Academic/Industrial Partnerships for Developing High Reliability Oceanographic Research Systems: Lessons Learned

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Problem

Academic Institutions developing high reliability Oceanographic research systems need to team with industry to cover all the engineering, installation, operation and maintenance skills needed to design, build, test, deploy and operate a successful system.
Description of the Problem

• Research labs are really good at developing early prototypes of the instruments and platforms critical to our science mission.

• However, High Rel (HR) design (high P(success) over the mission life) requires a range of expertise not generally found in every productive research lab including but not limited to:
  • Extensive, effective system engineering including reliability analysis
  • Parts, subsystem and vendor qualification
  • Material selection based on past HR system experience
  • Accelerated life testing and stress screening where appropriate
  • Rigorous, documented test, manufacturing and QA/QC processes and staff trained to an appropriate standard
  • Effective project management including legal and contract support
  • A pervasive team culture and resources appropriate for the design of HR systems

• Your 100 M$+ research system is not the place for your really creative, innovative research team to learn and then have to perform these skills.
  • However, it is a golden opportunity for your staff to upgrade and expand their skills.
Solution

• Build a team with the requisite expertise. It will probably include “for-profit” industrial partners.
  • Recognize that for-profit entities need to make a profit
  • Realize that even with a profit, there are many tasks that will still be more economical and sometimes only do-able by your for-profit partners

• Make sure the right work is being done in the right place, by the right people, at the right time with the involvement of all the right team members
  • Manufacturing of high reliability systems needs to be done by a group with a culture of high reliability manufacturing e.g. use of ESD straps needs to be second nature
  • The deployment engineer(s) needs to be involved at the right times in the design phase to ensure your gizmo can be put over the side with a high P(success)

This is not an example of proper, prior planning
The MARS Medium Voltage Converter
A Quick Case Study

- The most (and maybe only) new engineering challenge on MARS was the MV converter
- The original design for the novel DC/DC converter circuit came from a former University Professor working in a research lab at JPL
  - Every EE who has looked at this design is somewhere between very and wildly impressed
- UW and JPL were funded to develop the first prototype of the MV converter and later funded to develop a deployable MV converter for MARS
- Alcatel was eventually contracted to finish the MARS MV converter and subsequently delivered MV converters to NEPTUNE-Canada
- LESSON LEARNED: Hardening of the MV converter design by the right partner should have been part of the plan from the beginning
Alcatel’s Process

• 4 stages of prototype development with several levels at each stage
• Each stage had a well defined goal
  • Stage 1: Prove the risky parts of the design work
  • Stage 2: Build a fully functional but not necessarily deployable system
  • Stage 3: Build a fully function deployable system that has most of the design required to meet the reliability and manufacturing requirements
  • Stage 4: Build the fully engineered first article ready for production manufacturing
• Used existing, proven parts, circuits and subsystems wherever possible
• Started parts and vendor qualification for known, new parts early
• Started the manufacturing engineering early in the process
• The problem was not the new DC/DC circuit. It was all the ancillary control circuitry required to demonstrate a stable, fully functioning, 20 year life MV converter. And then building a deployable version with a reasonable probability of lasting 20 years
• Because our time frame forced us to accept an early stage 3 converter (maybe late stage 2) we did not get a full performance, 20 year system. But everyone knew this and we developed an upgrade plan with Alcatel
High Reliability Engineering

• Theory 1: The number of systems you’ve successfully fielded that have met a X year mission life requirement is a good indicator of your P(success) in designing an X+5 year system.

• Theory 2: If you don’t know what a FIT is, your P(success) in designing a HR system is probably low.

• A system designed for high reliability need to be analyzed to predict expected Failures in Time (1 FIT = 1 failure in 1 billion hours ~ 114,000 years)
  • Submarine telecom repeaters are of order 10 FITs

• Once the FIT rate for the system and subsystems is known, the probability of surviving the expected mission life can be estimated
  • Problematic parts can be replaced and problematic subsystems can be redesigned
  • Appropriate redundancy can be added

• Single point failures must be identified and addressed
  • Putting 2 subsystems in parallel does not necessarily double the system life

• This kind of analysis is pretty straightforward but incredibly boring
  • Except the serial/parallel topology analysis we did for the proposed 35 node, interconnected early NEPTUNE system was challenging and kind of fun

• Building a culture that accepts RE as a fundamental part of the process is hard
Lessons Learned 1

• Industrial, for-profit companies are (probably) a necessary evil
• Contracts have to include explicit, comprehensive technical requirements and spell out the appropriate
  • Design reviews
  • Status reports
  • Performance milestones and demonstrations
  • Design analysis reports
  • Deployment plans
  • Failure reports
  • Risk matrices
  • Subsystem acceptance tests
  • Factory acceptance tests
  • System integration tests
  • Pre-deployment tests
• This is not an easy or quick task
  • Ex. Req’t: Everything needs to ship on a truck that can make it across “the bridge”
  • Performance goals over and above the minimum requirements are OK
Lessons Learned II

- You need staff who can knowledgeably assess progress and P(success)
  - Make sure you have knowledgeable staff review plans and reports, witness performance demonstrations as well as all acceptance tests
  - Knowledge needs to include some familiarity with high reliability design best practices
- Stick to the contract
  - When the cable ship’s captain asks if it is OK to deviate from the carefully engineered cable slack schedule or lay cable outside the carefully permitted cable route; it’s nice to be able to say “I’d like to give you a break but we have to stick to the contract your company signed”
  - Contracts mods happened but they can be incredibly expensive
- Trust but verify
  - Forgetting one quick, simple test from a 3 day factory acceptance test can (and probably will) sink your perfect prepared plan
One Lesson Probably Worth Learning

- We keep reporting the same incredibly expensive ground fault, connector, corrosion, noise and similar mundane problems
- Shouldn’t we learn that some “expensive” industrial practices actually pay for themselves?
  - Reliability analysis
  - Highly Accelerated Lifecycle Testing and Highly Accelerated Stress Screening
    - Wouldn’t a community/industry connector test/qualification facility be nice?
  - Dedicated Quality Analysis and Quality Control staff
  - Dedicated test engineers and testing environments
    - X-Rays are cheap and effective insurance for some issues
    - Helium leak testing is not so cheap but highly effective insurance
    - Most connector vendors have a pressure test chamber
    - Design Engineers are different animals than Test Engineers are different than QA, ...
  - Shore side test systems
  - A mature, proven, documented soup to nuts design, procurement, manufacturing, test, deployment process
  - Economical, accessible wet test beds: MARS
  - Accumulation and distribution of institutional knowledge
One Vision for an Optimal Development System

Criteria of optimality: reducing overall lifecycle cost over many decades for many Oceanographic research systems

Creative, innovative research labs

The community gizmo hardening group

Industrial Partners

1000’s of affordable high reliability instruments, platforms, systems, ...

Stage 1 or 2-ish Prototype

Stage 3 or 4-ish Prototype

The missing link
Acknowledgments

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http://www.mbari.org/at-sea/cabled-observatory/
Google: “MARS observatory”
A Few Of Our Other “Failures”

- The ODI HV connector failure resulted in a complete recovery of the node and TRF and redesign of the connector
- The LV subsystem had to be rebuilt to address workmanship issues
- Integration of MARS into other observatory’s instrument development process

A Few Of Our Successes

- A modestly rigorous instrument checkout process using the MARS wet node simulator in the MBARI test tank uncovered lots of issues many of which would have been fatal but were easily fixed
- The ROV (extension) cable laying toolsled hardware and process
- Zero instrument failures on initial power on
MARS Electronics

MV Converter

Comms and LV Power Distribution