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Systems Engineering Lessons Applied in NNSA Weapons Programs

National Nuclear Security Administration

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What were the Lessons Learned Studies?

- **Purpose:** NNSA Defense Programs (NA-10) directed the Office of Systems Engineering and Integration (NA-18) to execute a comprehensive Lessons Learned Study (LL) on Life Extension Program (LEP), and Earned Value Implementation.
- **People Involved**
  - Groups
    - Federal
    - Design Agencies (LANL, SNL) (LLNL Peer review)
    - Production Agencies
  - Completed Interviews
    - Over 70 interviews for LEP
    - 12 team for the EV
- **Documents Reviewed**
  - Design Agency Documents
  - Production Agency Documents
  - GAO, OMB, IG and other Audit Reports
  - Program Planning Documents

Lesson Learned

- **Lesson Learned can be mapped into the following areas**
  - Requirements Development
  - Risk Management
  - Facility Management
  - Supply Chain Management
  - Staffing
  - Integrated schedule
  - Design-to Production
  - Earned Value
    - Product-oriented WBS
    - Reporting requirements
    - Change Control

Key Lessons Learned

- **Requirement Management:** Programs must implement a formal RM Program for identifying and assessing both technical and programmatic requirements and a formal process to evaluate and document requirement changes.
  - Freezing requirements in rational stages as development matures is a lesson that has been repeatedly learned, but not sufficiently applied. Adjudicating "necessary" change from "desired" change is the domain of a seasoned systems engineering and change control board.

- **Risk Management:** The need for a robust risk management program with appropriate resources is again a lesson that has been repeatedly learned, but not sufficiently applied.
  - Risk management must be practiced evenly between participants and stakeholders.
  - Mitigation activities need to be incorporated into planning.
  - Cost and Schedule Contingency & Management Reserve must be properly developed and incorporated.
  - Risk must be monitored and managed.

- **Facility Management:** Recovery from the Post-Cold War atrophy. The assumption that it would easier to reconstitute building and capabilities would be easier than to reconstitute people were flawed.

Key Lessons Learned

- **Supply Chain Management.** Outsourcing requires attention to detail and the effort to restore and/or cultivate new vendors is time consuming and contains extensive risks.
  - The use of COTS components extends the elements of risk. S
  - Sustainability of the Supply Chain must be a key factor in technology selection in future programs.

- **Staffing:** Staffing plans must be developed and implemented throughout each phase of the LEP and proactively managed for the Federal and M&O contractor staffs.
  - The lead time for background investigations, security clearances and training mandates detailed planning.
  - Overtime is not a plan!

- **Integrated Schedules:** A LEP at minimum will have 7 contractors to integrated at the same level that have to integrated down to very low levels within the WBS thus creating additional complexity. integrated schedule with networked logic was consistently identified as one of the greatest challenges
  - inconsistent WBS led to difficulties integrating scope
  - Vague activity definitions complicate understanding intent when schedules were created
  - Knowing critical path and near critical path work helps with prioritization, risk management, and overall work progress

Key Lessons Learned (Cont'd)

- **Transition of the Design-to-Production:**
  - The DA/PA contractual arrange cause increased complexity. More than half the production issue on recent LEP were related to this area.
  - DA mission and incentive (design) is different than PA (manufacture) are not incentivized the same.
  - The design reviews can not be just checklist but must have technical depth
  - Design development needs to stop or minimize the overlap with product development. Skipping certain production steps to save time in design development may force end up costing more delayed in production development and qualification.
  - Better training in the Product Realization Teams would be beneficial.
  - Quality needs to be better represented and implemented in the PRT
  - COTs needs to be better planned and risk understood. Late design changes can be problematic with COTS parts. Since some COPS part have to be pre-purchased, a late change can cause a lot to be scrapped or cause the qualification to start over.
  - The NNSA should establish design criteria mandating that the design be cost effective, easily produced, and readily disassembled as well as meeting the design intent requirements,
  - Quality, Trust, manufacturing, use of COTS have to be integral to the program and design process at the beginning.

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Key Earned Value Implementation Lessons Learned

- **Production Oriented WBS**
  - Consistent WBS across multiple contractors resulted in fewer communication and interphase issues
  - Not rolling multiple Work Packages (WPs) into a Control Accounts (CA) can increase the number of CAs and the program management burden. Likewise, having too many WPs can create an increased burden on that CA and potentially mask the EV data for that CA

- **Reporting Requirements:**
  - Reporting was only found burdensome in cases where more than two levels of site-internal management reviews were required.
  - Consistent reporting formats and requirements between programs would be beneficial
  - Needed to align site-internal business rhythms with reporting to Federal Program Offices (FPOs)

- **Change Control**
  - The change control level was the driving factor for the volume of change requests, suggesting a low threshold for change control could create a burden.
  - A distinct process should be developed to authorize the release of funds at time of variance.
  - "One major lesson--NNSA needs to educate each site on what really constitutes a baseline change. The number of hours wasted on baseline change requests where no scope was added was very frustrating. Being late or being over-cost is not a sound basis for writing a BCR."
  - Need to find the right balance on control levels
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So Why Did the LEP Experience So Many Lesson Learned?

- Root Cause Analysis: The correlation of the Lessons Learned observations and the production issues provided an indication of the potential root causes within the LEPs for the delays and overruns. It looked at two aspects:

  - There have been several studies on large industry and government projects to understand the factors that contribute to cost and/or schedule overruns. The correlation and consolidation of the factors from those industry and government reports produced 11 key factors that are applicable to LEPs . These factors were used as a criteria to assess the observations from the LEP to see how many of these factors applied to the LEP.

11 Key Factors That Can Contribute to Potential Project Overruns

	Explanation
1. Insufficient tools & project management infrastructure	Project tools and infrastructure are not set up to effectively plan, deliver, track, and report performance.
2. Resource shortages and/or inexperienced or unqualified project team	Project team lacks the quantity and mix of appropriate skills and expertise to manage the project at the Federal level or within the contractor.
3.Highly constrained, incomplete and/or fluid requirements	Project commences based on incomplete or fluid requirements that create incomplete or changing design definition causing project scope to be continually in flux that can lead to inefficiencies, unrecoverable cost overruns, and schedule delays. In addition, overly constrained requirements can create design and production issues.
4. Lack of proactive risk management	Lack of proactive risk management techniques to identify and address project issues and risks such that project risks are not fully identified, understood, and vetted suggesting that risk handling is not fully incorporated into total project planning.
5. Scoping issues	Project scope does not fully account for organizational, programmatic, technical, or lifecycle requirements.
6. Poor or lack of project coordination and integration	Projects elements are managed in silos with limited or poor integration among the participants, customers, and other project stakeholders.
7. Poor cost estimating	Project estimates are incomplete or insufficiently detailed for budgeting. Overly optimistic estimates, poor or outdated cost data, missed scope items, flawed assumptions, or labor and material not fully accounted for.
8. Unrealistic schedules	Project schedules are developed with preset expectation on delivery dates, highly constrained, optimistic, and weak correlation between work scope and resources that led to unrealistic completion targets.
9. Alternative Analysis (or Trade studies) not adequate/robust	The trade analysis is inadequately performed such that risks and potential complications of each alternative are not adequately considered in the down select decision.
10. Poor or lack of integrated budgeting & planning	Project programmatic requirements are not aligned with budget and execution plan.
11. Contracting Issue	Contract change or structure that overly constrains the flexibility of the contractor to respond to issues or normal business operations.

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Root Cause Analysis Results: Factor 1

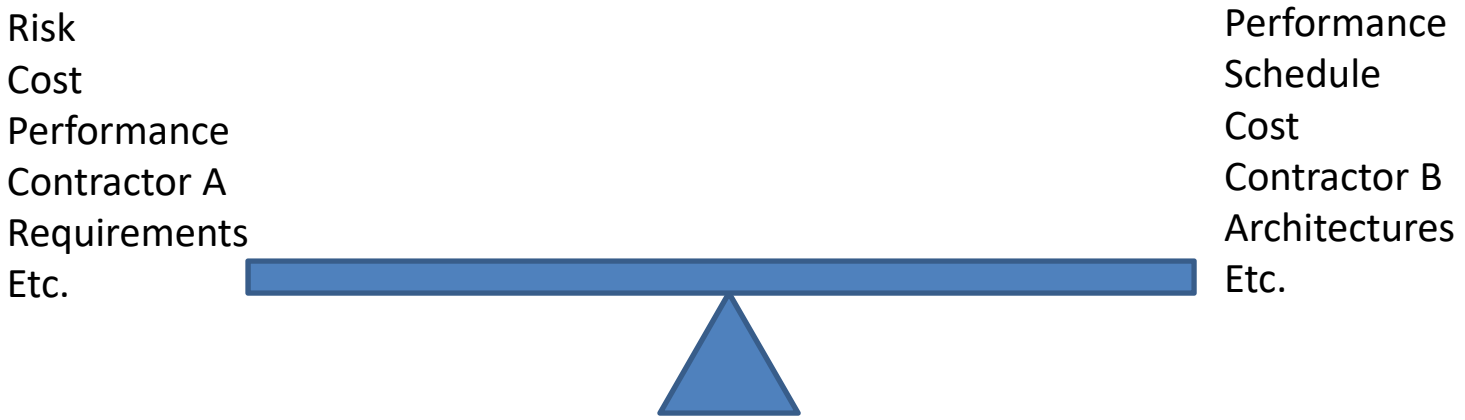
The LEP got caught up in the transition from the Cold War business model to the new expectations and constraints. **Cultural shift is an issue**

Cold War Era: Expert based with large flexible cash flows where performance and schedule were more important.

verses

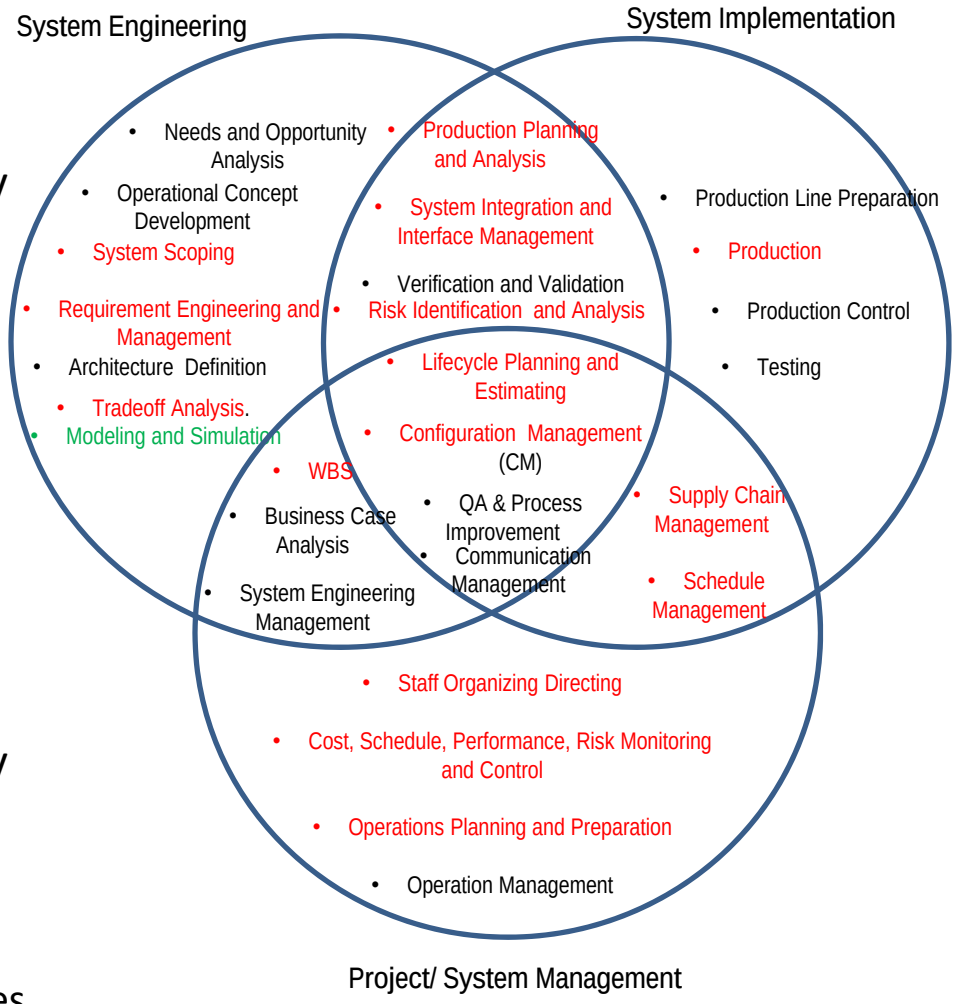
New Paradigm: Budgets are more restricted and more accountability and cost and schedule were becoming just as important as performance, and a balance between them was needed.

New Paradigm requires a different level of Program Integration. It is full time job of ensuring the proper balance among every aspect of the program.



Root Cause Analysis Results: Factor 2

- NSE **did not have full understanding Systems Engineering processes** and lacked the tools, training, and understanding to perform several key functions well or completely:
  - requirement engineering and management;
  - configuration management,
  - and full implementation of risk management.
- NSE **did not have full understanding Project Management processes** and lacked the tools, training, and understanding to perform several key functions well or completely:
  - cost estimating;
  - program planning;
  - resource-loaded integrated schedules,
  - and development of comprehensive Work Breakdown Structure.



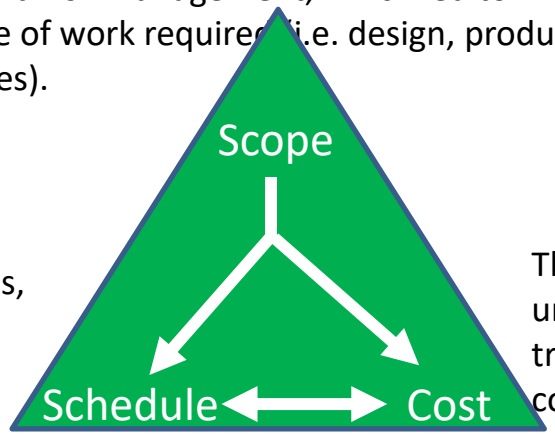
Root Cause Analysis Results: Factors 3 and 4

3. There was an old saying within the NSE, "we can solve any problem given enough money." This Cold War mentality established a false confidence that they could reconstitute facilities, processes, and experience that had been lost. The NSE was **overly optimistic with its ability to recover from the atrophy** in:
   - Production
   - Test Capabilities
   - People

4. Federal team **was not fully staffed to manage or implement all the processes** needed to adequately manage the LEP to balance cost, schedule, and performance.
   - The LEP had an insufficient staff to adequately manage which was compounded by the lack of experience to manage in the new paradigm.

Summary of the Root Cause Analysis

Atrophy and Cold War mentality contributed to an insufficient programmatic infrastructure, coupled with an insufficient understanding and training in requirements, configuration, and integration, and risk management, which led to misunderstanding the true scope of work required (i.e. design, production, facilities and capabilities).



The lack of the necessary processes, understanding, experience, and training in integrated schedule development contributed to poor integration of schedule.

The lack of the necessary, processes, understanding, experience, and training in cost estimating contributed to a weak cost estimate and budget management.

Without well-integrated cost, schedule, and scope, it became very difficult to balance the cost, schedule, and performance of the LEP. Thus, making the minimization of either a cost or schedule overrun very difficult.

Activities that Help Address the Key Factors that Contribute to Cost/Schedule Overruns

Factors	Explanation	Requi. Mgt	Risk Mgt	Interface Mgt	WBS	Modeling	Training	Lifecycle Model	Perf. Mgt	DPBPs
1. Insufficient tools & project management infrastructure	Project tools and infrastructure are not set up to effectively plan, deliver, track, and report performance. Inadequate use of performance management					✓	✓	✓	✓	✓
2. Resource shortages and/or inexperienced/unqualified team	Project team lacks the quantity and mix of appropriate skills and expertise to manage the project at the Federal level or within the contractor.						✓			✓
3.Highly constrained, incomplete and/or fluid requirements	Project commences based on incomplete or fluid requirements that create incomplete or changing design definition causing project scope to be continually in flux that can lead to inefficiencies, unrecoverable cost overruns, and schedule delays. In addition, overly constrained requirements such as safety can create design and production issues.	✓		✓			✓	✓		✓
4. Lack of proactive risk management	Lack of proactive risk management techniques to identify and address project issues and risks such that project risks are not fully identified, understood, and vetted suggesting that risk handling is not fully incorporated into total project planning.		✓	✓			✓	✓		✓
5. Scoping issues	Project scope does not fully account for organizational, programmatic, technical, or lifecycle requirements.	✓	✓		✓		✓			✓
6. Poor or lack of project coordination and integration	Projects elements are managed in silos with limited or poor integration among the participants, customers, and other project stakeholders.	✓		✓			✓	✓		
7. Poor cost estimating	Project estimates are incomplete or insufficiently detailed for budgeting. Overly optimistic estimates, poor or outdated cost data, missed scope items, flawed assumptions, or labor and material not fully accounted for.		✓		✓		✓			
8. Unrealistic schedules	Project schedules are developed with preset expectation on delivery dates, highly constrained, optimistic, and weak correlation between work scope and resources that led to unrealistic completion targets.		✓	✓			✓		✓	✓
9. Alternative Analysis not adequate/robust	The trade analysis is inadequately performed such that risks and potential complications of each alternative are not adequately considered in the down select decision.	✓				✓	✓			
10. Poor or lack of integrated budgeting & planning	Project programmatic requirements are not aligned with budget and execution plan.				✓				✓	

Federal Lessons Applied

- The development of a repository for Lesson Learned that the present LEPs are providing input and LEPs in early development are utilizing.
- New categories and requirements for Federal Program Managers for implementation of project/programs define in the Program Execution Instruction.
- The requirement for LEPS to perform Earned Value Management and the creation of the Project Controls System Description.
- Established DP Enterprise-wide Requirements Management Plan with a Requirements Management Advisory Board (RMAB) to promote more constructive discussion and understanding among ADAs on requirements
- Requirements Engineering and Management Guide Published
- Established DP Interface Requirements Agreement Development Process
- Developing a DP Integrated Requirements Information System (IRIS) database to map and first- and second-order interferes among programs/projects within DP
- Utilization of probabilistic risk assessment in future LEPs and better processes to develop Contingency and Management Reserve for cost and schedule are being explored.

Federal Lessons Applied (cont'd)

- Technology Readiness Assessment very early and at key gates.
- Initiated a new technology maturation process that incorporates the new RL calculator and better integrates elements within DP.
- Developed and implemented DP's Nuclear Weapon Acquisition Professional (NWAP) Certification Program to improve training
- Integrating with site change control processes through the stand-up of Integrated Product Teams (IPTs)
- New organization and processes developed to improve cost estimating.
- Established DP Work Breakdown Structure Guidelines
- Planned updates to DP Business Practices (DPBPs)
  - Product realization process to better reflect System Engineering
  - Improved Program Planning requirements: FPM needs to effectively solidify requirements early in the LEP and aggressively manage planning and scheduling early in the program to optimize design, stabilize cost, ensure adequate budget, and adequately inform IMS and WBS
  - Risk requirements
  - Exploring how r implement variable threshold by phase

Questions?

Backup Slides?