HUGHES

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Lightweight Exo-Atmospheric Projectile Technology Demonstration Program

Navy LEAP Lessons Learned Summary

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As it is with any program, upon conclusion some reflection on how the endeavor went invariably takes place. The Navy LEAP Technology Demonstration program was extremely challenging from all the classic perspectives; technical, cost, and schedule. Because of the high level of success experienced during the course of the program, particularly in light of the substantial technical innovations involved, a "pulsing" of the HMSC program participants was performed. Following is a collection of observations relating to "lessons learned" and factors contributing to the success of the program. They are loosely broken out into organizational, programmatic, and technical categories. Organizational items are those that relate to the method and/or means by which resources were tasked and allocated. Items that address the program goals and top-level schedule are collected into the programmatic category. There is no significance to the order.

Organizational

Colocate to facilitate teamwork, including customer representatives and major subcontractors. This further allowed customers/contractors to be involved in decisions, allowed for their knowledge and expertise to be brought to bear, and their presence during key tests enhanced credibility. People in close proximity that share common goals spawned effective resource sharing and problem solving.

Establish expectations regarding customer/contractor protocol. Doing this helped ensure that the relationship remained cordial, as opposed to antagonistic.

Implement cross-functional teams. They were called teams and management supported them to act as teams which provided the environment to become teams.

Allow the core team members to remain dedicated for the programs duration. Aside from the obvious benefits of continuity, this also provided breadth to all members. Having several members from the systems and design arena proceed all the way through integration, checkout and flight helped speed the process and increase success level. Furthermore, systems and design involvement allowed for first-hand learning of testability and logistics aspects which will be used in the future. Many of the team members got to know each other well which increased teamwork and commitment; many worked to the completion of the program.

Strive for team decisions. One person generally took responsibility but decisions were most often team ones. There was no finger pointing.

Employ the "A" team. Program was very fortunate to have many good multiple-skilled people.

The team must be allowed to propose solutions and all viable/practical ones must be supported with vigor to maintain an efficient and effective team. This allows for flexibility and abaptability.

Install management control within team. Teams maintained budget control, resource control, and detailed task definition/control. This and the previous one are fundamental to the worn-out concept of "empowerment". It should be noted that the majority of team members were not even aware of who their coworkers boss was. Very little "meddling" from outside management.

Dedicated procurement allowed for much quicker hardware receipt; breakdown of procurement due to transition allowed for dedicated buyer.

Build inspection and quality assurance into the process. Engineers were empowered to be responsible for assemblies and inspectors were dedicated to the program.

Dedicated technicians on team greatly improved repair/modification turnaround times.

Expeditious movement of hardware & test equipment was had by maintaining a dedicated transportation and shipping person.

One person maintaining the schedule program wide ensured timely and consistent information flow to the team members and to the outside.

Team actions and reporting were governed by the question "How will we get the job done?" not "Why are we not?".

Ensure frequent electronic and face-to-face communication between team members at all levels. Two basic types of meetings: staff to flow relevant "long-term" information (goals, status, schedule, priorities, resources) and high-frequency, short-duration team meetings to communicate and *deal* with information program wide (e.g., 7:30 AM meetings lasted about half an hour and allowed for quick ad hoc teams to be formed to address issues/bottlenecks). Be sure to create phone lists (include home phone) and assign beepers to key personnel. Voice mail is a great asset.

As the program evolves to round integration and checkout, implement the "missile mother" concept. Decisions bubbled up amongst teams were capped by missile mother, the centralized person for making decisions. Missile mother kept clear focus in the midst of mayhem. Individuals (e.g. missile mother, program manager, et al.) may have had authority over a task but were willing to share. Having dedicated personnel responsible for each flight test round was an excellent way to expedite schedules and prevent configuration problems.

Customer has to promote, with conviction, programs' significance to foster a team willing (when truly necessary) to invest heavily in both resources and time. Teams commitment comes from customers commitment.

Corollary: Do not *plan* for excessive hours, they are a reserve to accommodate special circumstances and situations. The physical and mental well being of the team members is vitally important and should be considered during crunch time. Efficiency and productivity is inversely proportional to exhaustion.

Deal with team morale. Videos allowed to be taken home helped the team to maintain the often ridiculous hours because it showed the family what was going on and why.

Recognition was mostly within LEAP, not amongst functional management. Many on the functional side were not aware of the extreme effort and innovation being put forth.

Functional management needs to support recognition and acknowledgement of successes, not just "failures".

Programmatic

First full-function flight occurred 11 months after initial IOM delivery; can't be more aggressive.

IOM required 27 months for initial delivery. This too is unprecedented.

Minimize the number of different missile configurations. Each configuration represents a new set of designs. If possible, though it seldom is, each design should build upon the previous, versus replacement.

High value objectives need to be attempted redundantly. If intercept is key and involves considerable risk then fly the SAME configuration more than once.

Minimize distribution of responsibilities within a program. Many contributors are manageable, but with great difficulty when they are independently managed.

Provide more focus on GFE requirements and ensure sufficient quantities are allocated; be specific on year/lot number.

Objectives drive program. When the objectives change, change the program accordingly. Tough decisions need to be made, not avoided.

Outside agencies (i.e., government labs) should continue to support requirements, performance and effectiveness analyses, but should **NOT** be suppliers; that should be left to industry. The requirements for lab-based "formal" document review and approval needs to be scrutinized. Only value-added processes should be maintained; an informal process was installed to crutch the formal process.

Establish in writing what approvals (Safety and otherwise) are required for each field test procedure early in the program so that the procedures can be provided in sufficient time for review. (A single government agency should have approval authority over any procedure. All others should be courtesy review only.)

Strong emphasis on development and approval of third stage-to-kill vehicle ICDs prevented any significant interface problems between Kill Vehicle and missile. Early and frequent working group meetings ensured understanding and concurrence on interfaces as the formal ICD was being developed.

No agency or contractor was truly responsible for the whole mission. That entity which was intended to be responsible did not submit to public scrutiny or accept much in the way of public discourse, therefore, effectiveness was substantially diluted.

System Engineering Working Group helped bring consensus regarding requirements and operational issues. However, there was too much time spent on statusing versus debating.

Sufficient customer presentations helped get customer "ownership" of certain tasks and risk.

Top-level goals helped set priorities. Everyone knew the goals and the constraints/sensitivities; complacency was never a problem. Lots of credible information from the top.

Overtime pay showed program support and commitment. It also recognizes the herculean efforts put forth to achieve overly aggressive schedule exacerbated by change in objectives.

Plan for, and implement, CTVs.

Procure and build enough hardware. Ensure sufficient spares/IOMs are planned to support testing (including destructive testing). This includes special test equipment.

Make schedule and asset allowance for integration and test failures. Consideration of risk is vital to proper planning. Clearer up-front planning would have raised value of keeping schedule; unrealistic schedules breed "don't care" attitudes. Very short term planning focus helped make best use of people but not use of best people. Rigorous test planning and realistic schedules need to be implemented to reduce the number of extended (12+ hour test days). Both hardware and test fidelity are at risk when personnel are fatigued and rushing to meet schedule.

Developmental programs don't benefit from an ITEP. Knowledge of test requirements evolves with design and integration, therefore laying out overall test plan early yields useless boilerplate and very likely unnecessary testing.

Do not move to another state in the middle of a flight test program.

Technical

CILs usage of actual embedded software on real flight computer with access to all functions greatly aided integration and checkout as well as allowed for rapid maturing of software.

Colocate simulation and software development activities. Close proximity allowed for easy cross-talk exchanges during the development and integration of both the embedded software and 6-DOF simulation. Closer integration with missile checkout should also be pursued.

Integrate simulation and embedded software development to the maximum extent possible.

Aim for exercising flight code in all flight simulations. CIL computers need to be upgraded for speed, reliability, ease of use, and commonality with embedded software tools and 6-DOF simulations.

Automate simulation verification procedure to allow for quick turnaround. Simulation verification could not be completed as early as planned because simulation models are developed and adapted as design firms up and tests are done.

Perform early embedded software integration. This allowed for more efficient executive checkout and ensures maximum maturity for CIL-level integration.

Perform software project tracking by software configuration item (CSC) versus design phase. It provided for smaller and more manageable pieces and gave better insight into true status.

Regressive testing should be scrutinized. Don't underestimate the potential for screw-up or side effects with the most minor of software changes.

Software schedules need to consider intermediate deliveries for special tests and early integration. Delays were incurred in delivering flight software to support special test versions that were accounted for at the outset of the program.

Software stressed maintainability and readability. (facilitated getting working) easy to change & back up to modes.

Test complex embedded software modules using 6-DOF. Software integration was expedited by creating input and output files in the 6-DOF and using those to exercise embedded software.

Embedded software should fully instrument and report on all external interfaces and include interface data, both input and output, on telemetry.

Enhance simulation output capability (e.g., plots and video) particularly as it relates to comparing various sources (i.e., different simulations, test data). Simulation visualization proved invaluable during embedded software/CIL integration.

Provide a means of high-level CIL integration prior to receipt of embedded software.

Enhance simulation fidelity, particularly in the area of fire/weapon control.

EMC between all test assets needs to be reviewed, not just the unit under test (i.e., missile).

Generate a Mission Requirements Document for each critical flight test. These proved invaluable in focussing requirements flow and providing the vehicle for debates regarding operational aspects.

Share simulation, software, and test data analysis tools early.

Preliminary versions of documents were created early with updates as issues became resolved. This was an excellent way to keep people informed while meeting aggressive schedules.

Design for repair, particularly of test assets. Expendables such as batteries, squibs, etc. should be easily replaced so as to support "destructive" (i.e., thorough) testing.

Don't freeze the design until necessary. Faster, less painful iterations are possible. Design team was involved in analysis as well as test.

Keep engineers active in vendor interface.

Use Fabrication Log Books for tracking hardware during assembly. More discipline necessary in early developmental assets (i.e., IOMs). More detail should be added.

Designers got feedback on design, including fixtures/handling because they were there during test.

Optimize test fixturing design to facilitate critical alignments.

Provide spares for delicate fixtures to minimize integration schedule impacts in the event of breakage.

Eliminate hypergolics to avoid excessive safety and handling requirements.

Minimize use of one-shot devices. Utilize dual, redundant squibs and drivers wherever possible. Isolate the return as well as the drive side of bridgewires until the appropriate mission time.

All field procedures should be performed on actual hardware in-house at least once prior to field operations.

All field procedures should be provided to the appropriate range organization as early as possible for review--but not before a dry run. This will minimize the effort required to review procedures twice due to major revisions.

Both CIL and Missile Checkout allowed for thorough proofing of the timeline.

Capture data on all tests. The unexpected is hard to predict and equally hard to understand without data.

Conduct all shipboard tests on only one ship so integration doesn't have to constantly be redone.

Do not run tests when personnel are exhausted or unfamiliar with the test set up.

Do test readiness reviews even on simple tests. Ensure sufficient test time is allocated for data review. Plan test activities such that all data from one test is reviewed prior to proceding with subsequent tests. Even simple tests merit a procedure/checklist and review by cognizant engineer.

Record test configuration (including test equipment and unit under test serial numbers) in test log books for every test.

For all new test equipment, design for reliability and ease of use/setup in the field.

Implement a more broad-based review of test processes (procedure and setup). All test plans & procedures designed to check interfaces between KV and third stage should be reviewed by both Missile Integrator and KV Contractor prior to beginning the integration process. In particular, test configurations must be checked to ensure that test configuration does not mask or prevent measurement of actual flight software and hardware. Test plans must be reviewed to ensure that instrumentation and observation will provide sufficient insight should a test failure occur.

Test directors/conductors must work constantly to ensure that only necessary personnel are present during ALL testing in the field.

Verify integrity of test equipment, setups, and procedures.

Written test requirements should be provided early to ensure the test organizations have sufficient time to provide proper equipment and procedures and clear understanding of test goals.

Prior to starting any hazardous operation in the field, a roundtable review of the configuration and procedure should be conducted with all personnel involved in the operation present.

Ship system interface needs high fidelity testing (i.e., shipboard hot battery test).