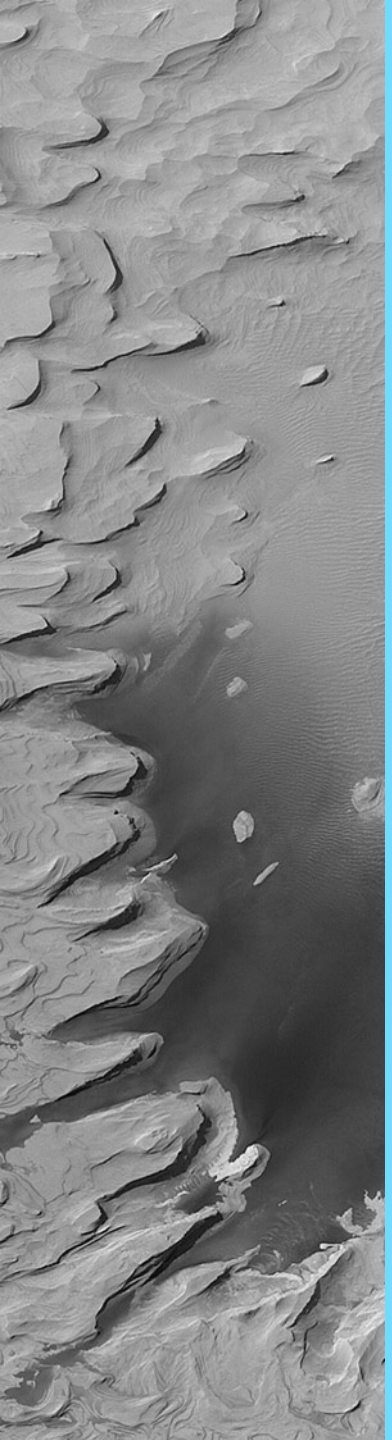

Mars Science Laboratory Quality Assurance Lessons Learned

(along with a few secrets to success…)

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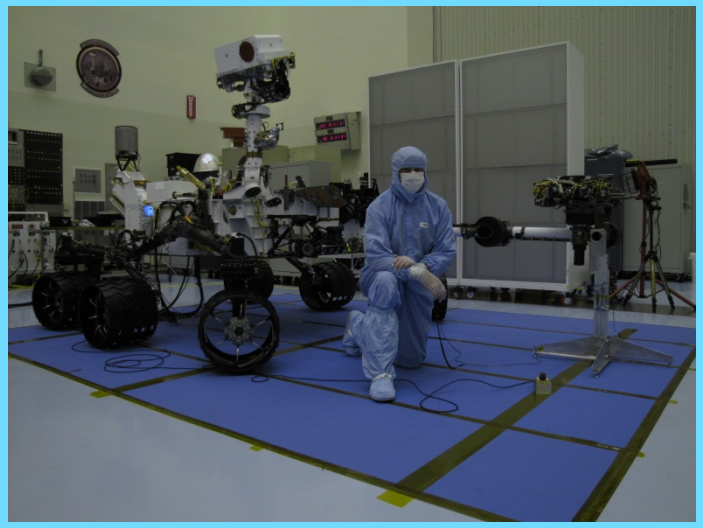
MSL HQA Manager
Jet Propulsion Laboratory
California Institute of Technology

March 22, 2012

Lessons Learned

- Following is a compilation of lessons learned that I gathered from my own experiences and those of the MSL Project QA Team

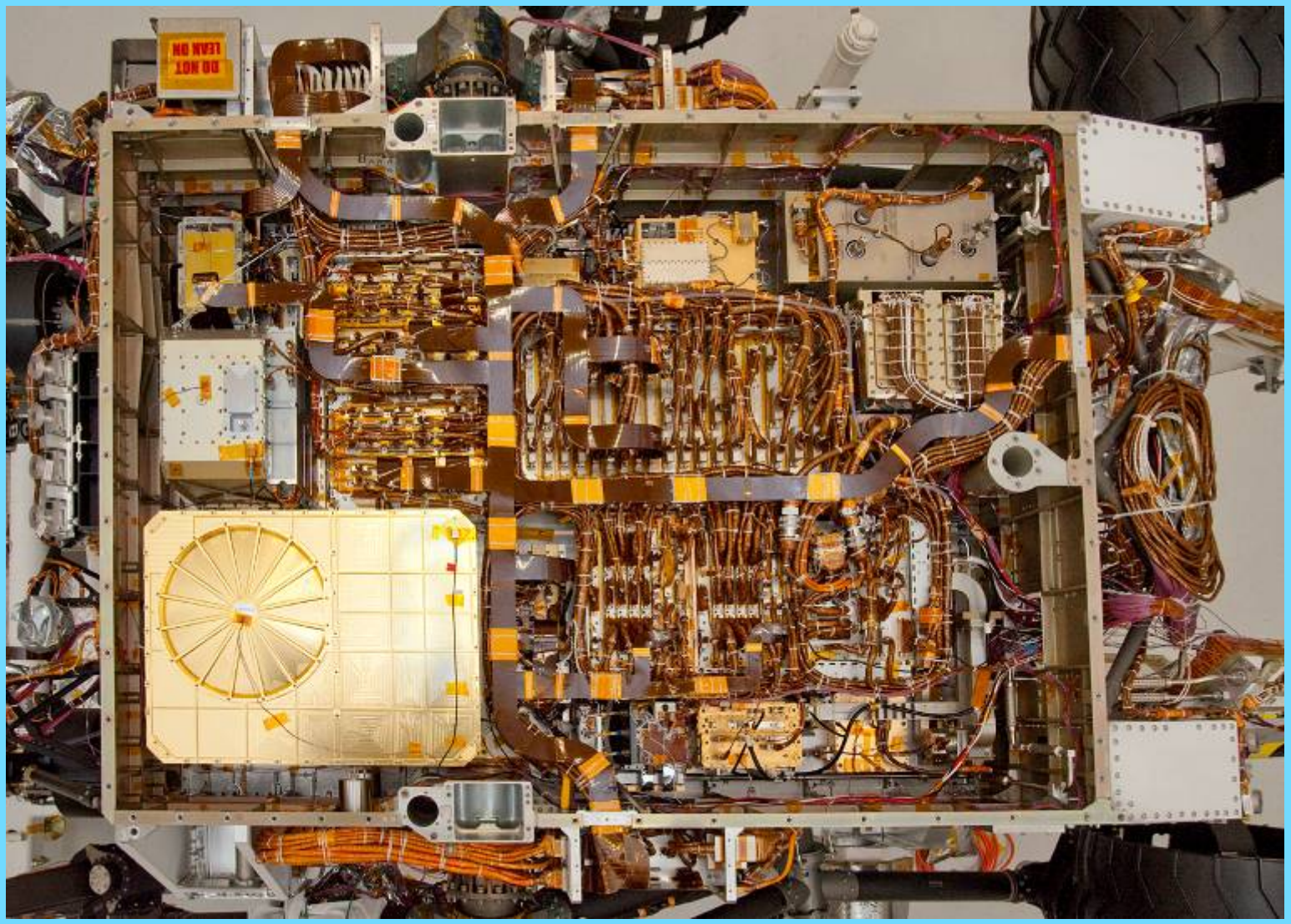
- These lessons can be traced to two fundamental principles of quality assurance in this business:
  - Traceability
  - Accountability



MSL Summary

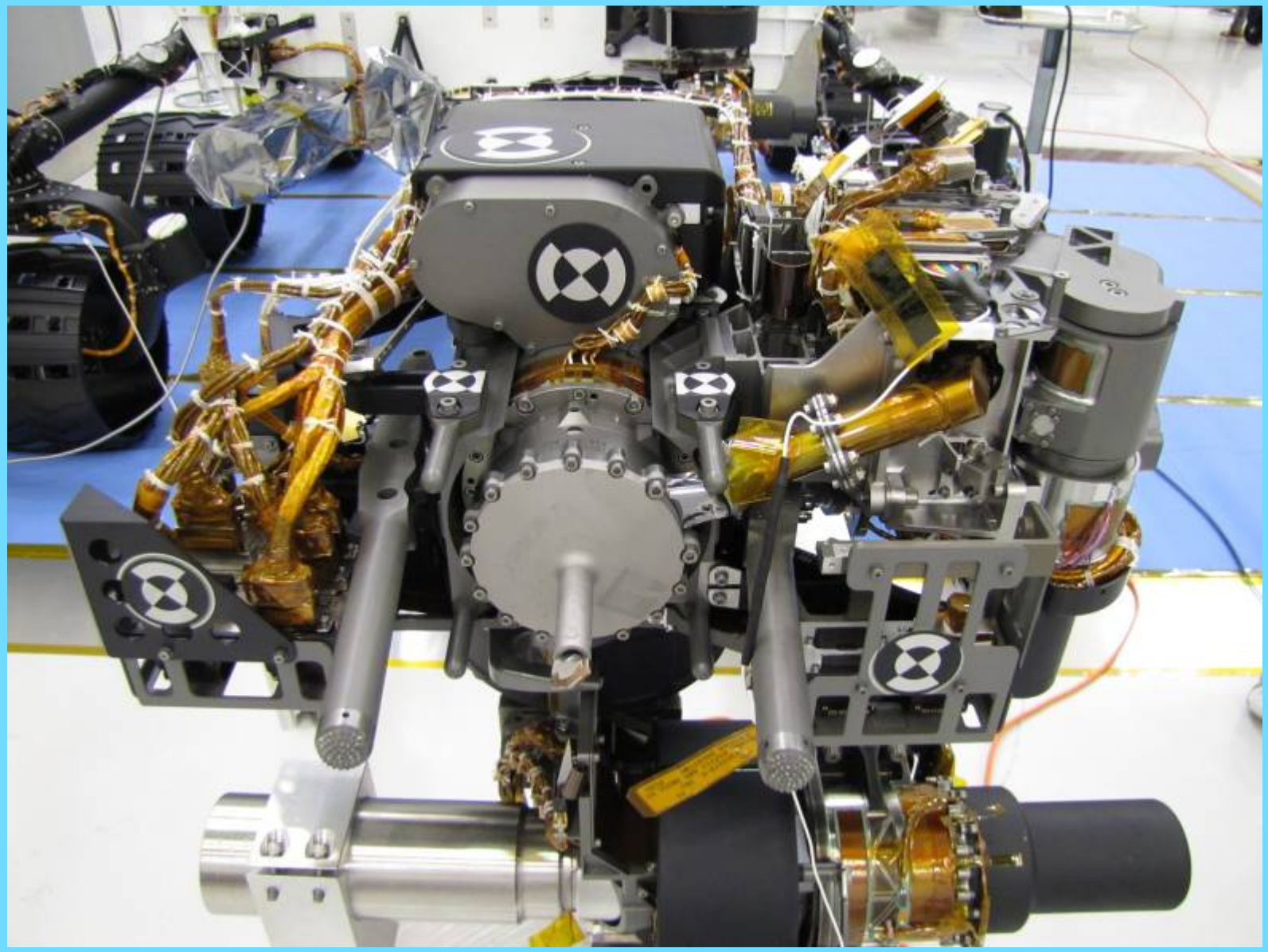
- The Mars Science Laboratory Project presented multiple challenges of complexity for hardware and software QA personnel
- Technical complexity was a major challenge
- This is a one-of-kind never-before-been-built Spacecraft with a nuclear-powered Rover
- It features a never-before-been-used “Skycrane” landing system featuring a Descent Stage which is a complex spacecraft within itself
- Equally complex was figuring out how to support multiple activities at multiple facilities in this country and around the world at the same time

Rover Chassis Internal - Complexity



There were over 11,500 connector mates and demates during MSL System I & T

SA/SPaH Turret - Complexity



GSFC-Provided SAM Instrument – Complexity

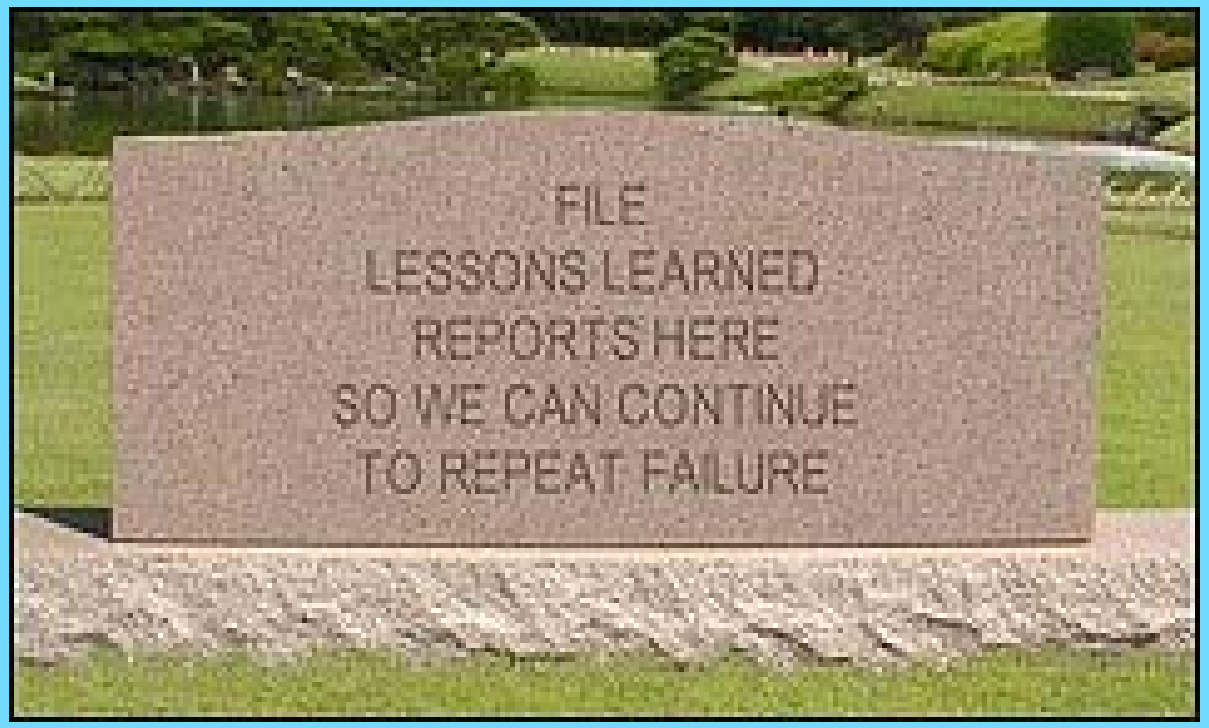
Lessons Learned

→ The smart infusion of Lessons Learned has become a key factor in managing a successful spacecraft development program

→ **Take full advantage of the multitude of information available about past lessons learned in this business**

Past Lessons Learned Reports

Don’t Let this Happen!

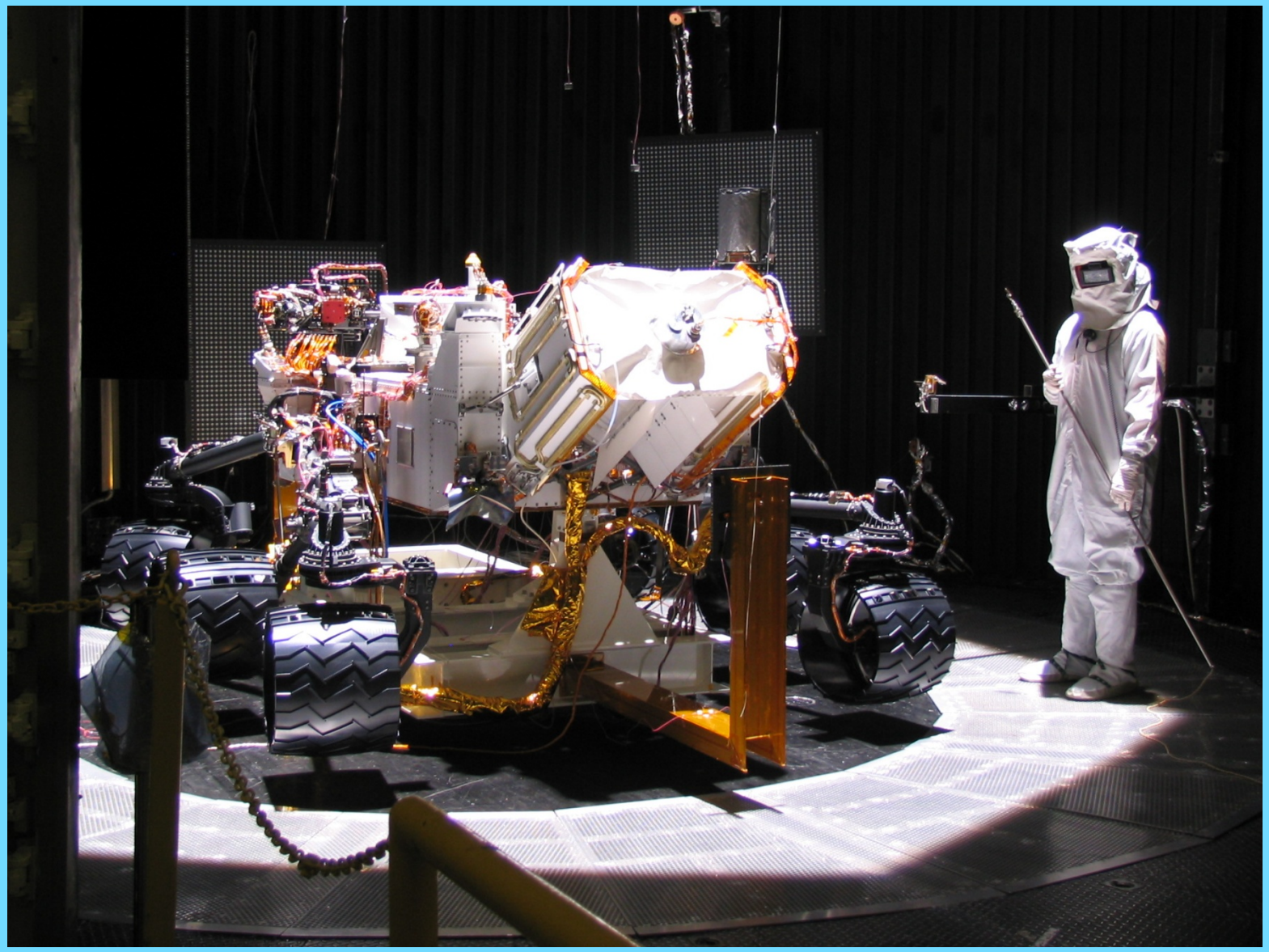


Lessons Learned….Which One?

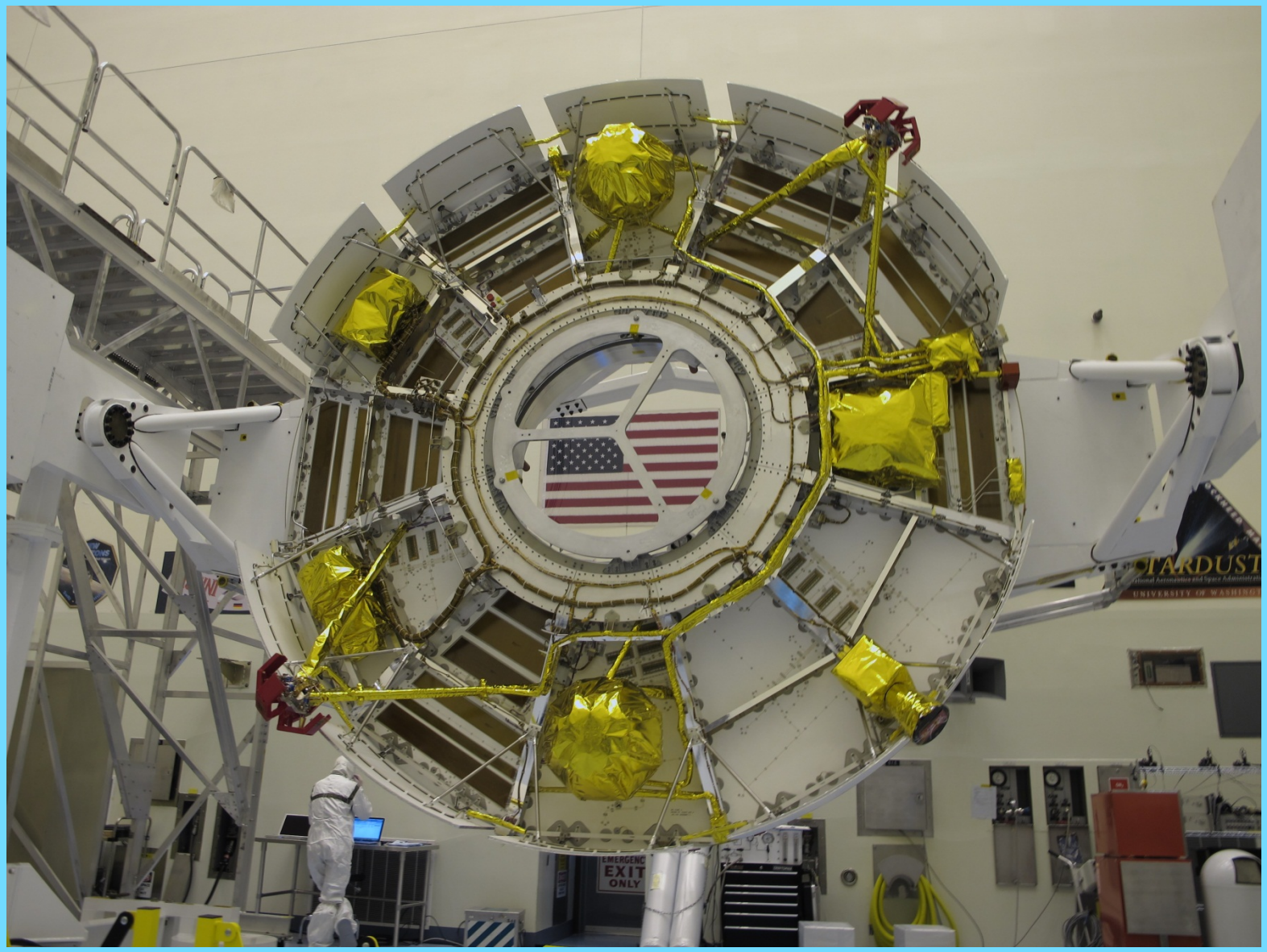
What we teach someone….

→ ***Is different than what they may learn!***

MSL Photos – Rover in Thermal Chamber



MSL Photos – Cruise Stage



MSL QA Lessons Learned Topics

- Early Project Involvement
- Planning QA Coverage/Managing Resources
- GSE Cables
- ESD Controls
- Powered-On and Powered-Off Test Operations
- Software QA
- Critical Hardware Handling and Transportation
- Launch Site
- Generating Lessons Learned
- Conclusions

MSL QA Lesson #1

- "Early Project Involvement"
  - **QA Needs to Get Involved With the Project Early-On With the "End-Game Deliveries" in mind right away**
- "Implementing Quality Early-On for the MSL Project"
  - Presented at QLF on 9/27/2006 by Paynter
- Get to know your QA counterparts at:
  - Your sub-tier suppliers
  - Your industry partners
  - Your international partners
  - All flight hardware providers
- ***Hit the road! Visit*** your Suppliers if you can early-on
- It makes a positive difference when you can meet face-to-face

MSL QA Lesson #1(*cont*)

- Give a presentation to your hardware suppliers/providers about the Project's objectives
- People appreciate the "big-picture"
- They take more ownership in a product when they understand how and where they "fit" into the "big-picture"
- Make them understand how they can significantly contribute to mission success
  - This goes for your sub-tier suppliers as well as your employees *in-house*
- There is something about "QA-Speak" between QA-counterparts that helps a lot during the course of hardware developments with external suppliers
- This really pays-off at the time of the end-game delivery!!

MSL QA Lesson #2

- "Planning QA Coverage"
  - **It is essential for QA to stay "one-step ahead" of the hardware activities so that proper QA-coverage can be planned and provided**
- It is ***vital*** to deploy your QA-resources in a timely manner
- In some cases, the work will go on if QA is not available to support it
- Since QA is a "Service Organization," we need to be proactive to stay informed so that we can be at the right place at the right time!
- Communicate and share information regularly
- A little bit of extra effort can go a long way!

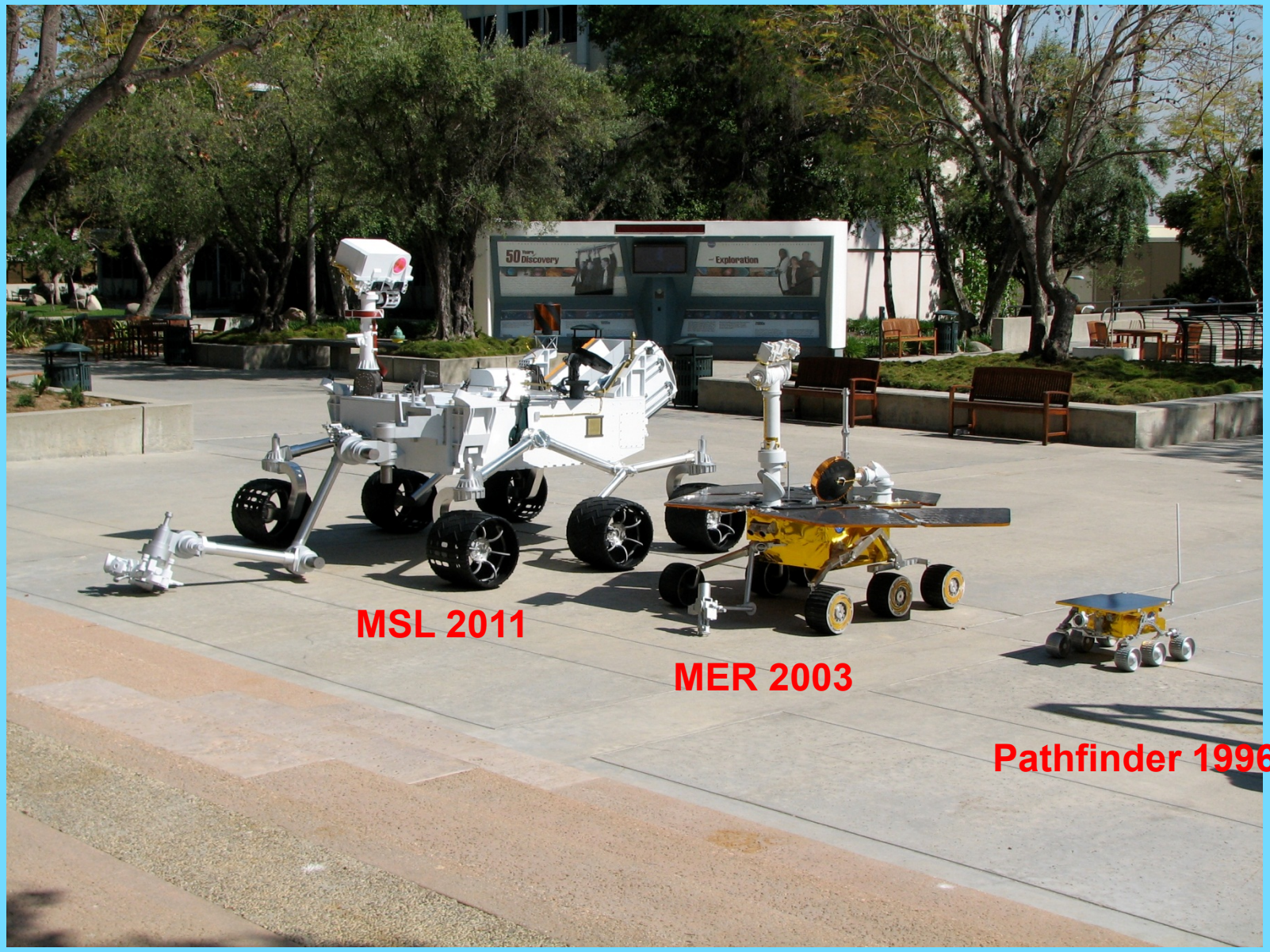
MSL QA Lesson #2 (cont)

- "Managing Resources"
  - **QA Managers and Leads Need to Strategically Match Their Engineers and Inspectors with the Job and the Customer**
- First and foremost, it is important to deploy your QA-resources in accordance with the skill-set needed to perform the work
- But in some cases, it is also important to deploy your resources so that you do not get "*personality conflicts*" which may adversely affect the work (*and your mental well-being!*)
- One strategic match that paid-off was matching experienced QAE's with inexperienced Engineers

MSL QA Lesson #3

- "Ground Support Equipment (GSE) Cables"
  - **One bad GSE Cable can ruin your whole day!!**
- I have experienced many problems in this area
- For some reason, people get this false sense of security because a piece of hardware (GSE) is "Non-Flight"
- This piece of "Non-Flight" hardware can cause severe damage to flight electronics
- This is what happened on MER when several motor encoder channels were damaged because of a bad GSE Cable
- Don't let it happen! Ensure that you implement an effective inspection program ***for all GSE Cables***

Mars Rover Comparison



MSL QA Lesson #4

- "ESD Controls"
  - **You can never relax when it comes to implementing strong ESD Controls**
- At JPL, we were used to handling ESD-sensitive devices with a HBM-sensitivity of < 200 Volts
- However, MSL presented new challenges with many ESD-sensitive components with sensitivities of < 50 volts or less
- Extra precautions, including extra training and the frequent use of air ionizers, had to be taken
- But the secret to the success of the implementation was that ***we educated everyone early and often*** such that these new practices became "routine"

MSL QA Lesson #5

- "Powered-On and Powered-Off Test Operations"
- **Implement a QA check-point in your test procedures to verify all equipment is *powered-off* as intended**
- We have always been used to verifying configurations are ready for powered-on testing and there have been lessons learned written to that effect
- But this is the first time that I have experienced a lesson learned in which we had hardware damaged because of a failure to power-off GSE equipment
- The flight hardware was powered-off but the GSE heater element was not
- This resulted in the overheating of the working fluid that damaged an accumulator in a pump assembly

MSL QA Lesson #5A

- "Buck Crenshaw"

- **Be prepared to have to deal with a myriad of issues if you hire Buck Crenshaw to perform source inspections**

MSL QA Lesson #5A (cont)

- "Buck Crenshaw"
  - **Be prepared to have to deal with a myriad of issues if you hire Buck Crenshaw to perform source inspections**
- The issues are mostly professional, but sometimes personal
- The issues are that Buck penetrates a suppliers' processes so well that he discovers problems that nobody else ever thought of!!
- Personal issues with Buck involved one instance where he threatened to change his name!
- Truth be told, Buck did an outstanding job at several MSL key suppliers
  - *And I talked him out of changing his name!*

MSL QA Lesson #6

- "Software QA"

MSL SQA Success Story #1

- **Early review of the Problem Failure Report (PFR) process led to quality improvements**

- Only ***48%*** of the early reports had the data necessary for SQA signature
- Two had technical oversights that required action
- Developed checklist for necessary data
- Trained SQA and Rover Flight Software (RFSW) teams
- After process improvements, ***78%*** were ready for SQA signature

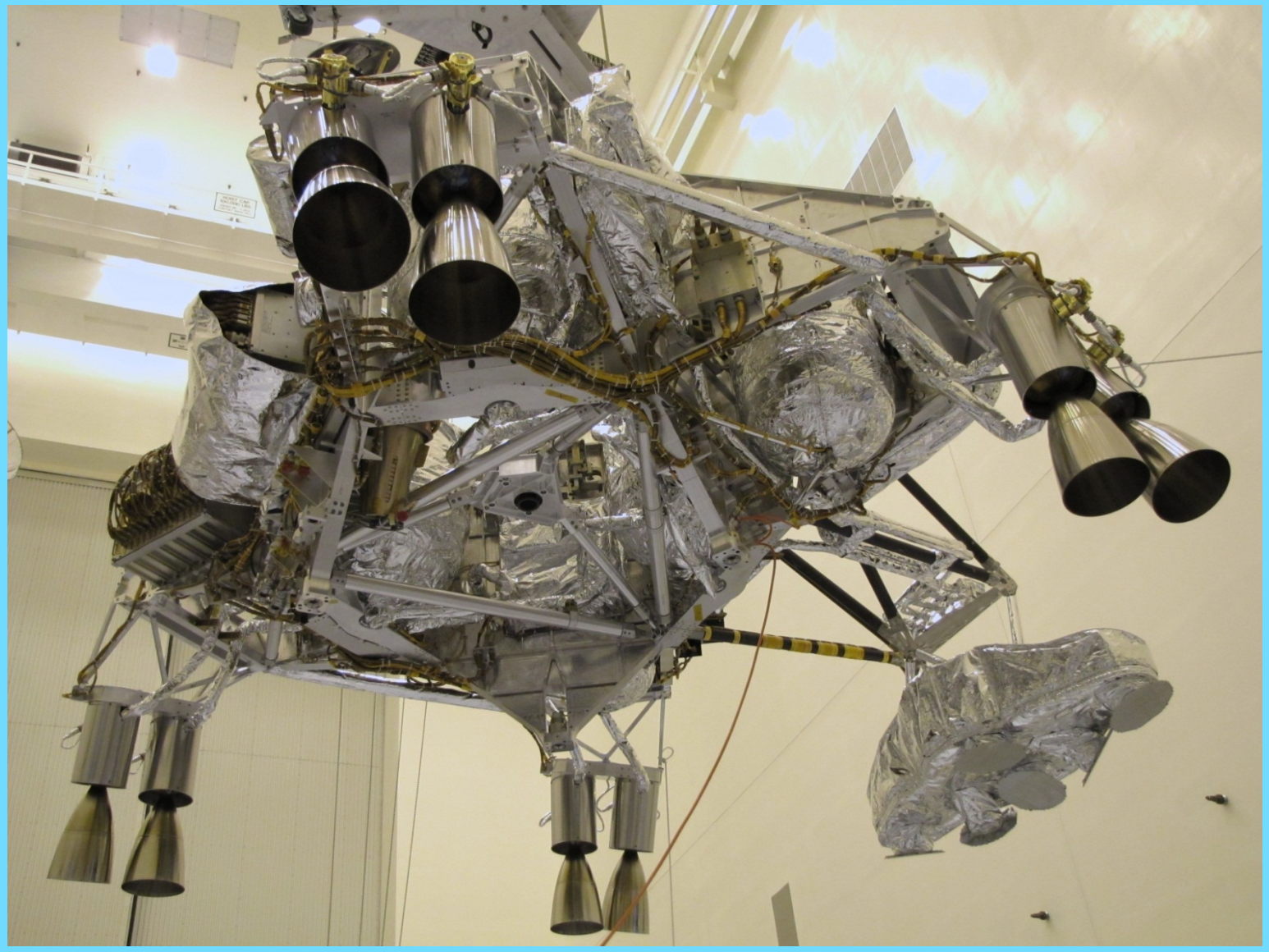
MSL QA Lesson #6 (*cont*)

- "Software QA"

MSL SQA Success Story #2

- **Building a tools infrastructure enabled high-velocity PFR review and closure**
  - Tools enhanced coordination, enabled faster reporting and enabled record keeping
  - Tools included Jira tracking system, checklist, JAVA programs and Excel macros

Descent Stage – Hazardous Crane Lift



Hazardous Op's – Rover Over Descent Stage

MSL QA Lesson #7

- "Critical Hardware Handing and Transportation"
  - **Work with your Safety Engineer to develop a strong hardware handling and transportation plan early in the program**
- MSL offered several challenges with regards to transporting hardware from place to place
  - This included cross-country transports as well as transports from Europe to JPL and vice versa
- My first recommendation is always for QA to hand-carry
  - It is the only way that you can guarantee the safety and the quality of the hardware is not compromised
- You can run into real challenges when the hardware requires an X-Ray exemption in this day and age!

MSL QA Lesson #7 (*cont*)

- Since 9/11 it has become increasingly more difficult for QA to hand-carry flight hardware on a commercial airliner
  - *With or without an X-Ray Exemption!*
- So we formed alliances with United, Jet Blue and TSA
- Although the paperwork at first was onerous, after we understood the system, it became rather routine
- Communication was key to the successful implementation of this process
- In instances when it was not feasible to hand-carry the hardware, we made arrangements with Jet Blue
- They allowed us to go on the tarmac at JFK and Burbank Airports to ensure that our actuators/motors were packed and secured properly in their cargo bay

MSL QA Lesson #8

- "Launch Site"
  - **QA Needs to Get Involved With the launch vehicle provider "Early-On" to clearly communicate the Spacecraft QA inspection point requirements**
- Launch Vehicle provider must allow time in their schedule to accommodate these inspection points
- Spacecraft QA must be responsive when the calls come to support these inspections!
- Per Lesson Learned# 1, get to know your QA counterparts on the launch vehicle-side
- "QA-speak" again plays a prominent factor in sharing important information between groups with a common-goal in mind

MSL Launch – Atlas 5

MSL QA Lesson #9

- "Generating Lessons Learned"
  - **QA needs to generate Lessons Learned during the Project and should not wait until the end to do so**
- Writing down lessons learned should become a normal routine of your work
- As with a lot of things in this business, the "*devil is in the details*"
- Sometimes, the *details* within a lesson learned is what can make a difference in implementing that lesson learned in a future application
- Generate the entire lesson learned while it is "fresh" in your mind
- Don't wait to do it!

Conclusions (1 of 2)

1) Get the word out early! QA should get involved early in all facets of the flight hardware development

2) Nothing beats good, solid communications and sharing information, especially between QA-counterparts

3) One bad GSE Cable could ruin your whole day!

4) In addition to inserting QA checkpoints into your procedures for “powering-on” flight hardware, include a “power-off” QA check-point as well

5) Early reviews and building a good, solid tools infrastructure helps enable Software QA to have a significant, positive impact on reconciling PFR’s

Conclusions (2 of 2)

6) Develop a strong critical hardware handling and transportation plan early and spread the word about it!

7) “QA-Speak” speaks volumes at delivery time

8) Generate Lessons Learned during the Project, not after

9) This is a tough business! Don’t lose your sense of humor….Enjoy the experience!

Having Fun Yet?

Back Up Charts

Lessons Learned Research

- In preparing this report, I researched a lot of Lessons Learned information, including:

1) "CAIB Lessons Learned"

2) "Learning from Other People's Mistakes"
   - Paul Cheng and Patrick Smith
   - *"Most satellite mishaps stem from engineering mistakes"*
   - *"It's always the simple stuff that kills you…. With all the testing systems, everything looked good."*

3) "Lessons Learned Mini-Course Langley Research Center"
   - Jim Van Laak

Lessons Learned Research

4) "Lessons Learned From Dr. Seuss"
   → "*Sometimes the questions are complicated and the answers are simple*"

5) "Knoco Stories"

   → From the knowledge management front-line
   → What is a Lesson Learned?

→ "A recommendation, based on analyzed experience, from which others can learn in order to improve their performance"

→ "**A Lesson Learned, is a change in personal or operational behavior as a result of experience**"
-- Nick Milton, Knoco

Lessons Learned Research

6) "Commentary: My Top 10 Lessons on Lessons Learned Systems"

→ Jay Liebowitz, *University of Maryland University College, USA*

→ The first key lesson is that capturing, sharing, and accessing lessons learned in a lesson learned information system (LLIS) must be embedded within the normal activities of the employee

-- Jay Liebowitz

7) "I have not failed 10,000 times. I have successfully found 10,000 ways that will not work."

-- Thomas A. Edison

Lessons Learned Research

8) "The *PMBOK® Guide"* defines Lessons Learned as:

→ The learning gained from performing the project.

→ Lessons Learned may be identified at any point. Learning can come from successes where we did something creative or imaginative and we would like to see it repeated on future projects

→ Learning can come from our failures where something failed to meet our expectations and we would like to improve and not make the same mistake again

→ It would be nice to say most of the learning comes from our successes, but the reality is that most of the learning comes from our failures

Lessons Learned Research

9) JPL management has expressed a strong commitment to identifying, documenting, and infusing lessons learned from flight projects. Lessons learned are critical mission success factors that can provide an effective countermeasure against avoidable risk when communicated and applied to other missions. The JPL lessons learned program is managed by David Oberhettinger within the JPL Office of the Chief Engineer

10) "U.S. Coast Guard Lessons Learned Locker"

→ The results from over 200 Years of Innovation

11) Constellation Program Lessons Learned

Lessons Learned Research

12) “Ares Knowledge Capture Summary and Key Themes”
-- R.H Coates

13) “DoD Military Lessons Learned”

14) “100+ Lessons Learned for Project Managers”

<u>Abstract:</u>

Jerry Madden, the former Associate Director of Flight Projects at NASA Goddard Space Flight Center (GSFC), collected 122 lesson learned nuggets from a variety of sources that are instructive to managers of NASA spaceflight projects. These aphorisms should be accepted where they may provide insight into NASA project management success.