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Owen Dominguez, PhD
Jose Parga, PhD

System Engineering Challenges at Los Alamos National Laboratory: Modernizing the System's Thinking Approach

Outline

- LANL Background
- SE Process @ LANL
- SE Challenges @ LANL
- LANL SE Approach Example
- How are we addressing these challenges?
- Conclusion

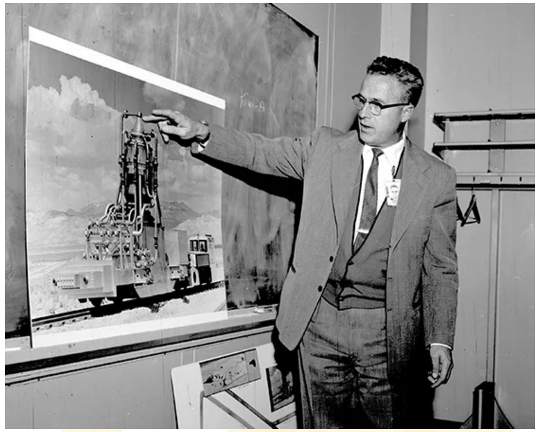
Background and Context

Inception of the Laboratory

- LANL began in 1943, a few years after the start of World War II, for a single purpose:
  - Design and build an atomic bomb
- It took just 27 months. On July 16, 1945, the world's first atomic bomb was detonated 200 miles south of Los Alamos at Trinity Site
- This test proved that scientists at LANL had successfully weaponized the atom

Innovation Timeline

1950s

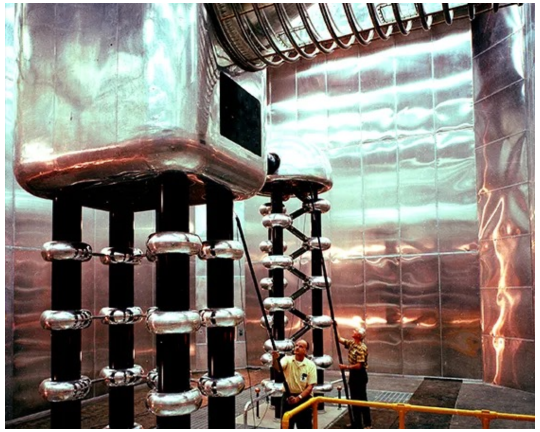


Rover nuclear reactor rocket program launched.

1960s

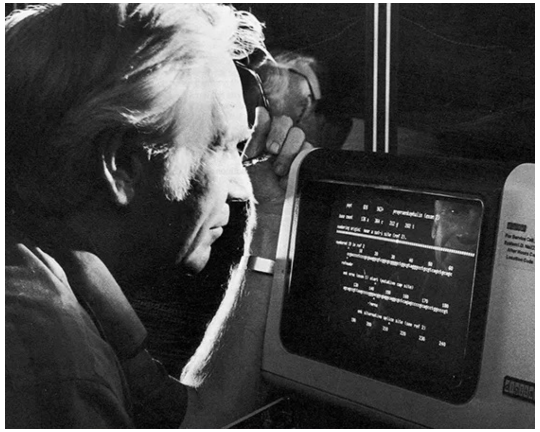
World's highest voltage Van de Graff accelerator used for nuclear physics experiments goes operational (1963).

1970s



Clinton P. Anderson the Los Alamos National Laboratory's Meson Physics Facility (LAMPF) achieves full energy beam (1972).

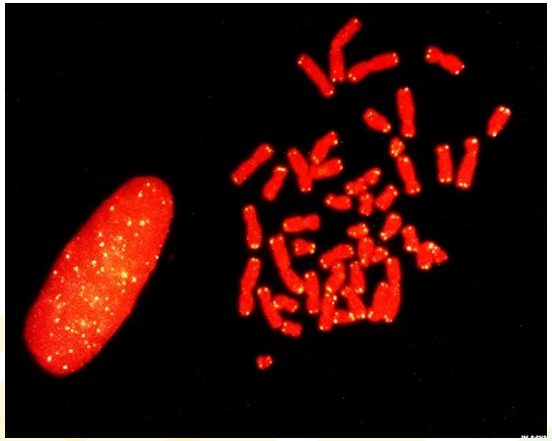
1980s



Establishment of GenBank, a database that serves as a national repository for genetic sequence information. LANL was later designated as one of three national centers for human genome studies (1988).

Innovation Timeline

1990s

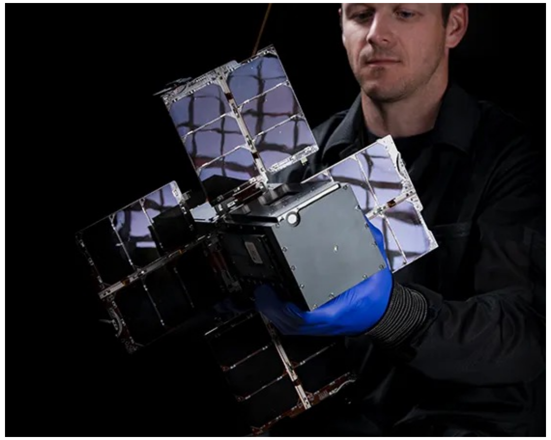


LANL scientists complete map of chromosome 16.

2000s

Roadrunner supercomputer exceeded sustained speed of 1 petaflop/s, or 1 million billion calculations per second.

2010s



Four tiny "cubeSats"—satellites small enough to hold in one hand—are launched into orbit in December 2010.

The Laboratory Today

Today, different research programs at LANL directly and indirectly support our basic mission: maintaining the safety, security, and reliability of the nation's nuclear deterrent without the need to return to underground testing.

With a national security focus, LANL conducts fundamental science in our six Capability Pillars:

1. Materials for the Future
2. Nuclear and Particle Futures
3. Integrating Information, Science, and Technology for Prediction
4. Science of Signatures
5. Weapons Systems
6. Complex Natural and Engineering Systems

Systems Engineering at LANL

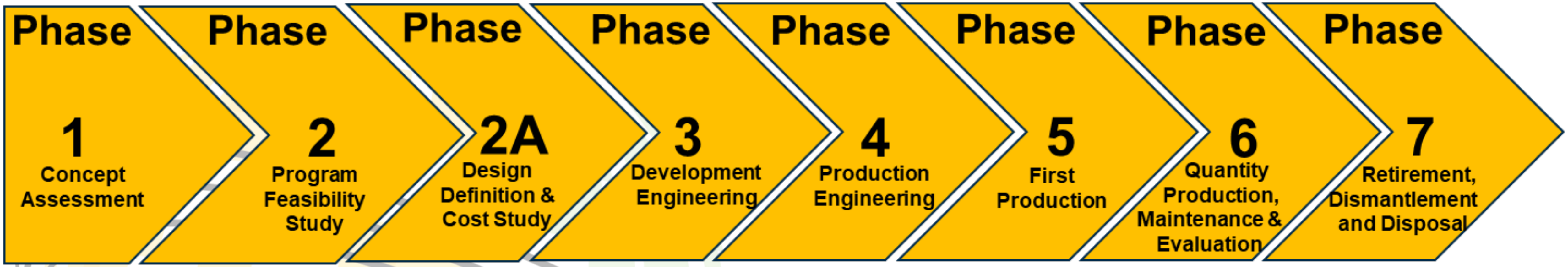
The Need for Systems Engineering at LANL

LANL has and will continue delivering effective systems for national and global security. Thus, SE practices are increasingly important to ensure:

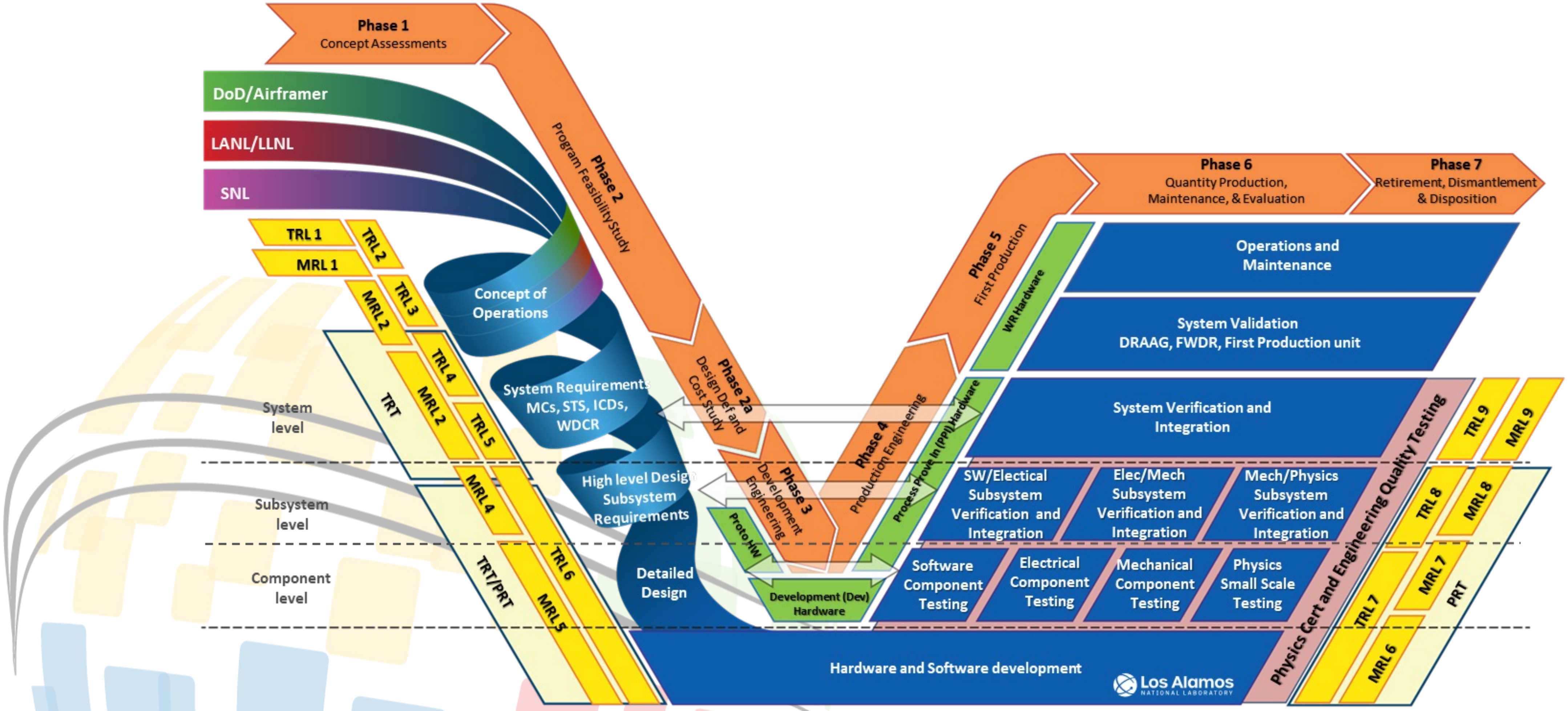
1. Components and subsystems work together seamlessly
2. Identify and mitigate risks throughout the project lifecycle
3. Requirements are clearly defined, understood, and met
4. The entire lifecycle of the system, from conception through decommissioning is considered

Phase X Process

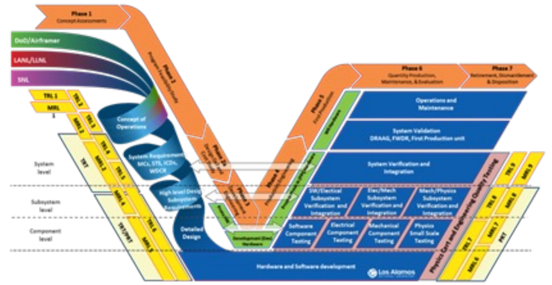
- Analogous to the INCOSE V-Model. The Phase X process is defined as:



Overlaying the Phase X on the System Engineering V



Key Similarities and Differences

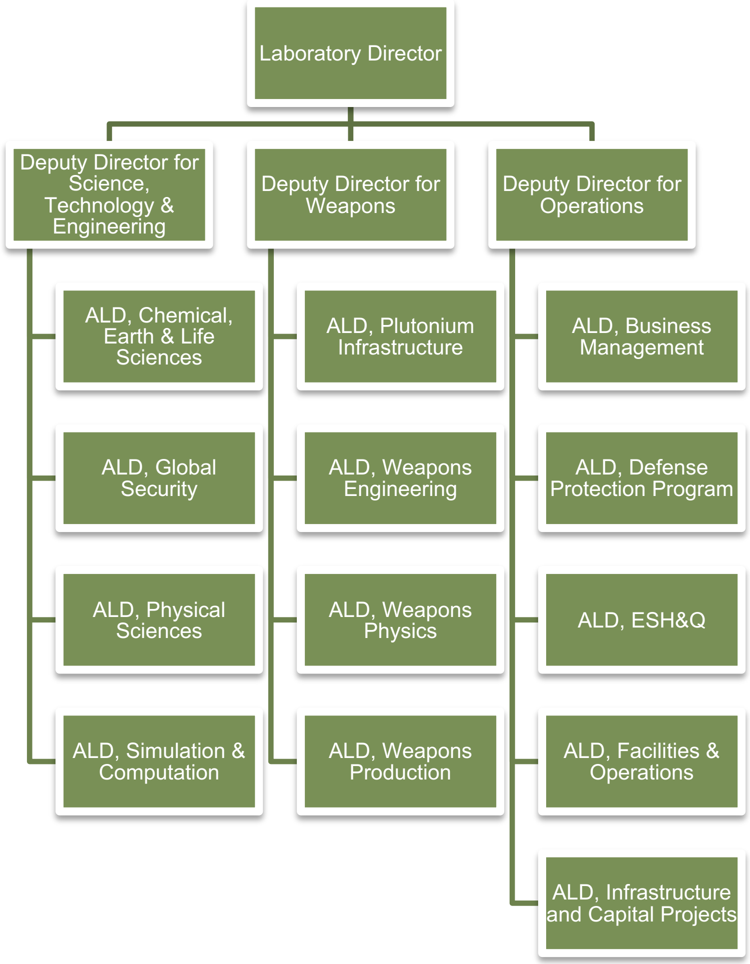


- The Joint DoD/DOE Weapon Development Process (Phase X/6.X) is very similar to the System Engineering V-Model especially at the high level.
  - They have nearly identical steps
  - They are both intended for large complex systems
  - Focus on Verification and Validation of system requirements
- The Phase X Process has many more details that further refine the process:
  - The process is linked to the DoD acquisition process
  - TRL/MRL Levels and where they must be accomplished
  - The Phase 2A phase gate requiring a baseline design and cost analysis that goes to the NWC and Congress for approval and funding in order to proceed
  - The physics thread of the process from design to testing
  - Safety and Security aspects in every part of the DoD/DOE process where they usually play a smaller role with most systems

Systems Engineering Challenges at LANL

Challenges – Broad Mission

- Managing the increased complexity of systems with diverse and often conflicting requirements
- Efficiently allocating resources (time, budget, personnel) across various components and phases of the project
- Ensuring effective communication and coordination among a large, multidisciplinary team



Challenges – New Workforce

- New employees may lack the necessary knowledge and skills specific to the systems engineering methodologies and the project domain
- Providing adequate mentorship and training to new workforce members
- Ensuring effective communication and collaboration between new and existing team members

Challenges – Tribal Knowledge

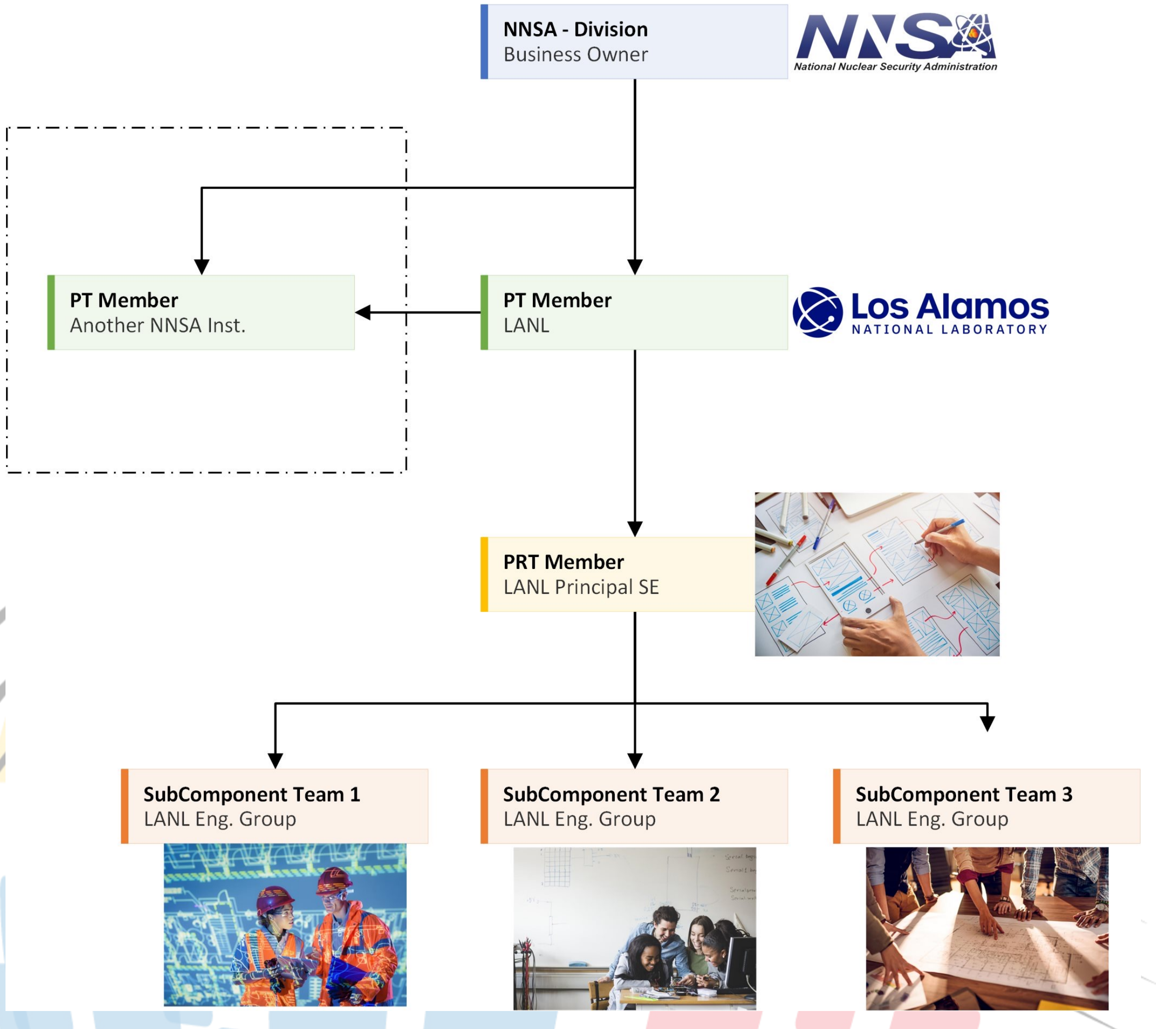
- Critical knowledge may be lost when experienced employees leave the organization
- Variability in how tasks are performed due to reliance on informal knowledge
- Difficulty in transferring knowledge to new or less experienced team members

LANL SE Approach Example

LANL SE Challenge Example

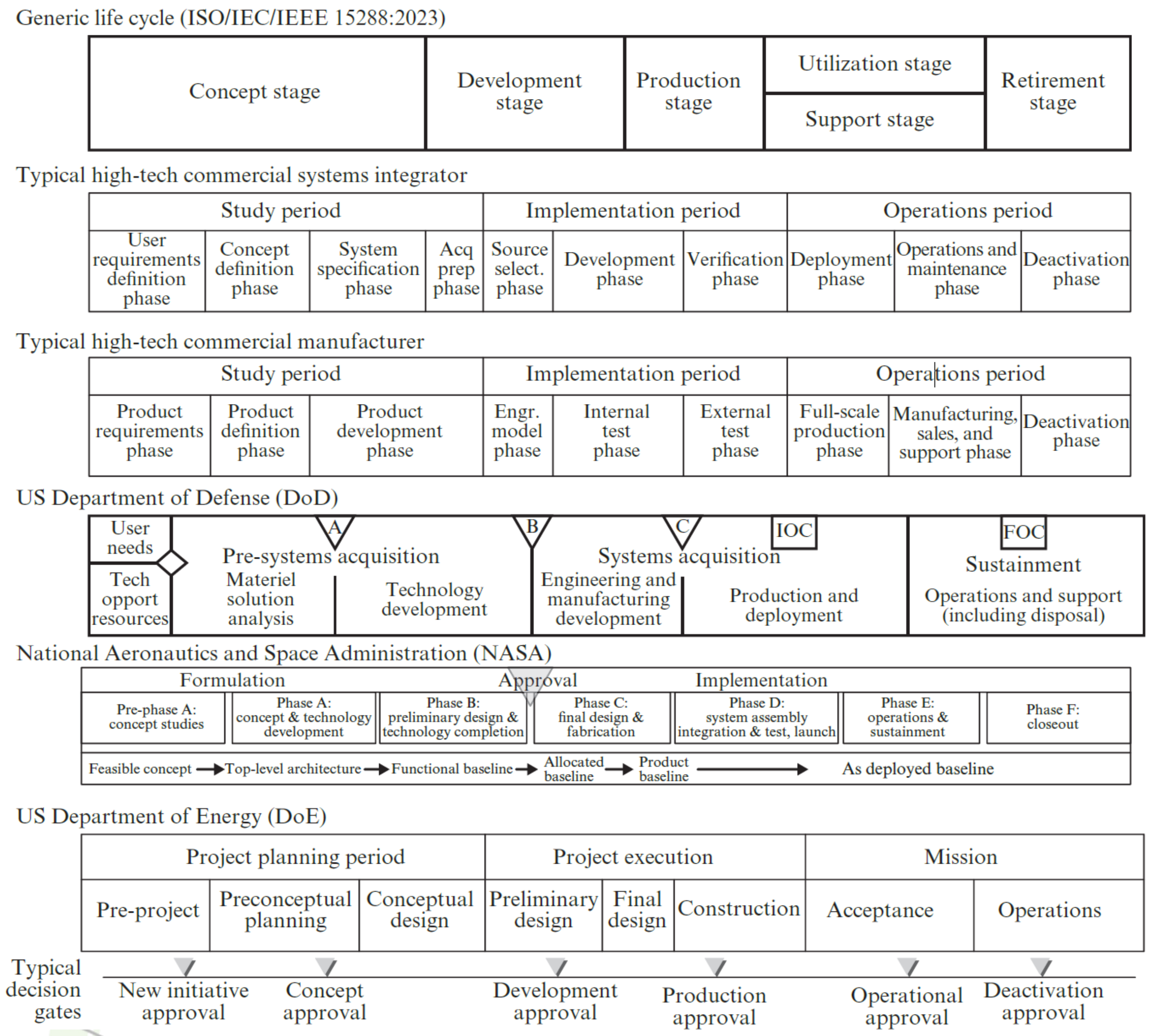
- The Comprehensive Nuclear-Test-Ban Treaty
  - The CTBT bans any nuclear weapon test explosion or any other nuclear explosion
- As a complex we haven’t exercised the entire lifecycle in decades
- Consequences for the SE processes
  - No final product testing, closing the V&V cycle
  - Maintenance/support stage differs
  - Deviation from standard SE cycle

Project Teams Organization

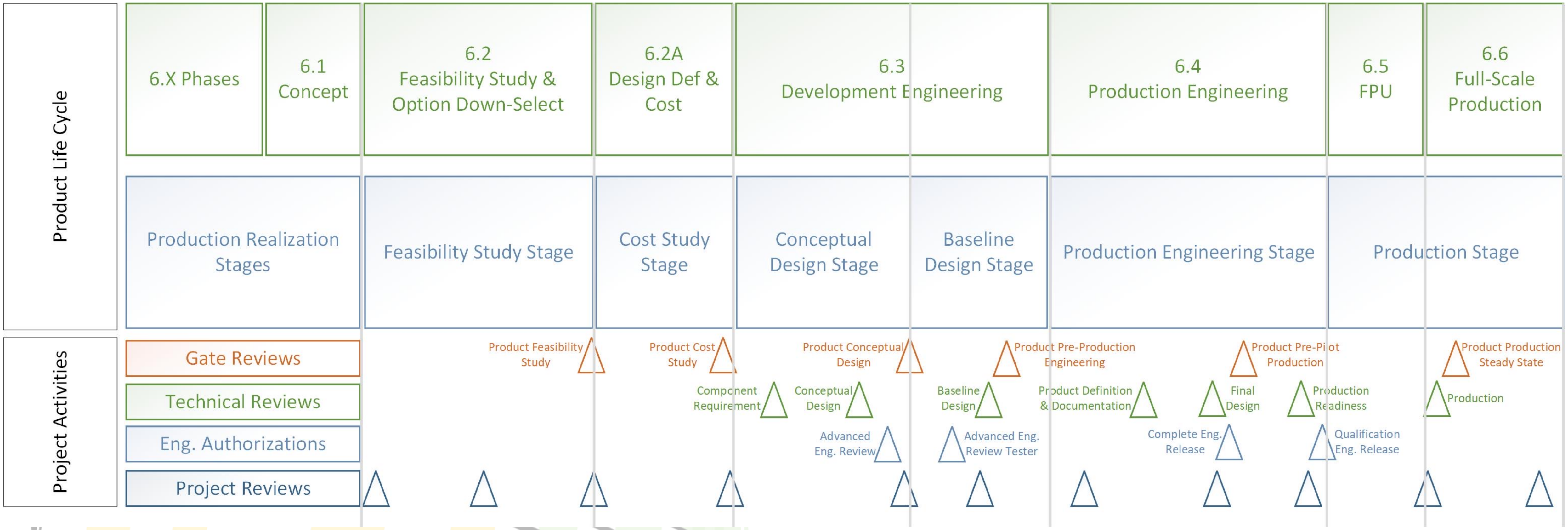


- The Project Team (PT) has the responsibility of decision and gate keeping.
- Other NSSA institutions form part of the PT team.
- The Project Realization Team (PRT) is the SE team.
- The Subcomponent teams deal with the technical challenges.

- Typical Life Cycle Stages:
  - Concept Stage
  - Development Stage
  - Production Stage
  - Utilization Stage
  - Support Stage
  - Retirement Stage



LANL Generic Life Cycle and Gates



Tailoring the LANL SE Life Cycle

- Life cycles models and SE processes cannot be directly applied to LANL projects
- Tailoring is needed for project, LANL, specific environment, other factors.
- Adaptation is needed

How are we addressing these challenges?

Engineering Leadership Council

- LANL stood up the Engineering Leadership Council (ELC) to guide and manage engineering policy and initiatives at the laboratory
- The ELC crafted a strategy document guiding LANL with a 5-year plan
- A major part of this strategy document is to create systems engineering common processes

SE Common Processes

- SE common processes are vital for LANL as they ensure efficiency, consistency, and quality in problem-solving and project execution

Industry Best Practices

LANL Engineering Policies

Systems Engineering Professional Certification

Tools and Trainings @ LANL

Industry Best Practices

- Survey will help the ELC assess what the SE maturity is at the laboratory as compared to others in similar industries
  - What are others in industry doing for SE projects?
  - What tools are they using?
  - How are they training their workforce?
- This survey has been adapted to examine internal SE capability across the laboratory

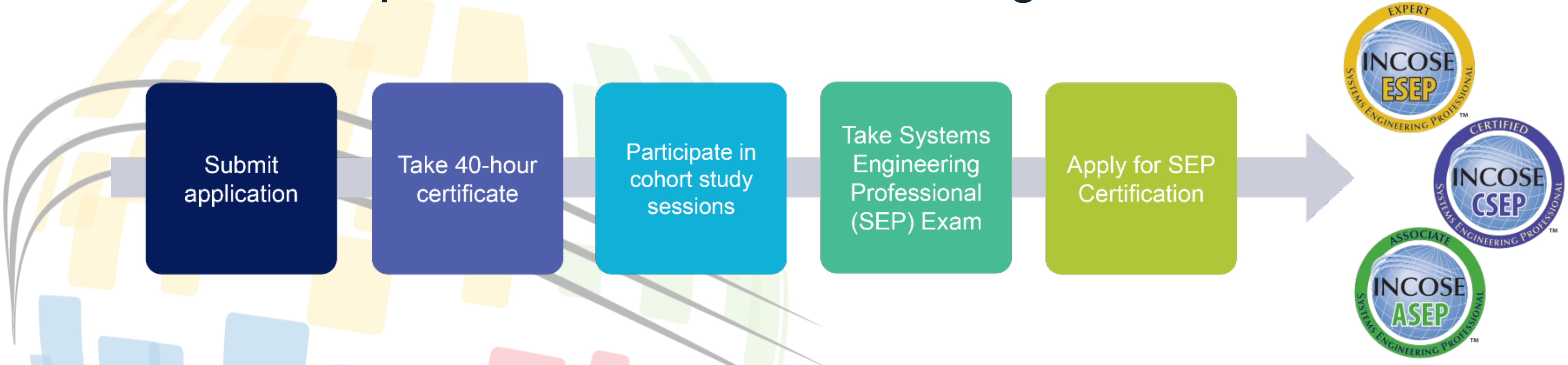
Engineering Policy

- Standardize how projects/programs are managed using a tailored framework based on risk
- Smaller low-risk SE programs do not require the same rigor as large high-risk programs
  - MBSE is a tool that might see better return in investment in a larger program
- Critical phase-gates will ensure that projects are successful before continuing to the next phase
  - Approvals based on risk (low risk → principal investigator; high risk → group leader)

Using results from the industry best practices survey to update processes described within LANL engineering policy

Systems Engineering Professional Certification

- Worked with external vendor to create a LANL SE fundamentals certification
- Cohort of 15 early- to mid-career employees who will take the program in-person
- Certificate provides sufficient knowledge to take SEP Exam



Trainings and Tools

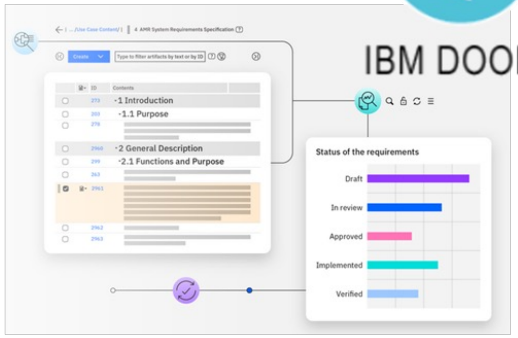
Trainings

- Formal on-demand trainings
  - Risk analysis
  - Requirements management
  - Trade Studies
  - Interface Control
  - Budgets (mass, power, etc..)
- Standard templates

Common Tools

windchill®

IBM DOORS



CAMEO SYSTEMS MODELER™

Jira

Confluence

Conclusions

- LANL has and will continue to do systems engineering for large complex systems
- Systems engineering common process will enable the laboratory to manage these projects by using standard and tailored practices
- Knowledge capture is important to ensure transitions are smooth and knowledge is retained as employees rotate through the organization
- Using software tools like MBSE and Requirements Management will enable better coordination and documentation of projects

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