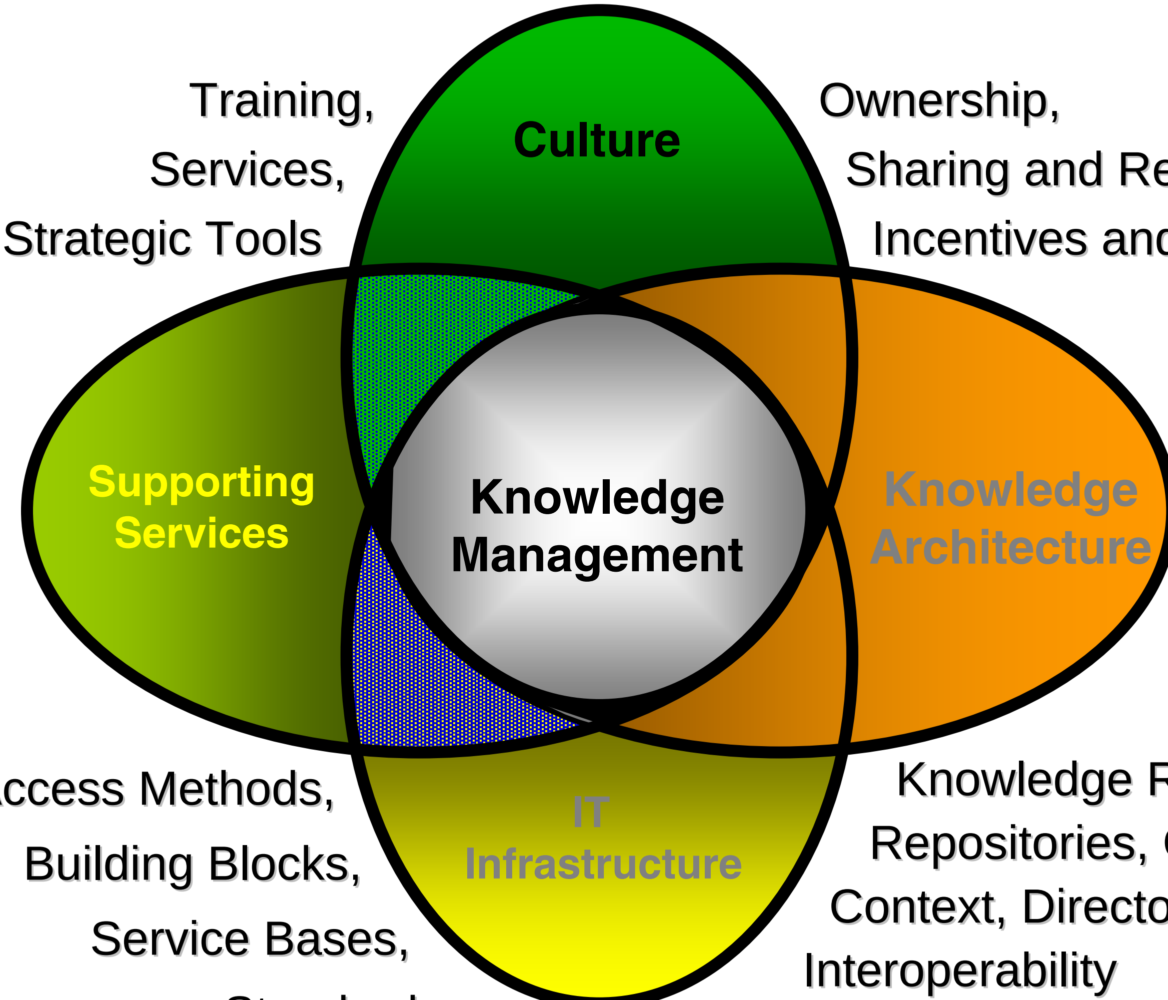
Key Lessons Learned and the Activities Taken or Remaining to Fully Address Them

Lesson learned	Actions taken or under way	Actions remaining
Establish realistic cost and schedule estimates	• Obtaining multiple independent cost estimates • Conducting risk analysis of schedule estimates	• Ensuring objectivity when reconciling alternative estimates
Ensure sufficient technical readiness of the system's components prior to critical decisions	• Conducted preliminary studies of key technologies and components	• Ensuring sufficient technical maturity before proceeding to production
Provide sufficient management of contractors and subcontractors	• Increased presence at contractor sites • Plan to increase number of system engineers • Plan to hire three specialists in earned value	• Assessing the number of earned value specialists needed commensurate with increased acquisition activities
Perform effective executive-level oversight	• NOAA's program management council meets regularly to oversee project	

Success Requires Agency Wide Support for an Easily Accessible, Searchable, Interconnected/Integrated System

Training,
Services,
Strategic Tools

Ownership,
Sharing and Reuse,
Incentives and Rewards

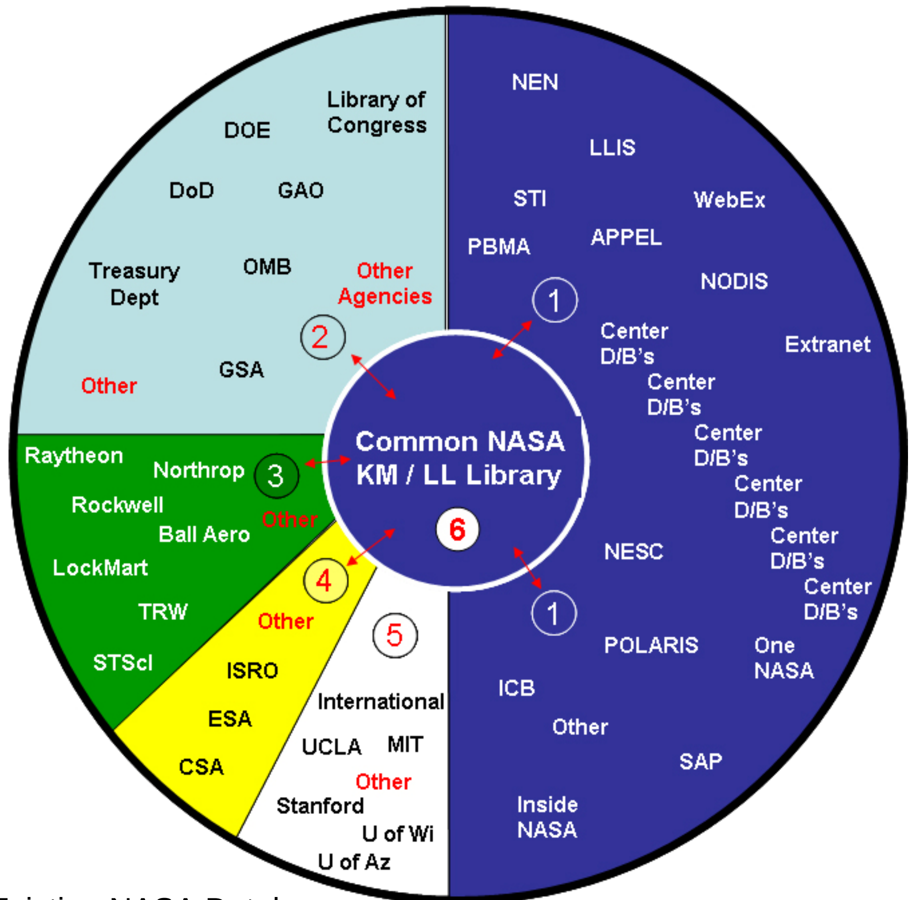


Access Methods,
Building Blocks,
Service Bases,
Standards

Knowledge Resources,
Repositories, Content,
Context, Directories,
Interoperability

Methodology

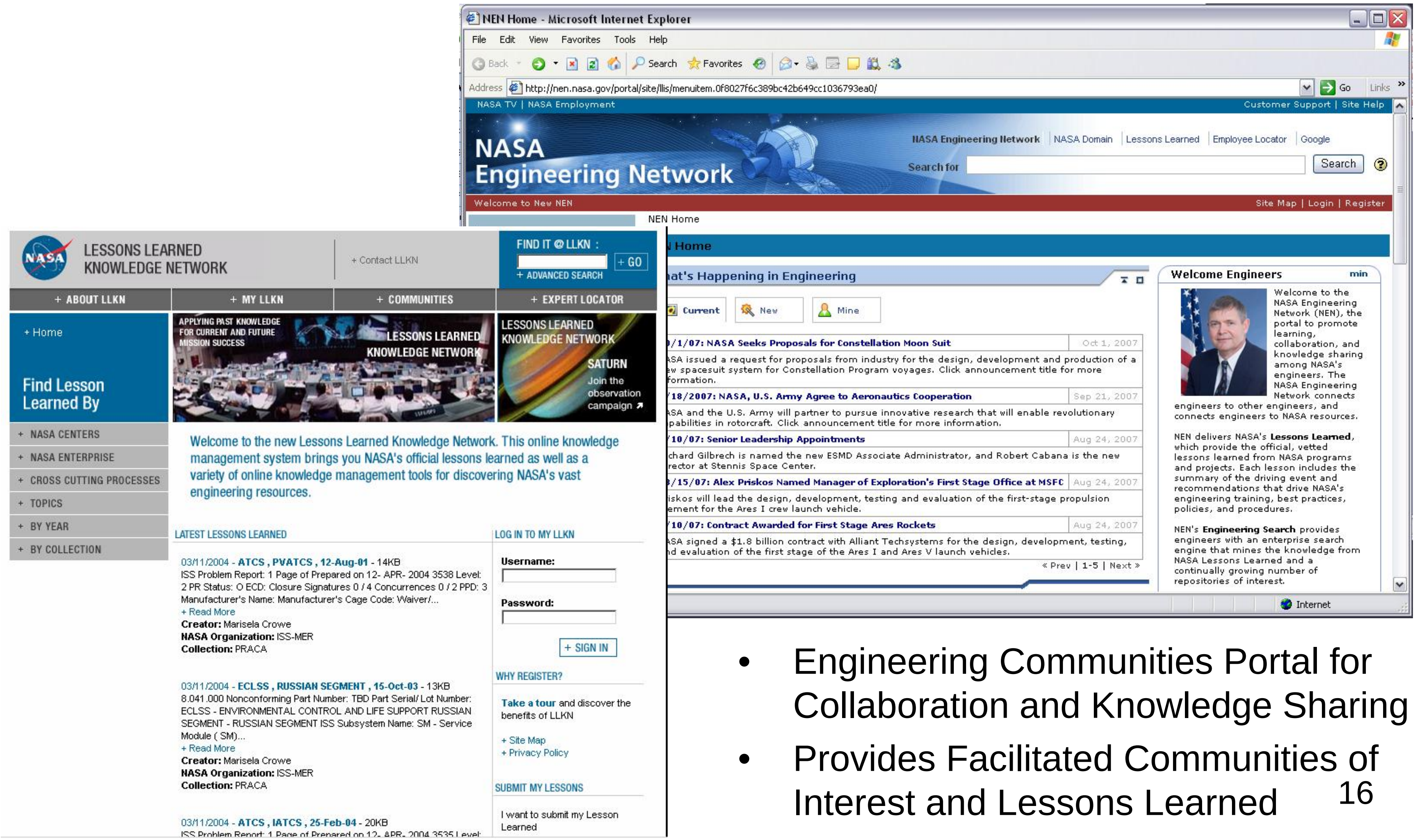
- **The NASA Office of Chief Engineer is working towards fixing the problems and issues in the following manner:**
  - **Enhancing its legacy KM/LL systems to maximize functionality while trying to integrate distributed databases**
  - **Educating and sharing knowledge among the user community within and outside NASA**
  - **Gaining access to the disparate sources and making rich, pertinent data quickly and easily accessible to anyone, any where, any time and in a form that is compatible with diverse individuals and organizations**



1) Existing NASA Databases;
2) External Government Databases
3) Contractor Databases;
4) Foreign National Databases
5) Academia;
6) Central Hub

Lessons Learned and Knowledge Sharing at NASA Today

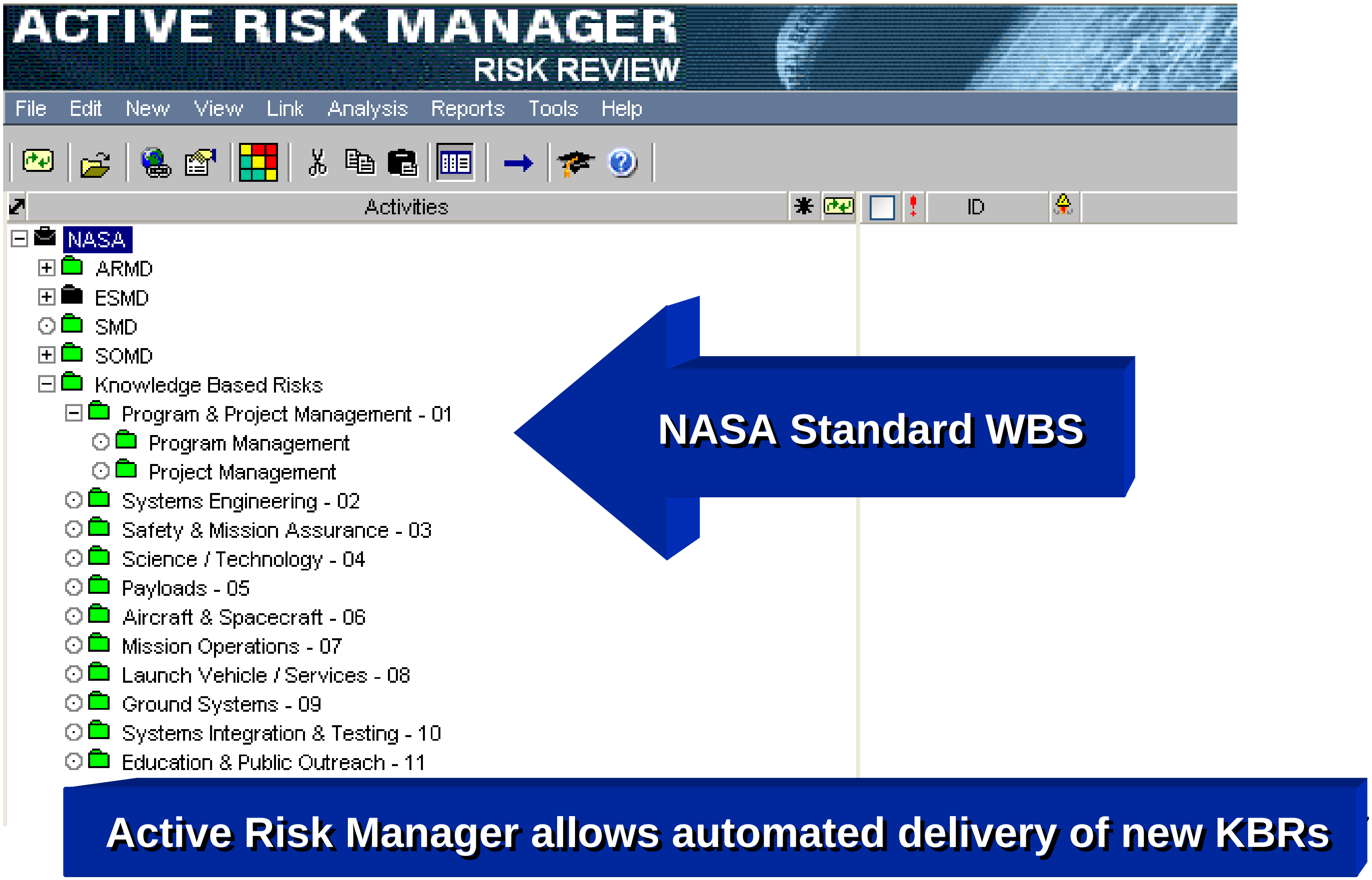
NASA Engineering Network (NEN)



- Engineering Communities Portal for Collaboration and Knowledge Sharing
- Provides Facilitated Communities of Interest and Lessons Learned

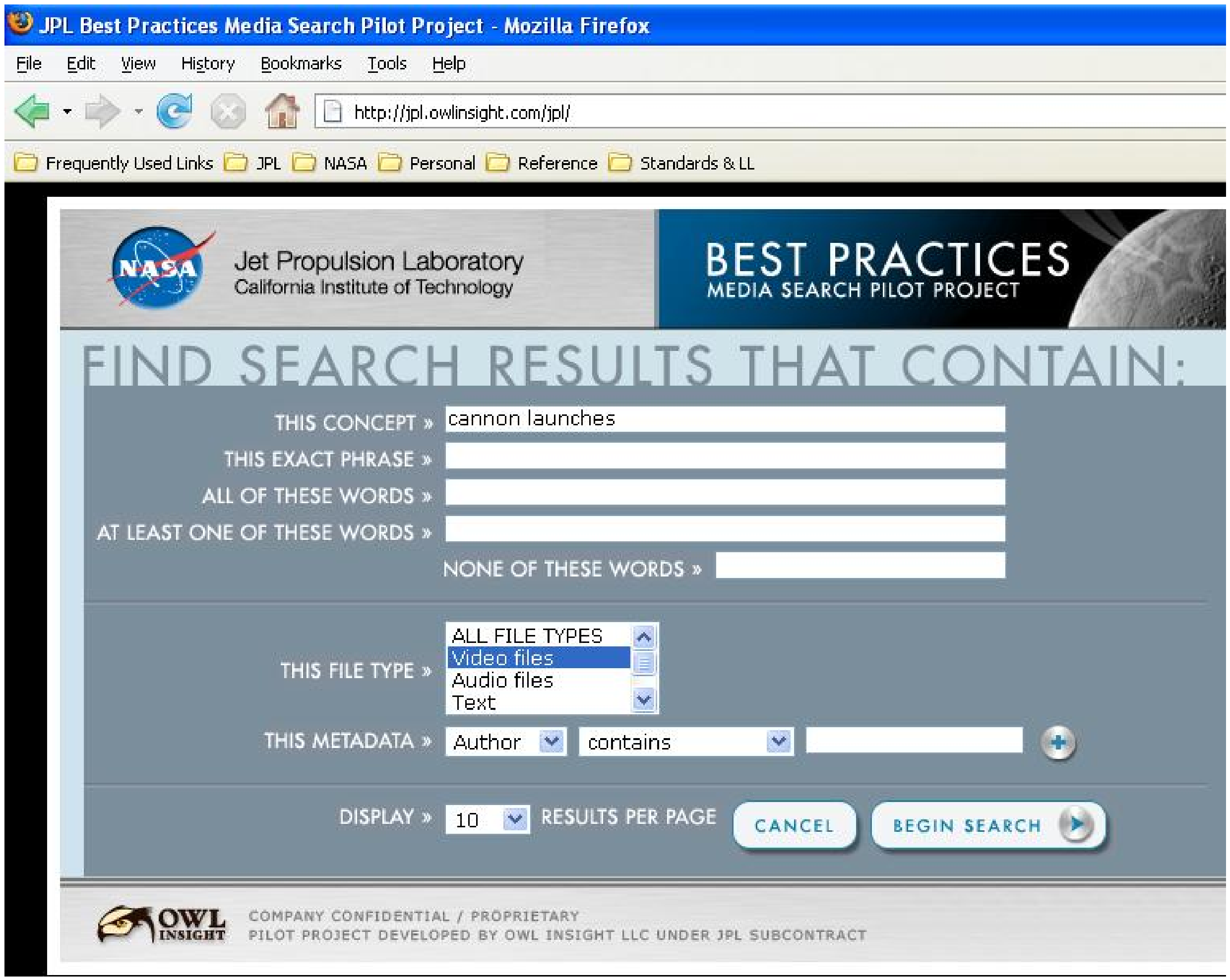
Lessons Learned and Knowledge Sharing at NASA Today

ESMD Risk-Based Approach to Knowledge Management



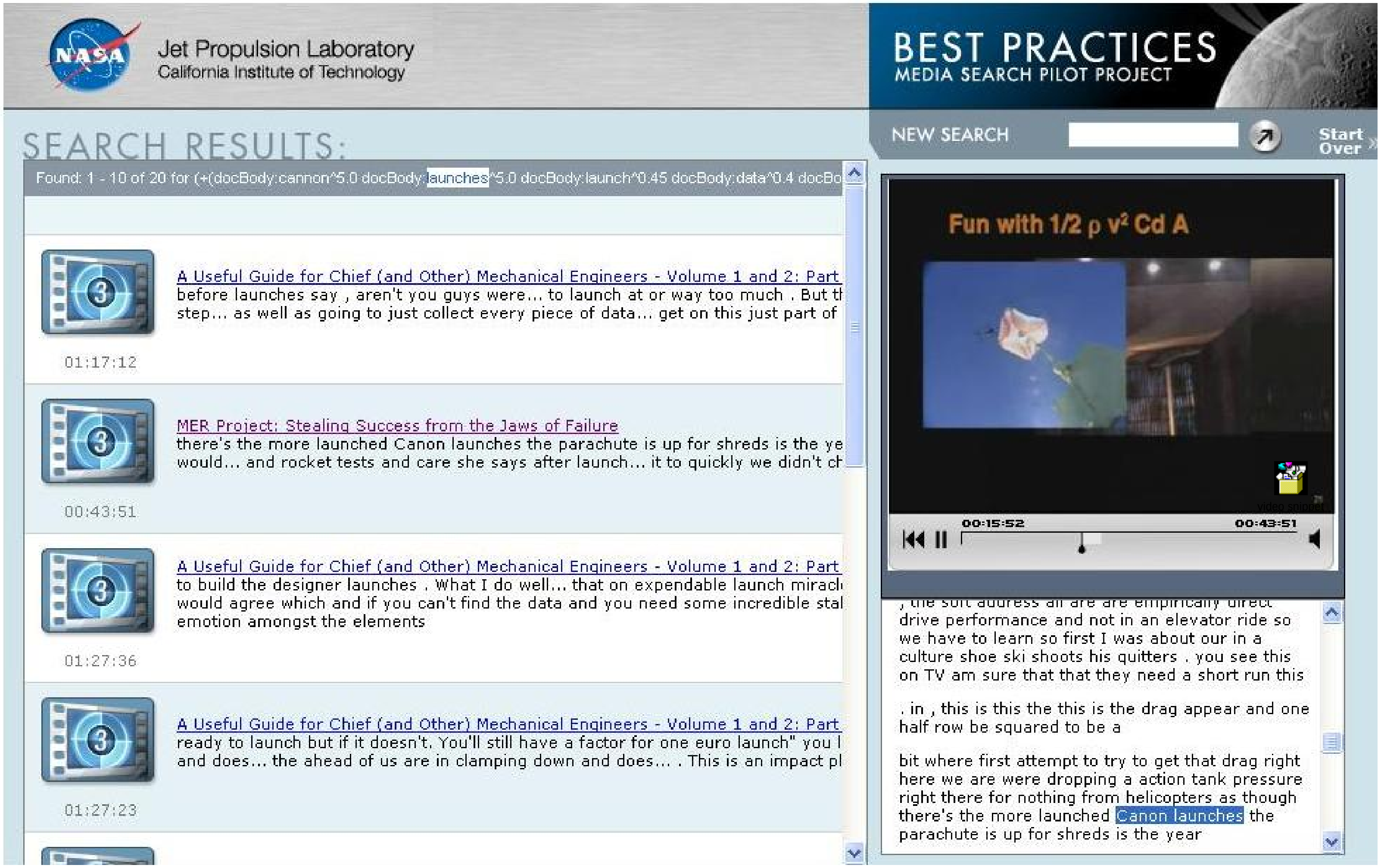
Media Search® Demonstration

Step 1. Online user enters search terms, and selects the file type “Video Files”



Media Search® Demonstration

Step 3. User plays short snippet from 43 min. video or reads transcript (note misspelling)



What is the Agency Doing?

Codification & Training

Lessons Sources

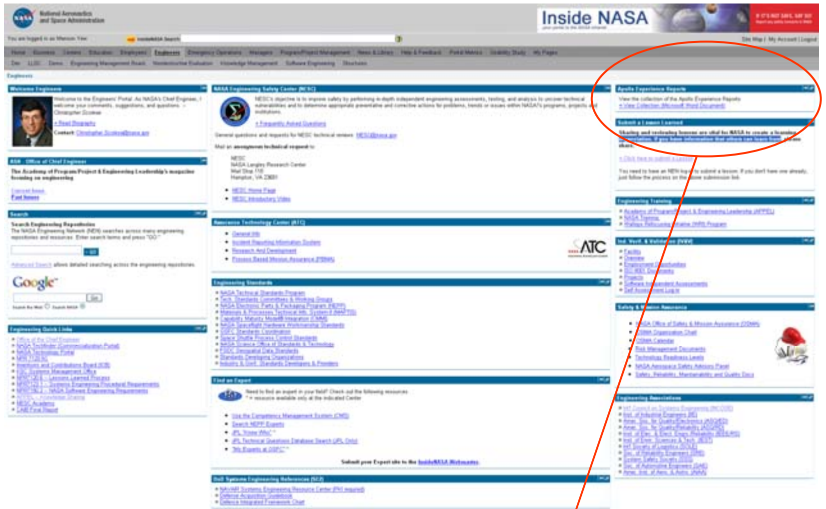
Program
Policy directives
Technical standards
Memoranda
Operations sheets
Test methods
Parts alerts
FAR/NFAR
Training
Mentoring
Best practices
Caution & warnings
Storytelling (interviews)
Trade studies
NESC Tech Bulletins

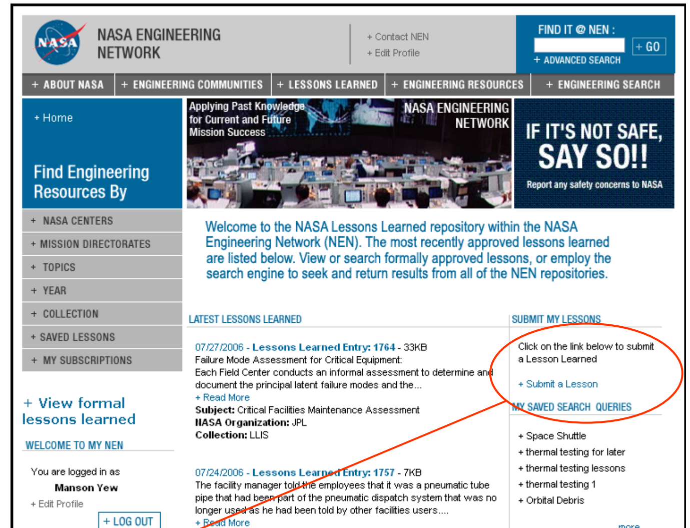
NASA LLIS
Other collections of LL
expert opinion (ppt)
Technical Reviews
Major Milestones
Key Decisions Points
Lifecycle phases
Mishaps
Corrective action systems
Whitepapers
Technical Papers
Prototypes
Source Evaluations Boards
Tech Talks

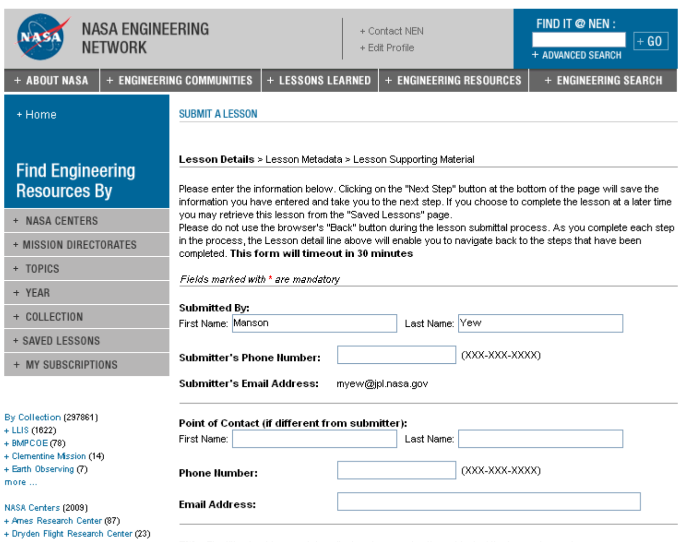
LL Best Practice

- Integrate lessons to policy, standards, and procedures
- Embed a “how to” capture process
  - Review LL at major milestones, tech reviews & other decision points
  - Determine lessons relevancy to project
  - Assess project compliance with LL recommendations

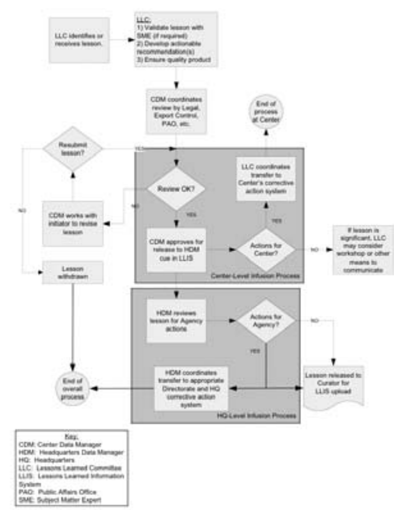
Capturing Lessons



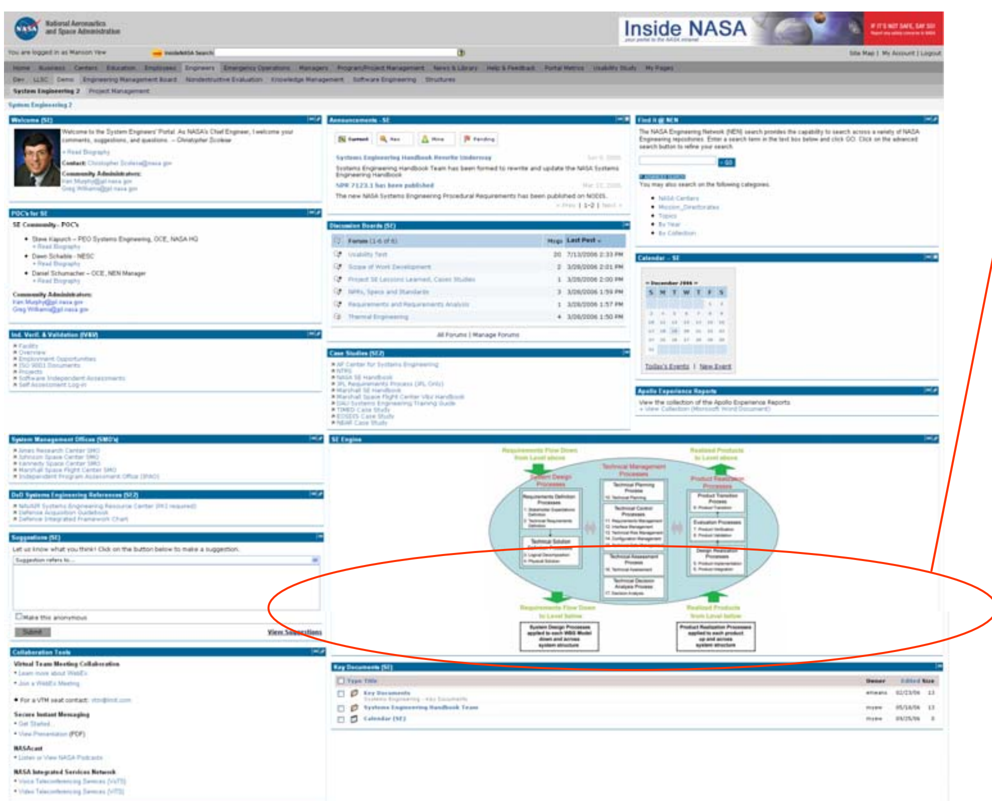




Multiple entries to the same submission form and workflow controlled lessons learned process



Policy Makers Embedding Lessons into Processes



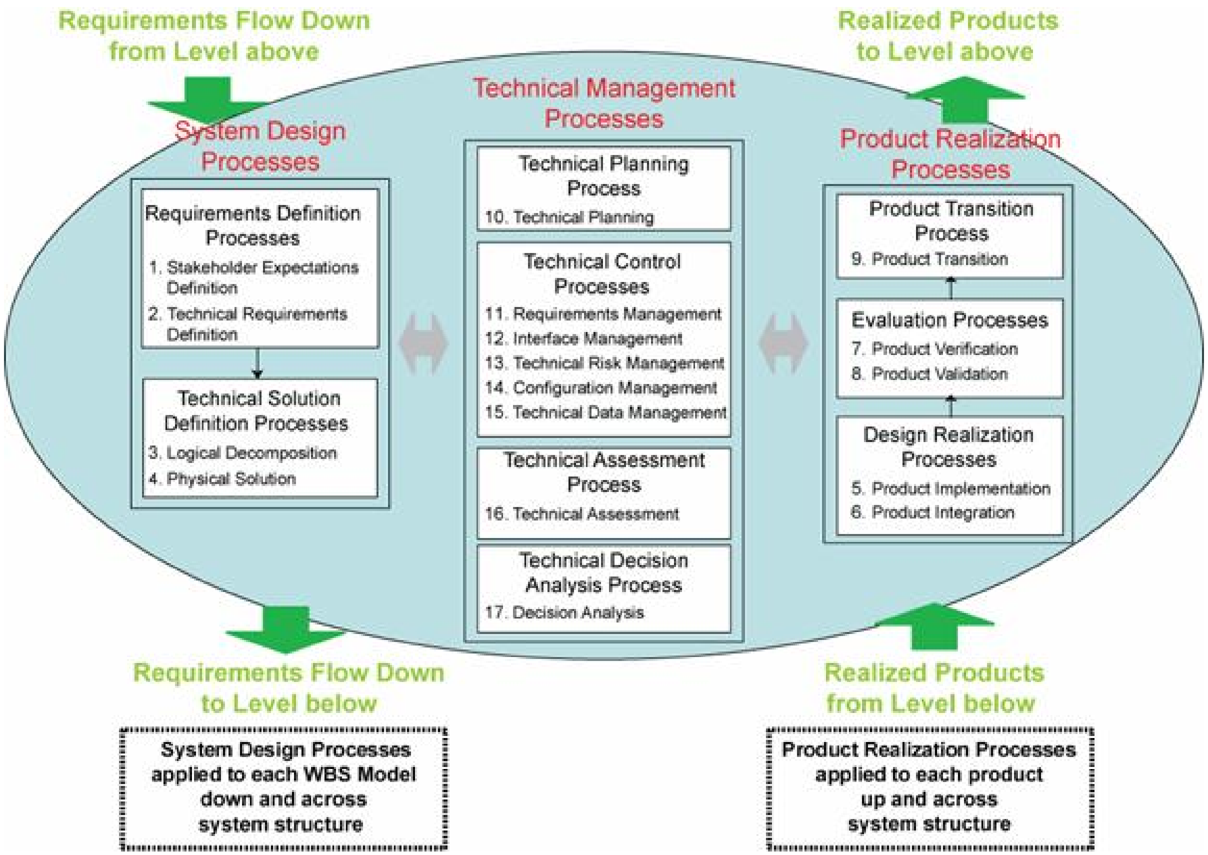
NASA System Engineering Handbook rewrite team using NEN to collaborate among 60+ subject matter experts

- Lessons Learned Process
- Program & Project Management
- Systems Engineering
- Safety and Mission Success
- Knowledge Management

SE Engine

National Aeronautics and Space Administration
Office of the Chief Engineer

http://nen.nasa.gov/portal/site/llis/menuitem.593d615c982f63c1b649cc1036793ea0/



System Engineering Handbook/SP6105

- **6.1.2.3 Lessons Learned**

  No section on technical planning guidance would be complete without the effective integration and incorporation of the lessons learned relevant to the project.

- **Systems Engineering Role in Lessons Learned**

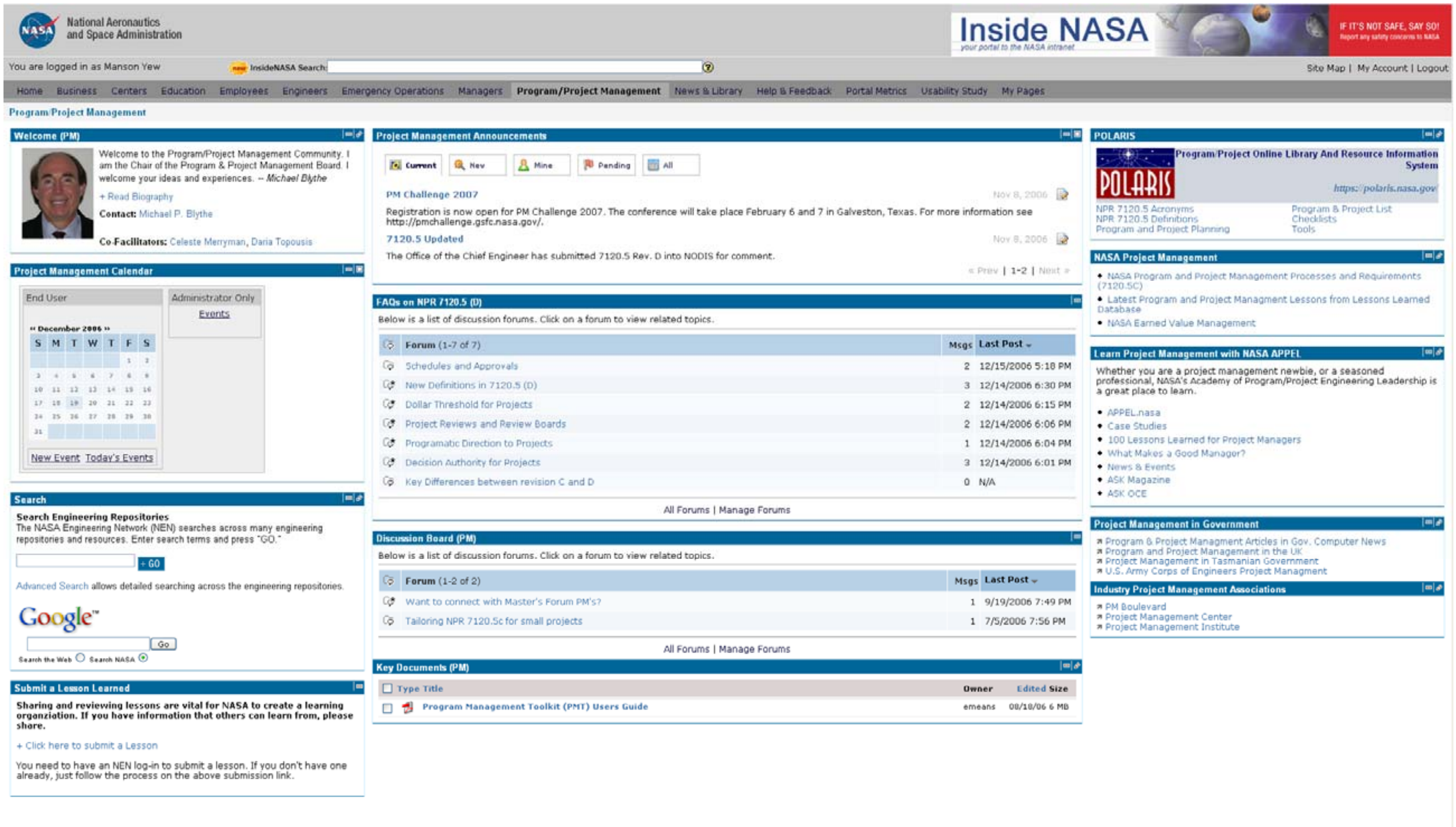
  Systems engineers are the main users and contributors to lessons learned systems. A lesson learned is knowledge or understanding gained by experience—either a successful test or mission or a mishap or failure. Systems engineers compile lessons learned to serve as historical documents, requirements' rationales, and other supporting data analysis. Systems engineering practitioners collect lessons learned during program and project plans, key decision points, life-cycle phases, systems engineering processes and technical reviews. Systems engineers' responsibilities include knowing how to utilize, manage, create, and store lessons learned and knowledge management best practices.

- **Utilization of Lessons Learned Best Practice**

  Lessons learned are important to future programs, projects, and processes because they show hypotheses and conclusive insights from previous projects or processes. Practitioners determine how previous lessons from processes or tasks impact risks to current projects and im

Polaris:

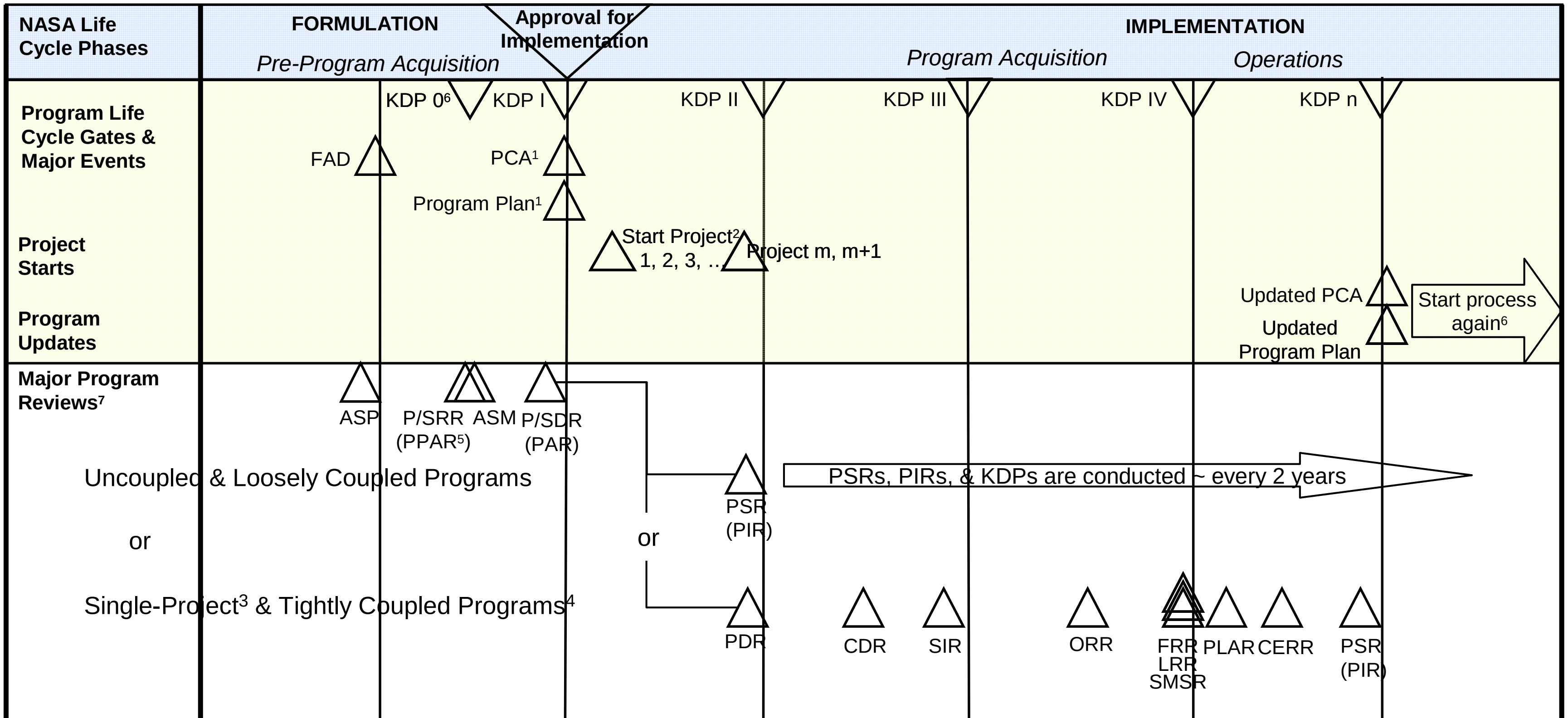
http://nen.nasa.gov/portal/site/llis/menuitem.725



Role of LL in Life Cycle

- Program Life Cycle
  - Formulation Phase (KDP 0,1)
  - Implementation Phase (KDP 1..N)
  - Technical Reviews (PSRR,PSDR)
- Project Life Cycle
  - Formulation Phase A-B (KDP A-C)
  - Implementation Phase C-F (KDP D-F)
  - Technical Reviews (SRR, SDR, CDR, ORR, FRR, PLAR, DR)

Lifecycle



FOOTNOTES

1. PCA and Program Plans are baselined at KDP I and reviewed and updated, as required, to ensure program content and budget remain consistent.
2. Projects, in some instances, may be approved for formulation prior to KDP II. Initial project pre-formulation generally occurs during program formulation.
3. Single-project program reviews from PDR until operations are the same reviews as the project reviews (not duplicates).
4. Tightly coupled program reviews generally differ from other program types because they are conducted to ensure the overall integration of all program elements (i.e., projects). Once in operations, PIRs are conducted ~ every 2 yrs.
5. KDP 0 and the PPAR may be required by the Decision Authority to ensure major issues are understood and resolved prior to formal program approval at KDP I.
6. When programs require upgrades (e.g., new program capabilities), the life cycle process will be restarted when directed by the AA, i.e., the program's upgrade will go through the same formulation and implementation steps as originally done.
7. These reviews are conducted by the program for the independent SRB (with the exception of the ASP, ASM, FRR, SMSR) and described in Section 2.5

ACRONYMS

ASP—Acquisition Strategy Planning meeting
ASM—Acquisition Strategy Meeting
CDR—Critical Design Review
CERR—Critical Events Readiness Review
FAD—Formulation Authorization Document
FRR—Flight Readiness Review
KDP—Key Decision Point
LRR—Launch Readiness Review
ORR—Operational Readiness Review
PPAR—Preliminary Program Approval Review
PAR—Program Approval Review
PCA—Program Commitment Agreement
PDR—Preliminary Design Review
PIR—Program Implementation Review
PLAR—Post-Launch Assessment Review
P/SDR - Program/System Definition Review
P/SRR—Program/System Requirements Review
PSR - Program Status Review
SIR—System Integration Review
SRB—Standing Review Board
SMSR—Safety and Mission Success Review

SMA http://kscsafety.ksc.nasa.gov/

- KSC-KDP-1473 Mishap
- KSC-KDP-P Close Calls
- SMA Plan

Institutional/ NPR 7120.7
Research & Technology/ NPR 7120.8

NPR 7120.5C

- **2.2 Program Formulation**
- 2.2.2.a Prepare a Program Plan.
- The Program Manager shall evaluate lessons learned from existing and previously executed programs and projects to identify applicable lessons for use in program planning and execution.
  - 3.Early in program formulation, the Program Manager, in consultation with the MDAA (or MSOD), shall recommend a Technical Warrant Holder (TWH). The NASA Chief Engineer selects the TWH.
- **3.4.8 Capture Knowledge**
- 3.4.8.1 Purpose: The intent of this activity is to accrue knowledge in an organized fashion to improve the performance, and reduce the cost and risk of future programs and projects, and to adhere to Federal and NASA requirements for records management and retention. Lessons learned are disseminated by the OCE and reflected in modifications to NASA training.

▪

What Can the Centers Do?

- OCE provides a very small amount of funds to each center—a demonstration of good faith
- Centers can:
  - Recognize the value to the Agency of a strong learning organization and apply local resources
  - Identify local lessons and knowledge and proactively make available to the rest of the Agency
  - Hold center programs and projects accountable for becoming learning organizations—continuously seek lessons of others across the Agency and document and share lessons of their own
  - Embrace story telling, training, case studies, center wide learning sessions
  - If new ways of learning are discovered, share the methods with others (e.g. ESMD approach to Risk Based Knowledge Sharing)
  - Provide participants and not just presence at Agency level Lessons Learned activities—passion and strong opinions are welcome and will be valued among peers
  - Prevent “Not Invented Here” from spreading—it has no place in a learning environment

What Centers Are Doing?

Codification & Training

Lessons Learned: Sources

Programs/Projects
Policy directives
Technical standards
Memoranda
Operations sheets
Test methods
Parts alerts
FAR/NFAR
Training
Mentoring
Best practices
Caution & warnings
Storytelling (interviews)
Trade studies
NESC Tech Bulletins
Flight Rules

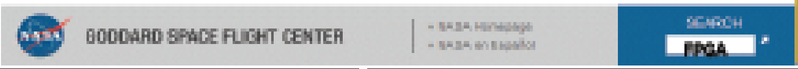
NASA LLIS
Other collections of LL
Expert Opinion
Technical Reviews
Major Milestones
Key Decisions Points
Lifecycle phases
Mishaps
Corrective action systems
Whitepapers
Technical Papers
Prototypes
Source Evaluations Boards
Tech Talks
Risk Management Systems

JPL Flight Design Principles

Flight Project Practice	Flight Project Practice Provision	Lesson Learned or Guidance Document	Lessons Learned Abstract
		NEN #1770	**JSC Lesson Learned:** [A copy of the JSC lesson learned was provided to Ezra Abrahamy, JPL Occupational Safety Program Office.]
		NEN #1779	**KSC Lesson Learned:** [A copy of the KSC lesson learned was provided to George Beck, JPL Facilities Maintenance and Operations Section Manager.]
5.9.2.5	Each Category I and Category II project develops a Cost Analysis Data Requirement (CADRe) to support independent cost analysis by NASA.	NEN #1772 - Know How Your Software Measurement Data Will Be Used	When software measurement data used to support cost estimates is provided to NASA by a project without an understanding of how NASA will apply the data, discrepancies may produce erroneous cost estimates that disrupt the process of project assessment and approval. Major flight projects should verify how NASA plans to interpret such data and use it in their parametric cost estimating model, and consider duplicating the NASA process using the same or a similar model prior to submission.
6.2.4	"Projects determine predictions of telecommunications link performance via engineering analysis using a statistical treatment and characterization of the link parameters."	NEN #1765 - Managing Rover-Orbiter Relay Link Prediction Variability	The difference between the predicted versus achieved data volume returned by the Mars Exploration Rover relay link impacted the daily planning of rover driving and science data collection. This problem can be alleviated by refining the operations and science data return planning process. This should reflect a priority scheme based on (1) a minimum volume requirement (30 Mb for MER) and (2) a daily assumption of achieving a data volume level of one sigma (1 standard deviation) less than the predicted volume.
6.12.3	All facilities intended for processing, operations, or testing flight hardware undergo a combined audit by the responsible QA, Safety, and technical organizations to ensure their suitability for the intended efforts. The project safety manager ensures that potential hazards to hardware or personnel safety are corrected prior to the start of the effort.	NEN #1764 Critical Facilities Maintenance Assessment	CFMA is an ongoing NASA activity that was initiated following the March 2000 HESSI spacecraft overtest incident that severely damaged the spacecraft. CFMA is a comprehensive assessment of NASA critical facilities and equipment to identify inadequacies in ground facility readiness that could harm people or NASA hardware. It involves an inventory of critical facilities and equipment, identification of equipment failure modes, establishment of appropriate reliability centered maintenance (RCM) methods, and related activities. This lesson captures a NASA Preferred Practice that was drafted but did not complete a NASA-wide review cycle.

Goddard Design Rules

A search on the term "FPGA" will yield:

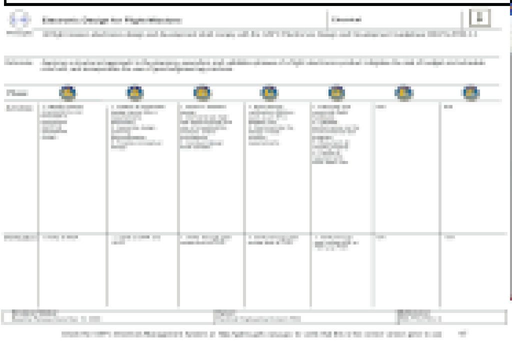


Goddard Space Flight Center

Rules for the Design, Development, Verification, and Operation of Flight Systems

GSFC – STD – 1000
Baseline Release
December 10, 2004

GOLD Rule 2.10 – Electronic Design



Link to specific NASA LLIS data

Link to specific MIL-STD

Link to klabs.org page on FPGA design

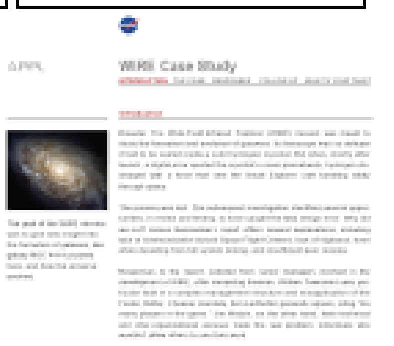
Link to JPL Blue Book FPGA rules

4.12.10.2 *ASIC/FPGA synchronous designs* - The synchronous design of ASIC or FPGA shall be verified, as a minimum by post-route timing analyses using a place and route tool and test vector simulation with timing checkers performed at the primitive level. Timing of boundary conditions (pin-outs) shall be constrained for place, route, and test vector simulation.

4.12.10.3 *ASIC performance characterization* - Functional tests shall be performed with simultaneous digital, analog and mixed signal circuitry to assess interactions, as well as, separate tests on each portion of the ASIC.

4.12.10.4 *Use of behavioral models* - ASIC design shall develop behavioral and hardware description models to capture implementation of system design specifications and evaluate performance.

Link to relevant case study



Center Governing Document: STD 512/5005

LLNo.	Category	Subject	Topic	**Link**
1779	Safety	Power Outage	• Evacuation of employees with disabilities • Command and control structure • Administrative leave decision • Unscheduled power outage-emergency • Internal battery powered fire alarm/ paging • PAWS battery backup • Emergency lighting systems	**CCEMP JHB 2000 Rev D** **JDP-KSC-P3001** **JDP-KSC-P-3003** **JDP-KSC-P-3012**
0902	Logistics	Hydrazine Cylinder Shipping	DOT exemptions must be included in shipping documentation	**5005-4.9 Packaging per NPR6000.1** **- 4.9.1 Shipping containers** **512-5.1 Preservation and packaging**
0623	Config. Mgmt	Tethered Satellite System De-Integration Process	Failure to maintain adequate configuration control of hazardous items	**5005-4.1 General** **512-3.1.4 Configuration Control**
0618	EPA	Ruptured Paint Drum	55 gal waste paint drum ruptured while in storage at an offsite hazardous waste storage facility	**RCRA Laws and Regulations** **40CFR Part 261**
0588	Operator Error	SRB Holddown Post Incident	Handling of heavy unbalanced items on marginal pallets along with limited space to maneuver the load caused the load to fall off the pallet. Classified as a "near miss".	**5005-4.6 Personnel and training** **512-3.1.2.3 Handling and Transportation** **-3.6 Personnel and Training**
0587	Safety/ Training	High Pressure Incident	Failure to read a gage correctly. Failure to document detailed work instructions on a Safety Reviewed system.	**5005-4.6 Personnel and training,** **5.8.2 Safety Requirements on KSC property** **512-3.6 Personnel and Training**

Technical Authority & Technical Excellence Plan KSC-KDP-PLN-5400

4.4.4.3.3 **Lessons Learned:** The KSC Engineering Director will continue the Lessons Learned and Knowledge Capture Initiative in conjunction with the SMO. This activity sponsors and facilitates knowledge capture and dissemination across KSC. Engineering will expand its responsibility to include Agency-wide Lessons Learned, where appropriate. The KSC engineering community, including CEs and LDEs, are required to document program/project lessons learned. These items will also be archived and disseminated to the engineering community, including documentation in Agency-wide Lessons Learned, when appropriate.

30/60/90% DESIGN REVIEW ITEMS

Item Number	Work Product	Responsible Party	Required?	Status
1	Team Roster	LD	Mandatory	Updated from 60% DR
2	Concept of Operations	SE	Mandatory	Updated from 60% DR
3	Subsystems Requirements Document (SsRD) 3.1 Context Diagram/Interface Diagram 3.2 Subsystem Description 3.3 Requirements 3.4 Requirements Traceability Matrix (RTM) 3.5 Requirements Verification Matrix (RVM)	SE	Mandatory	Updated from 60% DR
4	Interface Control Document (ICD)	LD	If Applicable	Updated from 60% DR
5	Field Investigations	LD	If Applicable	Updated from 60% DR
6	Trade Study Report	LD	If Applicable	Final
7	Lessons Learned Review	SE/LD/SOE	Mandatory	Updated from 60% DR
8	Detailed Subsystem Schedule	SE	Mandatory	Updated from 60% DR
9	Subsystem Cost Estimate with WBS Identified	LD	Mandatory	Updated from 60% DR
10	Identification of Risks	LD	Mandatory	Updated from 60% DR
11	Plan for Prototype (s)	LD	If Applicable	Updated from 60% DR

Lessons Learned Entry

Lesson Info:
- **Lesson Number:**
- **Lesson Date:**
- **Submitting Organization: KSC**
- **Submitted by: Geoffrey Rowe**

Subject: Clock Timing Circuit For LETF DAQ System

Description of Driving Event:

The new LETF Data Acquisition *(DAQ)* system will have over 100 channels at 3 million samples per second per channel. We have been able to design this system because National Instruments has produced an 8 channel PXIe board that will fit in our budget and be compatible with the LabVIEW development system we have been using at the LETF.

Two Challenges Based On: We need all 100+ channels to be synchronized to each other. The PXIe chassis have a central clock system that can be externally synced to other PXIe chassis very easily *(BNC connector)*. Therefore I assumed the easy synching of multiple PXIe chassis would imply that all the boards in these chassis would be synched.

Challenge #1:

The 8 channel PXIe board we chose for our design did not have a way to synchronize to the PXIe chassis clock (No Phase Lock Loop – PLL - on the board). Therefore this board would require an external clock in order for all the sensors *(such as in a different PXIe chassis)* to be sampled at the same time *(simultaneous sampling)*. We could have brought out a chassis's internal 10 MHz clock and routed it to all the boards using the boards' input terminals.

Challenge #2:

While we could have routed the PXIe chassis 10 MHz clock to all the boards by using a buffered clock from one PXIe chassis, this would not give us the maximum sample rate. The 8 channel board has a maximum sample rate of 3 Msps if we use an external clock that is an integer multiple of 3 MHz. Otherwise, we get a maximum sample rate of 2.5 Msps.

Notes:
1. We also wanted to tie all our sample data to an absolute time stamp. That way we could compare data from different DAQ systems using this absolute time. That would require an event clock that would time stamp when we started to record data (trigger time). We were going to buy an event timer *(trigger time stamp unit)*. It would probably be based on GPS time *(or IRIG-B)*.
2. We would like the sample clock to be locked to absolute time so that long term tests would not see any drift from absolute time. The GPS time units typically have a 10 MHz clock synched to absolute time.
3. It would also be nice to be able to set the data acquisition PCs' internal time to the nearest second.

So in summary, we needed a way to sync all the sample clocks and have a custom sample clock that is at a frequency where we could use the maximum speed on a 8 channel 3 Msps boards.

Solutions:

We found one manufacturer that makes a distributed GPS clock source that has an option for a custom frequency that is locked to GPS time. The unit also time stamps the last 20+ trigger event so that we could use the unit as:
1. 10 MHz clock sample clock, for all other boards, that is locked to GPS absolute time
2. Custom 9 MHz sample clock locked to GPS absolute time (integer multiple of 3 MHz)
3. Time stamp triggers to the nearest 200 nsec (nsec is one billionth of a second).
4. Distribution amplifiers for 10 MHz and custom 9 MHz with star configurations
5. When the Instrumentation Trailer is located where the GPS satellites are not available, we need to continue having a low drift clock source. This unit also has this feature.
6. Compatible Ethernet clock for setting the PCs time *(with another inexpensive hardware converter)*.

Purchase a Spectrum Instruments TM-4D with optional 9 MHz clock output.

Lesson(s) Learned: Look for single unit that can do many functions that seem to be isolated from each other. Do not rely on built-in clocks as the only source for sampling data. Do not assume all boards can sync to the system clock. Avoid KSC IRIG-B time stamping; even of it is already available for free. National Instruments has a clock timing board that fits into the PXIe chassis. But, do not just solve the clock problem when you can also have a custom clock, chassis sync, and time stamps of triggers by using another manufacturer's unit, for the same price.

Recommendation(s): A challenge in one area, can often lead to an even better overall solution than just solving the original challenge. Therefore see problems as challenges that force us to open the search wider than the problem at hand.

LETF LL

Lessons Learned Entry

Lesson Info:

- **Lesson Number:**
- **Lesson Date:**
- **Submitting Organization: KSC**
- **Submitted by: Nikolas Harger**

Subject: Cable Requirements

Description of Driving Event: With the advent of new technology and faster sampling rates the use of certain KSC type cables for instrumentation should be evaluated to ensure proper signal integrity.

Lesson(s) Learned: Previous KSC instrumentation cables at the LETF did not use twisted shielded insolated pairs with an overall shield; this is a necessity for data acquisition.

Recommendation(s): Evaluate all cabling for design meets or exceeds the recommendation of manufacturers of COTS products and industry standards.

LETF LL

Lessons Learned Entry

Lesson Info:

- **Lesson Number:**
- **Lesson Date:**
- **Submitting Organization: KSC**
- **Submitted by: S. Tallutto**

Subject:

Sandblasting and painting using a sub contractor for structural steel towers in the LETF.

Description of Driving Event: Sandblasting and painting using a sub contractor for structural steel towers in the LETF.

- Detailed SOW with exact sizes, lengths, sq ft, etc…
- Multiple walk downs to clarify issues
- Review board for choosing final contractor (score card)
- Factor in 10% contingency for "unforeseen" problems or issues.
- Test paint for Lead and PCB's.
- DO NOT specify blast media size. If you need to use steel grit because of recycling it, let the contractor choose the size of the steel grit.
- Determine EXISTING steel profile, before setting final profiles (1.5 mils – 3.5 mils)
- Things be to onsite:
  - Quality plan, medical records, training records, certifications
  - Contractor trailer/supervisor
  - Full time NACE inspector on site is a must
- Determine final paint – HS-11, etc….
- Obtain notification/details of blast media to ensure blast media is the proper size, style, grade, etc…
- Review NASA spec 5008 in detail, may require deviation in SOW to vary from final profile range of 1.5-3.0mils. (LETF went up to 3.5 mils).
- Application of final coat. LETF used Zinc HS-11 primer only. Paint thickness applied was 4.0-6.0mils thickness. LETF allowed up to 9.99 mils and obtained a 1 yr warranty against cracking, bleeding, chipping, and flaking.
- If lead and or PCB's are in the paint, determine blast media….black beauty, coal slag, steel grit, recycled or not, starblast, etc…
  - If it has PCB's, may have to use steel grit, recycle the blast media and dispose of it in a separate area. Environmental must get involved.
- Determine what class (A, B, C) protection is required…LETF used class A (the highest) due to Lead and PCB's. Full respirators, gear, blowers, fully sealed, tented, wash trailer, etc…
  - Techs required certain training, full face masks, lead blood tests every month, etc…
- Must obtain proper blasting equipment and info:
  - Nozzle diameter (use gauge)
  - Internal hose diameter

Lesson(s) Learned:

1. **Perform multiple walkdowns**
2. **Factor in 10% contingency for unforeseen issues.**
3. **Test old paint for lead and PCBs.**
4. **DO NOT specify blast media, let the contractor determine this.**
5. **Determine existing steel profile prior to starting.**
6. **Review NASA-STD-5008 in detail.**
7. **Steel grit will rust quickly and stain the surrounding area.**
8. **Black Beauty Grit worked best and is cheaper.**
9. **Loose electrical, wiring and cables will be damaged if left unprotected.**

Recommendation(s):

1. **Perform multiple walkdowns**
2. **Factor in 10% contingency for unforeseen issues.**
3. **Test old paint for lead and PCBs.**
4. **DO NOT specify blast media, let the contractor determine this.**
5. **Determine existing steel profile prior to starting.**
6. **Review NASA-STD-5008 in detail.**
7. **Black Beauty Grit worked best and is cheaper.**
8. **Loose electrical, wiring and cables will be damaged if left unprotected. Protect these items prior to sandblasting.**

Records Management

Item	If the records pertain to	and consist of	which are	then the records are
101	programs/projects relating to both manned and unmanned space flight, aerospace technology research, and basic or applied scientific research AND meeting one or more of the following criteria: are "first of a kind,“ establish precedents, produce major contributions to scientific or engineering knowledge, integrate proven technology into new products, or are/have been subject of widespread media attention or Congressional scrutiny. Note 1 Evaluation and termination. Records documenting results of program/project, specific manned or unmanned flight or experiment upon completion: including: Analysis of mission results Final mission or experiment reports Lessons learned studies Mission/experiment reports (preliminary or final Mission failure or accident investigation records Publications and conference proceedings	records essential for understanding the history of a program/project from inception to completion defined by the stages in program/project's life. Note 1 contains a list of eight stages and potential records that might be created in each.	held at office of record	**permanent**. Cut off records at close of program/project or in 3-year blocks for long term programs/projects. Transfer to records center storage. Transfer to National Archives 7 years after cutoff. Special media records will be transferred in accordance with 36 CFR § 1228.270 (electronic records), 36 CFR § 1228.266 (audiovisual records), 36 CFR § 1228.268 (cartographic and architectural records), and/or current transfer instructions specific to individual formats. < N1-255-04-3>
102			all other copies	**temporary**. Destroy/delete when no longer needed. <N1-255-04-3>

Recognizing & Recording

Dissemination & Infusion

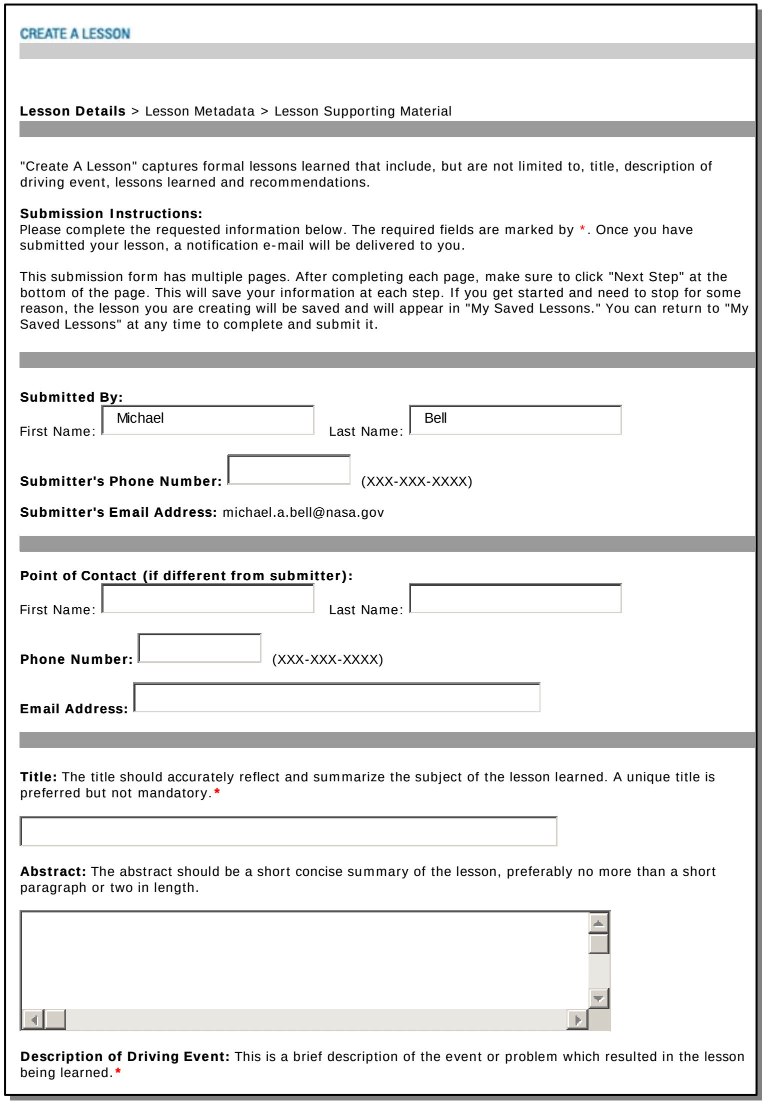
Lessons Sources

Program
Policy directives
Technical standards
Memoranda
Operations sheets
Test methods
Parts alerts
FAR/NFAR
Training
Mentoring
Best practices
Caution & warnings
Storytelling (interviews)
Trade studies
NESC Tech Bulletins

NASA LLIS
Other collections of LL
expert opinion (ppt)
Technical Reviews
Major Milestones
Key Decisions Points
Lifecycle phases
Mishaps
Corrective action systems
Whitepapers
Technical Papers
Prototypes
Source Evaluations Boards
Tech Talks

National Aeronautics and Space Administration
Office of the Chief Engineer

Create a Lesson



CREATE A LESSON

Lesson Details > Lesson Metadata > Lesson Supporting Material

"Create A Lesson" captures formal lessons learned that include, but are not limited to, title, description of driving event, lessons learned and recommendations.

Submission Instructions:
Please complete the requested information below. The required fields are marked by *. Once you have submitted your lesson, a notification e-mail will be delivered to you.

This submission form has multiple pages. After completing each page, make sure to click "Next Step" at the bottom of the page. This will save your information at each step. If you get started and need to stop for some reason, the lesson you are creating will be saved and will appear in "My Saved Lessons." You can return to "My Saved Lessons" at any time to complete and submit it.

Submitted By:
First Name: Michael Last Name: Bell

Submitter's Phone Number: (XXX-XXX-XXXX)

Submitter's Email Address: michael.a.bell@nasa.gov

Point of Contact (if different from submitter):
First Name: Last Name:

Phone Number: (XXX-XXX-XXXX)

Email Address:

Title: The title should accurately reflect and summarize the subject of the lesson learned. A unique title is preferred but not mandatory.*

Abstract: The abstract should be a short concise summary of the lesson, preferably no more than a short paragraph or two in length.

Description of Driving Event: This is a brief description of the event or problem which resulted in the lesson being learned.*

Significant Events that change Policy, Standards or Procedures

Share Existing Lesson

Jet Plume Simulation

Abstract:

Plume simulation used during the preflight wind tunnel test program was not adequately implemented. Temperature effects were not modeled in cold jet plume simulation parameters used during testing

Description of event:

Plume simulation used during the preflight wind tunnel test program was not adequately implemented.

– **Observed significant wing lift and vehicle lofting in STS-1**

- **Measured strains showed negative structural margins**
- **Under-predicted ascent base pressures (base drag over-predicted)**

– **Temperature effects were not modeled in cold jet plume simulation parameters used during testing**

LESSON: Although the hot plume re-circulation effect is less significant on an axis-symmetric vehicle, it should be accounted for when defining pressure on the base and aft portion of the vehicle

Recommendations:

Corrective Actions

The Post-flight tests using hot plume simulations improved base and fore body pressure predictions.

The ascent trajectory was changed to a flight with a greater negative angle of attack through High Q

a. **The negative angle reduced wing lift**

b. **The negative angle had to be evaluated for Orbiter windows and**

the ET side wall pressures

Other topics: ascent aerodynamics

SHARE EXISTING LESSON

Lesson Details

Use "Share Existing Lesson" feature to share lessons formatted in existing report, analysis, presentation, or video during the course of conducting NASA business. These lessons may not necessarily delineate recommendations. ITAR or controlled information is not appropriate for this feature. "Share Existing Lesson" is moderated.

Submission Instructions
Please complete the requested information below. The required fields are marked by *. Once you have submitted the lesson, a notification e-mail will be delivered to you.

***Submitted By:**
First Name: Michael   Last Name: Bell

Submitter's Phone Number: (XXX-XXX-XXXX)

Submitter's Email Address: michael.a.bell@nasa.gov

***Point of Contact:**
First Name: Last Name:

Phone Number: (XXX-XXX-XXXX)

Email Address:

***Title:** The title should accurately reflect and summarize the subject of the lesson learned. A unique title is preferred but not mandatory.

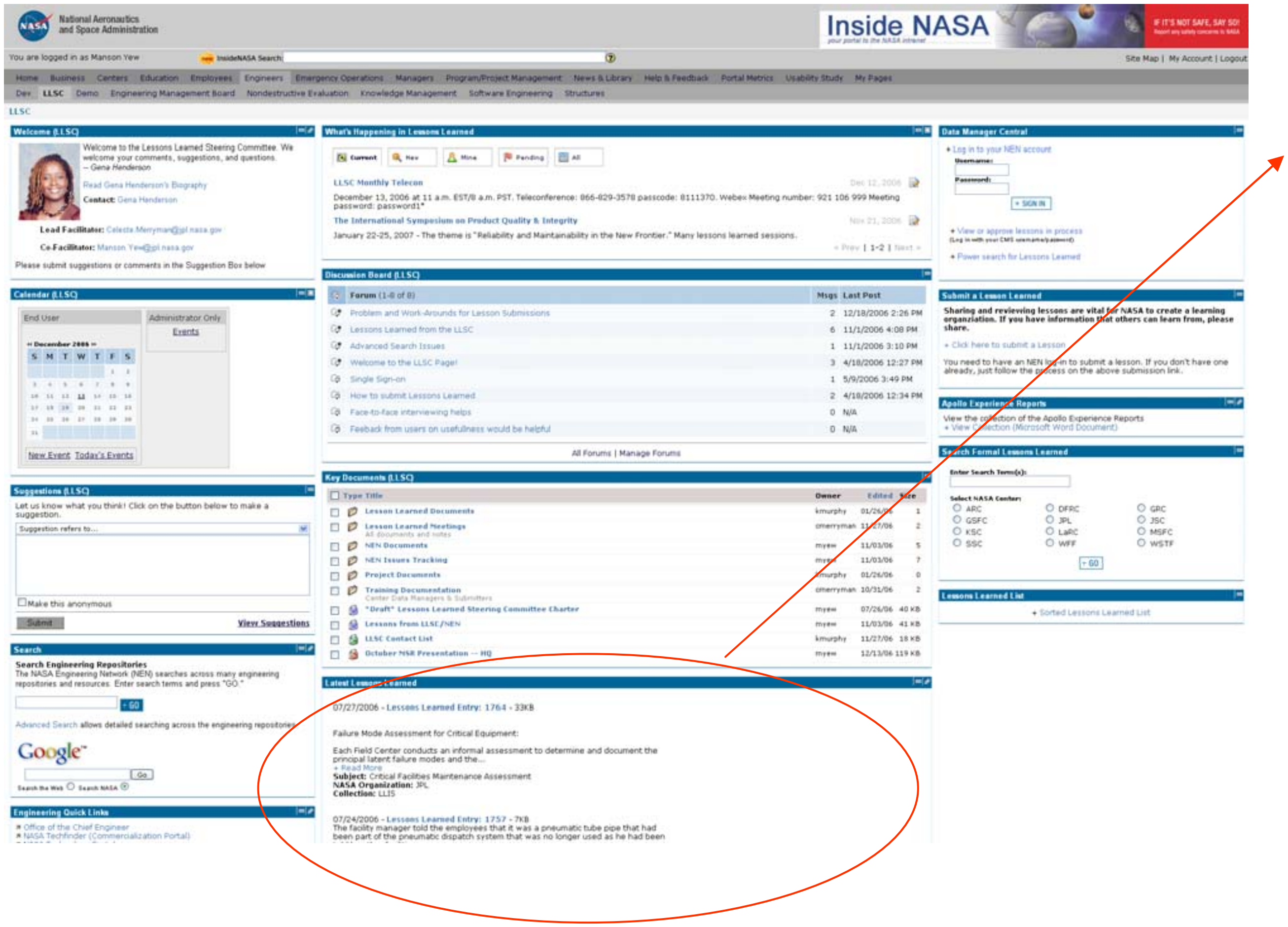
***Abstract:** The abstract should be a short concise summary of the lesson, preferably no more than a short paragraph or two in length.

***Supporting Documentation:**

(Click "Browse" to find on your local system the file you wish to upload.
The size of the file should be **less than 100 MB**. The file name should not contain spaces or any of \, |, ^, :, ", %, /, >, <, ?, * characters.)

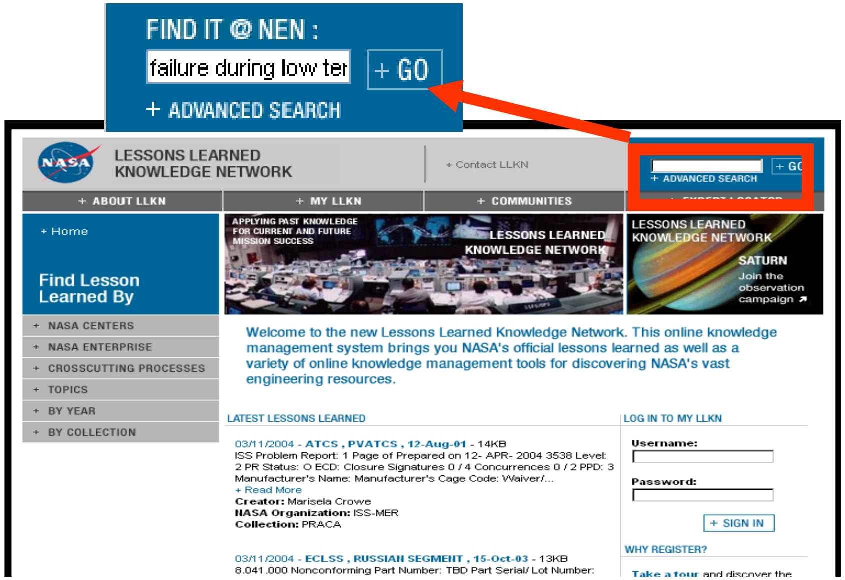
***Organization:**
NASA --- Center: Select NASA Field Center

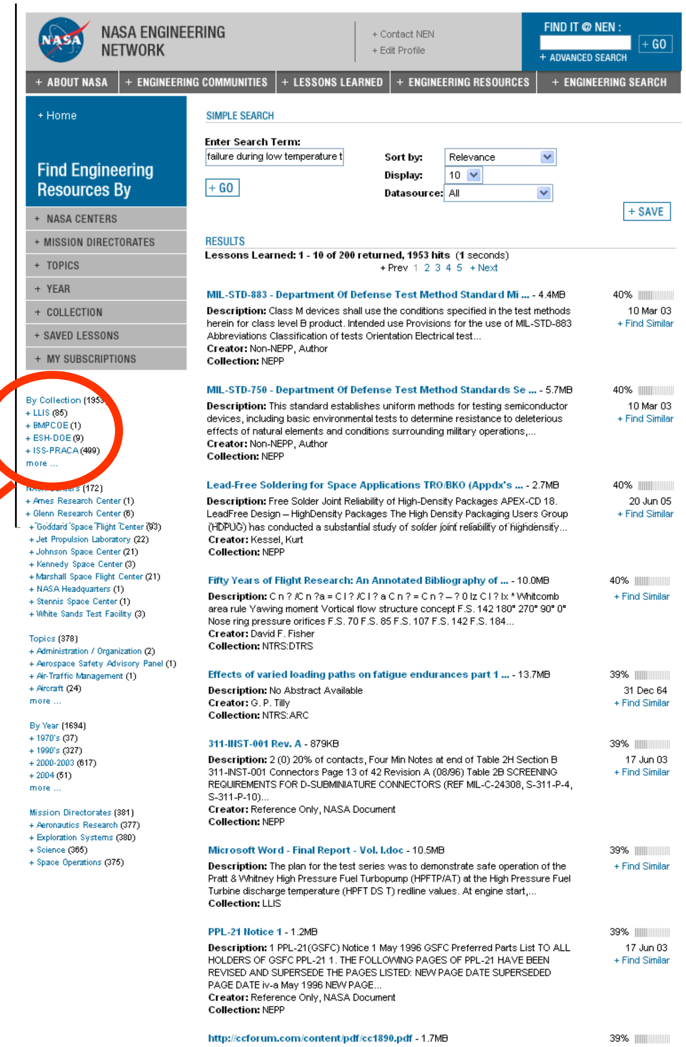
Disseminating Lessons and Best Practices



Push relevant lessons learned to communities

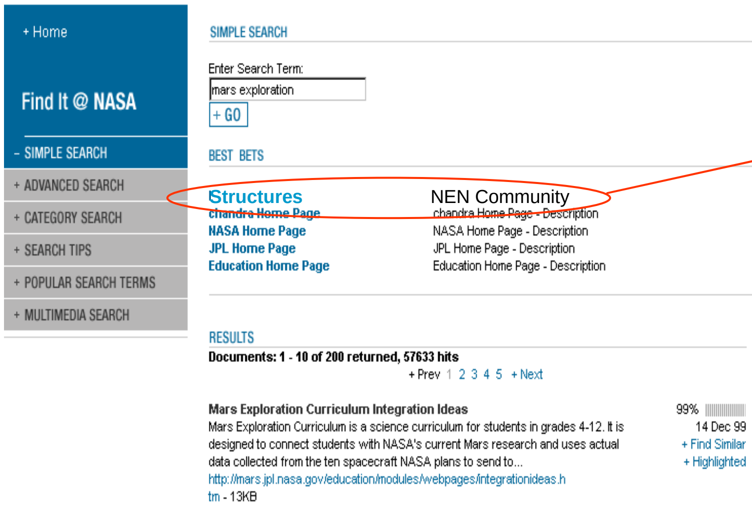
Finding Solutions

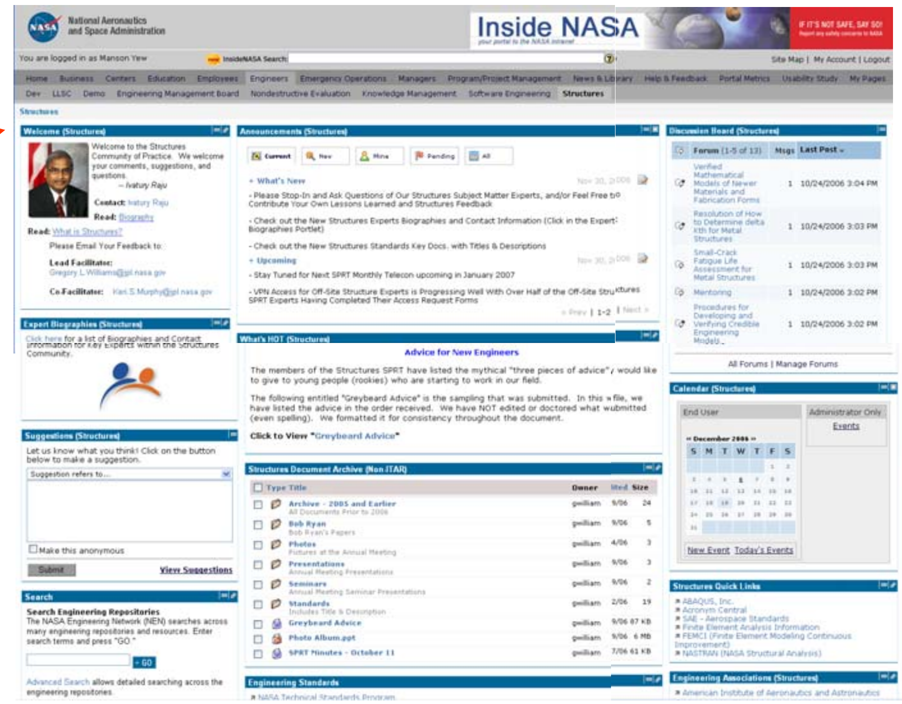




Search across multiple repositories.
Faceted navigation
to drill down into results

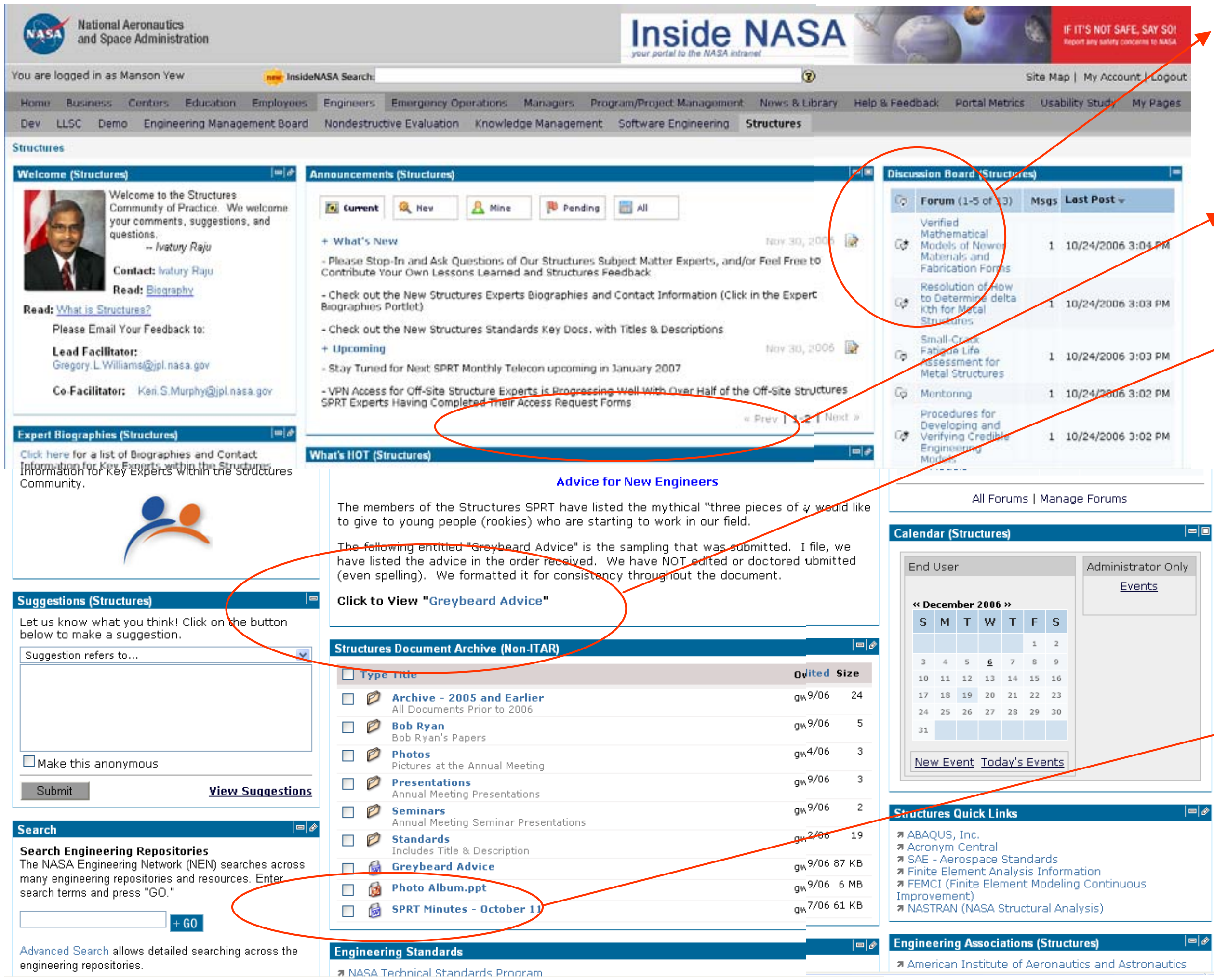
Finding Solutions (cont.)





NEN searches may lead to community of expert practitioners

Disseminating Lessons and Best Practices



Discussions on key topic areas

Greybeards' advice

Key community documents

Engineering standards

Infusion

From: David Oberhettinger [mailto:David.J.Oberhettinger@jpl.nasa.gov]
Sent: Wednesday, August 01, 2007 5:54 PM
To: Heng
Cc: Henderson, Gena M. (KSC)
Subject: Two Added LLs

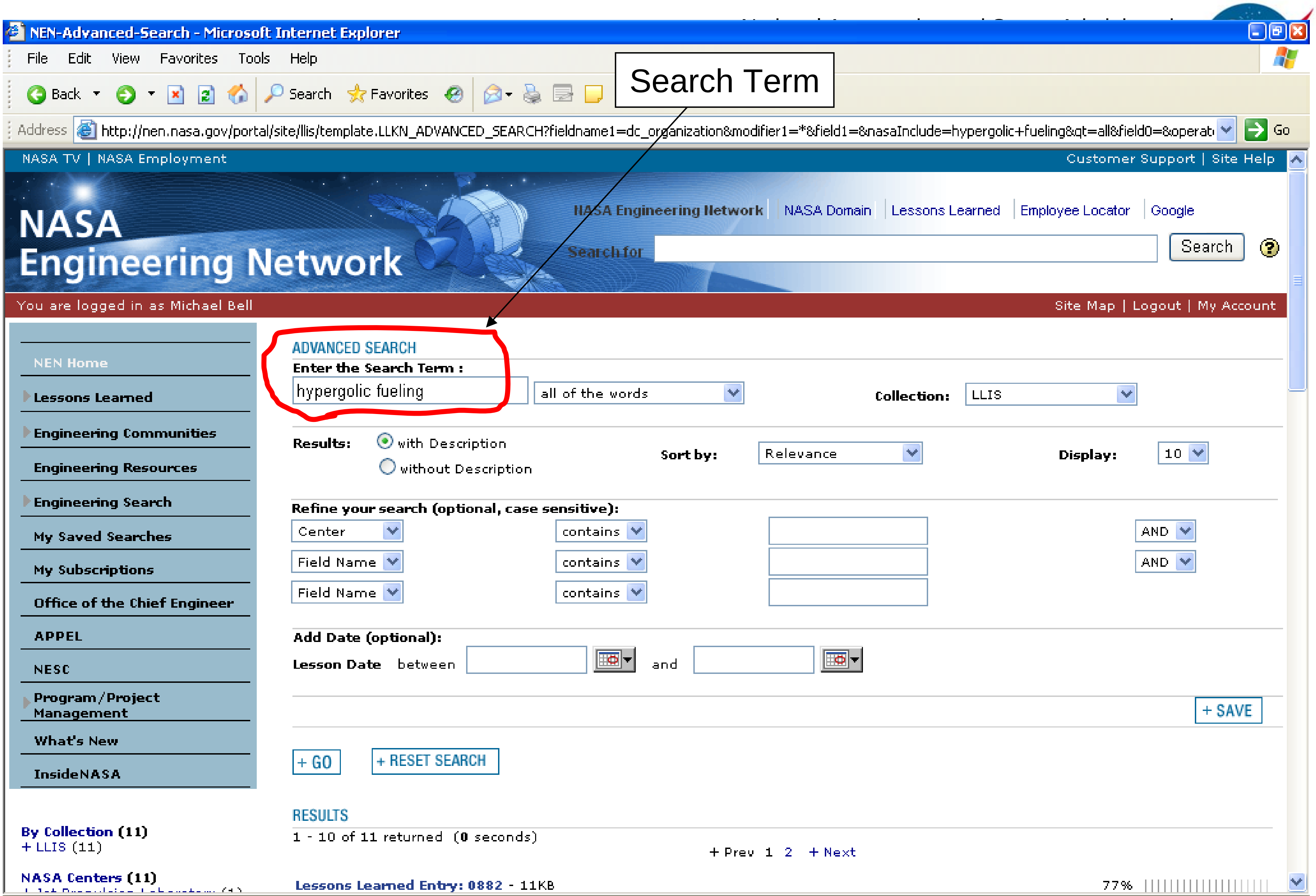
Jake:

I added a new KSC and a new JSC lesson learned to the cross-reference for JPL cross-referencing/infusion — in the first two rows under the FPP tab. Thank you.

I've also sent a copy of each lesson to the respective JPL subject matter expert.

The Centers are generating some useful and well-written lessons. Dryden had a well-written one too, though it's a topic not that critical to our ops.

David


Search Term
NEN-Advanced-Search - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://nen.nasa.gov/portal/site/llis/template.LLKN_ADVANCED_SEARCH?fieldname1=dc_organization&modifier1=*&field1=&nasaInclude=hypergolic+fueling&qt=all&field0=&operat
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all of the words
Collection: LLIS
Results: with Description
without Description
Sort by: Relevance
Display: 10
Refine your search (optional, case sensitive):
Center contains AND
Field Name contains AND
Field Name contains
Add Date (optional):
Lesson Date between and
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+ GO
+ RESET SEARCH
RESULTS
1 - 10 of 11 returned (0 seconds)
+ Prev 1 2 + Next
Lessons Learned Entry: 0882 - 11KB
77%

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Address http://nen.nasa.gov/portal/site/llis/template.LLKN_ADVANCED_SEARCH?fieldname1=dc_organization&modifier1=*&field1=&nasaInclude=hypergolic+fueling&qt=all&field0=&operat

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+ Cryogenic Systems (1)
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+ Facilities (1)
more ...

By Year (11)
+ 1990's (6)
+ 2000-2003 (5)

Mission Directorates (11)
+ Aeronautics Research (7)
+ Exploration Systems (10)
+ Science (2)
+ Space Operations (6)

+ GO   + RESET SEARCH

RESULTS

1 - 10 of 11 returned (**0.04** seconds)

+ Prev 1 2 + Next

Lessons Learned Entry: 0882 - 11KB — 77% — 01 Dec 94 — + Find Similar + Highlighted

Description: This practice identifies the use of a laser alignment system for installation of machinery with rotating shafts (i.e., pumps, motors) to obtain optimum alignment coupling, resulting in less wear and increased reliability. The...
Creator: Wilson Harkins
Subject: Computer-Aided Laser Shaft Alignment of Rotating Machinery
NASA Organization: KSC
Collection: LLIS

Lessons Learned Entry: 0752 - 12KB — 30% — 01 Feb 99 — + Find Similar + Highlighted

Description: Ball type check valves are suitable for smaller applications, while poppet type valves are more appropriate for large flows, such as in the Space Shuttle Main Engine (SSME) application shown on Figure 1. Internal check valve...
Creator: Wil Harkins
Subject: Check Valve Reliability in Aerospace Applications
NASA Organization: MSFC
Collection: LLIS

Lessons Learned Entry: 0485 - 6KB — 30% — 12 Dec 96 — + Find Similar + Highlighted

Description: The "most probable cause" of the Mars Observer mission failure was identified as migration of substantial amounts of nitrogen tetroxide oxidizer upstream through the check valves where it condensed on the cold...
Creator: C. Guernsey
Subject: Isolate the Propulsion Pressurization System from the Propellant Tanks (1993)
NASA Organization: JPL
Collection: LLIS

Lessons Learned Entry: 0094 - 3KB — 30% — 30 Jul 92 — + Find Similar + Highlighted

Description: During removal of the purge adapter from thruster R4D, liquid MMH was observed leaking from the thruster nozzle. Failure to require a specific hose route resulted in a liquid trap being inadvertently formed causing liquid MMH to...
Creator: David Pennington
Subject: Thruster Purge Operations
NASA Organization: KSC
Collection: LLIS

Lessons Learned Entry: 0057 - 5KB — 30%

Done, but with errors on page. Trusted sites

Lessons Learned Entry: 0094

Lesson Info:

- **Lesson Number:** 0094
- **Lesson Date:** 1992-07-30
- **Submitting Organization:** KSC
- **Submitted by:** David Pennington

Subject:

Thruster Purge Operations

Description of Driving Event:

During removal of the purge adapter from thruster R4D, liquid MMH was observed leaking from the thruster nozzle. When the leak was discovered the OPF high bay hypergolic exhaust fans were actuated, the high bay evacuated, and fire and medical support were requested to stand by. The leaking MMH was caused by a liquid trap present in the fuel suction hose. The trap was formed by excessive hose length, which was routed to the next level above, then down to the purge adapter. The routing and hose length was left over from a previous operation on the left side of the orbiter.

Lesson(s) Learned:

Failure to require a specific hose route resulted in a liquid trap being inadvertently formed causing liquid MMH to leak from a thruster nozzle.

Recommendation(s):

Update operational procedures to include a requirement to ensure proper hose configuration and routing prior to beginning purge operations

Infusion

Date: Tuesday, August 30, 2005

To: 'huu.p.trinh@nasa.gov'; 'jwaller@wstf.nasa.gov'; 'carl.s.guernsey@jpl.nasa.gov'; 'John.Mcgee1@jsc.nasa.gov'

From: Goodin, Ronald J

Cc: Gillett, Ronald R; Hall, Roger D; Bell, Michael A; Kirkpatrick, Paul D; Frazier, Wayne

Subject: Hypergolic lessons learned

All,

I am conducting research for Exploration planning hypergolic fueling options at KSC. The Agency Lessons Learned database was queried and all of you had generated excellent lessons. It may seem that a lot of work went into generating lessons and submitting them into what may appear a black hole, so I wanted you all to know that your lessons are being put to good use.

Thanks,

Ronnie Goodin
KSC S&MA

Newly published lessons subscriptions

Category: **Mission Directorates/Exploration Systems**
Document: **Mars Exploration Rover Project: Stealing Success From the Jaws of Failure (Lessons Learned Entry: 1797)**
Document: **Design and Analysis of Electronic Circuits for Worst Case Environments and Part Variations (Lessons Learned Entry: 1804)**

Category: **Mission Directorates/Space Operations**
Document: **CSAM Augments X-Ray Inspection of Die Attach (MRO Ka-Band Anomaly) (Lessons Learned Entry: 1803)**
Document: **Mars Global Surveyor (MGS) Spacecraft Loss of Contact (Lessons Learned Entry: 1805)**

- Category: **NASA Centers/Kennedy Space Center**
  Document: **Human Factors Engineering; Acceptance, Implementation, and Verification as a System (Lessons Learned Entry: 1801)**

  Category: **Mission Directorates/Exploration Systems**
  Document: **NASA Mishap Investigation Report Review, application to LRO and LCROSS (Lessons Learned Entry: 1795)**

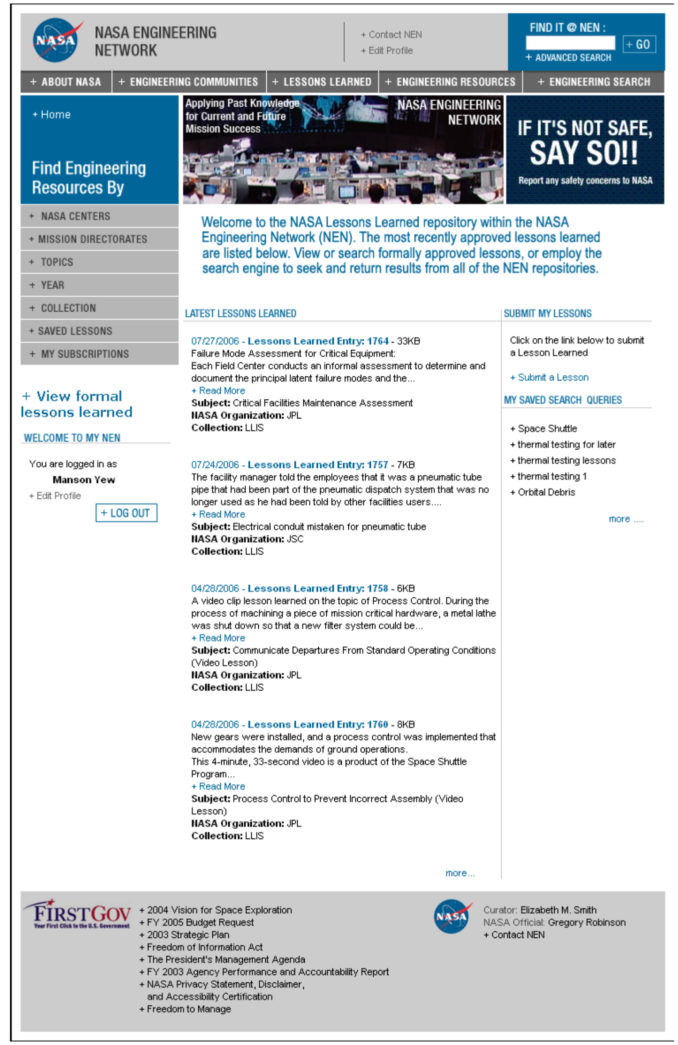
  Category: **Mission Directorates/Aeronautics Research**
  Document: **Verify the Proper Performance of Critical Backups (Lessons Learned Entry: 1781)**

  Category: **Mission Directorates/Space Operations**
  Document: **How to Plan and Manage Project Reserves (Lessons Learned Entry: 1780)**
  Document: **Erroneous Onboard Status Reporting Disabled IMAGE's Radio (Lessons Learned Entry: 1799)**

Lessons Learned Success Stories

Lessons Learned Success Stories

- **Apollo Lunar Module**
- **Shuttle Integration**



Success Story: Apollo LM

Description of Driving Event:

- As part of the Constellation Program's review of human spaceflight lessons learned, NASA hosted a July 20, 2007 panel discussion with a group of engineers who were members of the Apollo Lunar Module Reliability and Maintainability (R&M) Team. The team members are retired employees of Grumman Corporation, the prime contractor for the Lunar Module (LM). One set of lessons learned that was discussed focused on the Apollo approach to reliability engineering (Reference (1)):
- The Apollo approach of shared NASA/contractor responsibility for achieving LM reliability (Reference (2)) strengthened efforts to incorporate reliability features into the design. As indicated by Figure 1, reliability was infused into the design relatively early in the project life cycle, with part of the achieved reliability captured by design requirements by the release date of the NASA Request for Proposal (RFP). Because NASA issued a brief RFP that stated only functional requirements, it provided Grumman with substantial freedom to make LM design tradeoffs. Had NASA allowed discipline experts to impose detailed design requirements in the RFP without a full understanding of system-level impacts, some requirements might have detracted from mission success and crew safety.

Success Story: Apollo LM

Lesson(s) Learned:

The Constellation lunar lander program faces challenges similar to those faced by the Apollo program 45 years ago in terms of achieving reliability and mitigating crew safety-critical and mission-critical risks.

Recommendations:

- Lock system reliability into the early design such that the test program is relied upon for screening and verification.
- Evaluate design alternatives and conduct trade studies at the system level to obtain an optimal overall design.
- Provide a primary and a redundant backup where feasible, preferably by dissimilar means, for safety-critical and mission-critical systems.
- To accommodate future LM design changes and unanticipated flight configurations, test critical hardware beyond its qualification test levels to failure.
- Actively manage performance margins so that the design margin can be allocated optimally.
- To achieve lunar lander reliability under the Constellation program, provide a strong Lander advocate during the design of the Crew Exploration Vehicle (CEV).

Significance of Shuttle Lessons Learned

Applicability to Ares I (Less 1 → Greater 5)	1	2	3	4	5
5			2-Fault Tolerant Avionics Risk Management	Margin Mgmt. Instrumentation RGAs in GVT	SRB IOP Ops Cost Drivers
4		S/W Verification Facilities	Lightening Slosh Baffles	Liftoff Loads GVT DOLILU	Engine Inlet Screens STA as Flight Article
3			Flex Modes Effects on FCS	Buffet Software Reliability	Ascent Aero Anomaly MPS Pressure Oscillations
2			RCS Seat Extrusion	RCS Combustion Instability RCS Inter-granular Cracking	
1				Flex Hoses	

Less → Greater

Significance to Shuttle

Risk of Crew/Vehicle Loss

Risk to Cost/Schedule

Ground Vibration Test

Description of Event

- **Carefully developed Ground Vibration Test (GVT) program identified and facilitated correction of math model errors and precluded critical problems in-flight and potentially costly hardware redesign**
  - **Disciplines benefiting from GVT included Loads, POGO, Flutter & Flight Control Analyses**
- **Building Block Approach**
  - **Starting with element GVT**
  - **Ending with full scale mated test at MSFC**
  - **¼ Scale Model GVT followed by full scale GVT**
- **The stiffening effects of the internal SRB chamber pressure were evaluated in a ¼ scale GVT**
- **Element GVTs**
  - **SRB – L/O & Boost Phase, & Burnout**
  - **ET with various liquid levels**
  - **Orbiter FREE-FREE & constrained at ET interface**
- **Mated GVTs**
  - **Orbiter/ET – Boost Phase**
  - **4 Body mated, L/O, High Q, & SRB Burnout**

Ground Vibration Test (cont'd)

Lessons Learned

- **Extensive investment into the Shuttle GVT Program can save money on Ares I**
  - **Dynamic Characteristics of SRB Verified including:**
- **Liftoff, High Q and burnout configurations**
- **SRB/MLP Interface**
- **Dynamic response at rate gyro locations**
- **Dynamic interaction of SRB structure with visco-elastic propellant**
- **The effect of chamber pressure of the SRB dynamic properties**
- **Upper stage alone in Free-Free and constrained at SRB interface configurations could be a sufficient and cost effective GVT for Ares I**

Conversion of Static Test Article (STA) to the Flight Orbiter

Description of Event

- **The Orbiter STA was originally intended for Orbiter structure strength demonstrations**
  - **Planned to be subjected to ultimate loads**
  - **Demonstration of 1.4 times limit load**
  - **Very difficult to simulate combined thermal and mechanical loads**
- **Prior to test start, the decision was made to limit loading to “limit plus” load level**
  - **Test article was not stressed beyond yield**
  - **This test was supplemented by component testing to 1.4 times limit loads in areas of low margin and sensitive joints**
  - **The Orbiter test article was treated as flight hardware (configuration management, problem dispositions)**
- **Post test, the STA was converted to flight hardware and used as the Challenger’s airframe**

Lessons Learned

Thoughtful planning of the test hardware and transitioning it to “flight status” could result in significant cost savings

TAKE AWAYS

- Sharing Knowledge and Learning is important to the center and the Agency and needs resources as well as constant attention—Trust
- Center points of contact must have passion and must be resilient—we need participants and not presence
- Knowledge sharing and learning will not work unless it is believed to be important at the highest levels—Walk the talk and Accountability
- Knowledge is just that until it is integrated, with context, into design/flight rules, policy, standards and then trained, communicated, and practiced across the workforce
- There are no silver bullets--no quick fixes. There are a lot of opinions and they are generally all good and worthy of consideration (Knowledge that is "Not Invented Here" has no place in a learning organization)
- Massive amounts of lessons and knowledge exist at each of our centers, platforms to communicate the lessons and knowledge exist as well. The challenge is to pull it all together, make it easy to access, raise the awareness and then make it beneficial enough for the workforce to take the time to seek the knowledge
- Agency policy is required to provide a minimum amount of guidance and structure and centers need to meet the intent—however centers need to maintain unique identity

LLIS/NEN Demonstration

http://llis.nasa.gov

Q & A