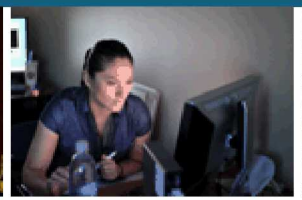
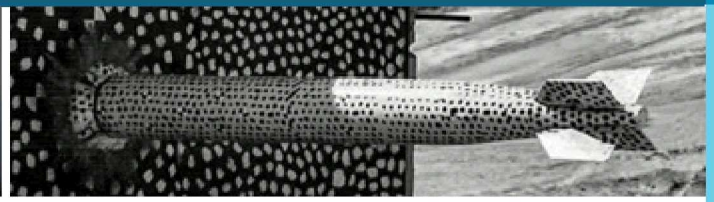
SAND2019-6388C

Analysis of Alternative Optimized Nuclear Weapon Stockpiles under a Resource Constrained Enterprise





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MORS 87thSymposium | 17-20 June 2019 | U.S. Air Force Academy, CO

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Background

National **N**uclear **S**ecurity **A**dministration (NNSA) has the unique challenge of developing and comparing strategic plans for weapon system development & production that span 25 plus years

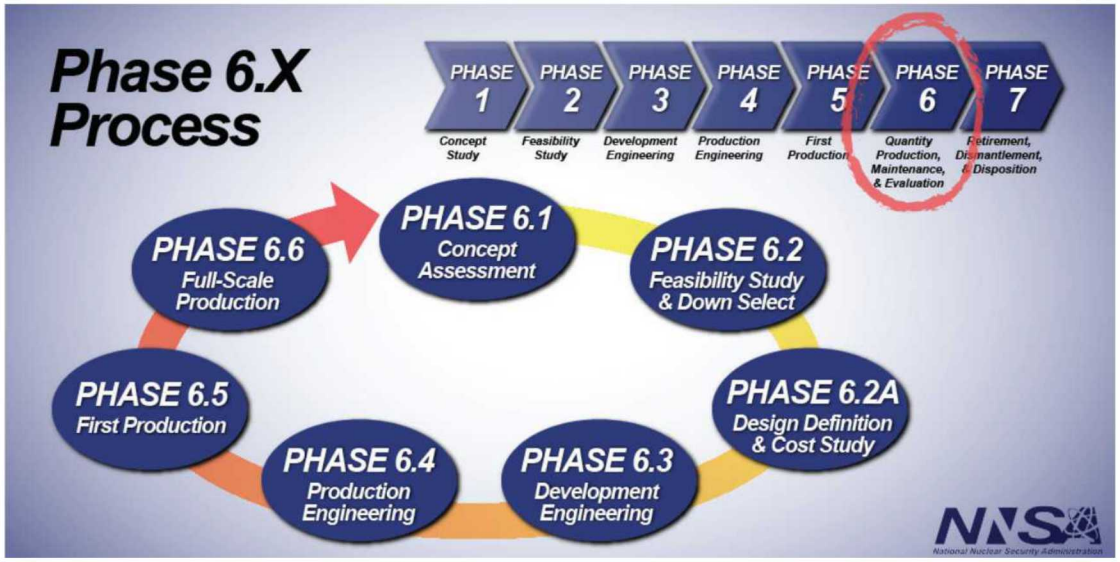
A NNSA sponsored collaborative, multi-site analysis group, the **E**nterprise **M**odeling & **A**nalysis **C**onsortium (EMAC), developed and refined the process, tools, and approach NNSA needed

Stockpile **O**ptimization **U**nder a **R**esource **C**onstrained **E**nterprise (SOURCE) model is a large-scale mixed-integer linear program that was designed to understand integrated development & production schedules and workloads across multiple sites

SOURCE Process Motivation

Support NNSA stakeholders and decision makers that manually assess stockpile plans with unique characteristics:

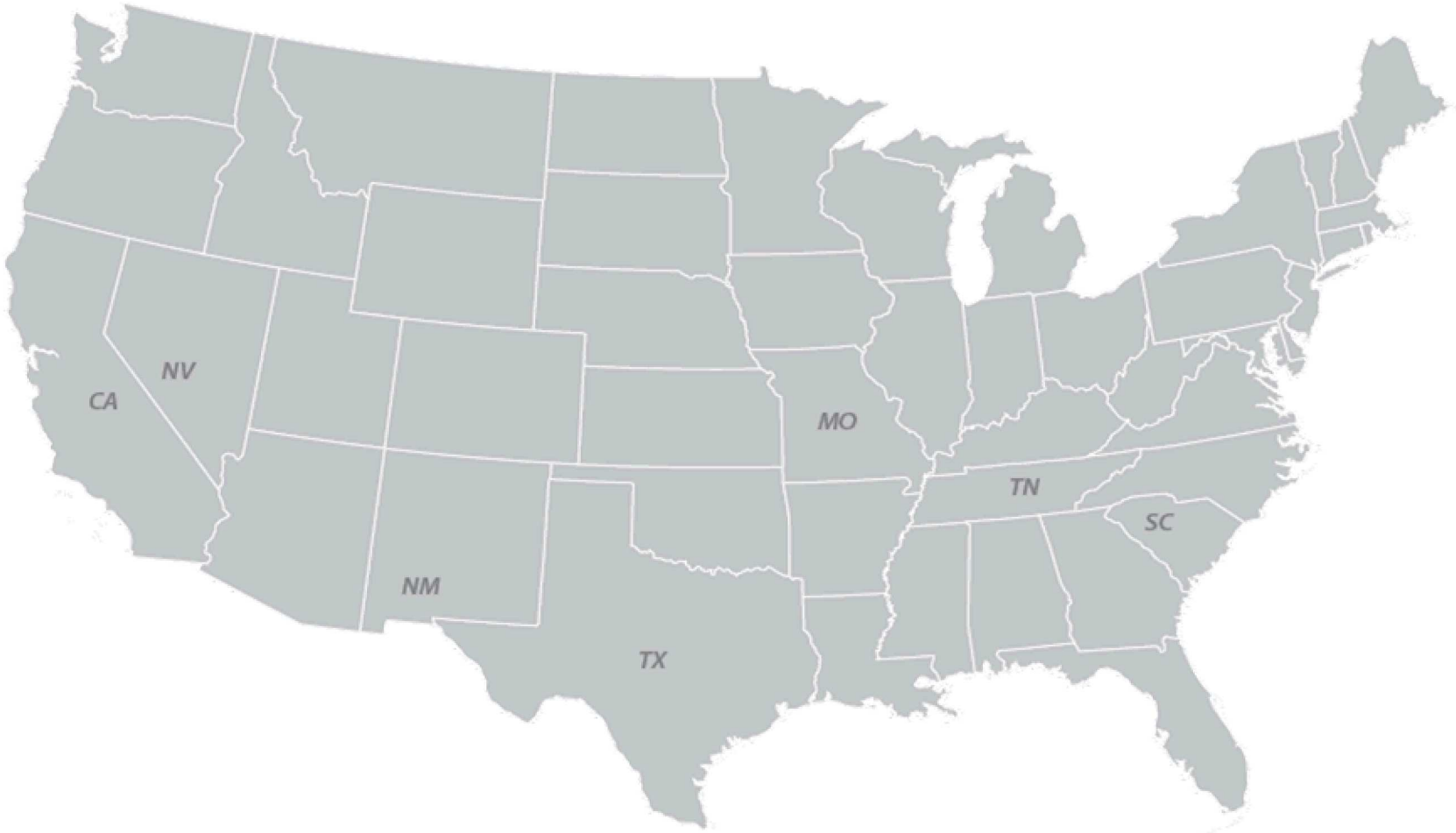
- Time horizon is multiple decades
- Activities occur at multiple locations with different capabilities, constraints, and business rules
- Long lead time products are competing for limited resources
- Numerous drivers require near constant updating and evaluating of alternative scenarios (e.g., Nuclear Posture Review, DoD requests, etc.)
- All phases and activities for warheads are considered



https://www.energy.gov/sites/prod/files/2018/06/f53/6x%20process.pdf

Ability to analyze an integrated view of warhead activities across the Nuclear Security Enterprise

Nuclear Security Enterprise (NSE) Mission Space is Vast



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Nuclear Security Enterprise (NSE) Mission Space is Vast

★ Headquarters

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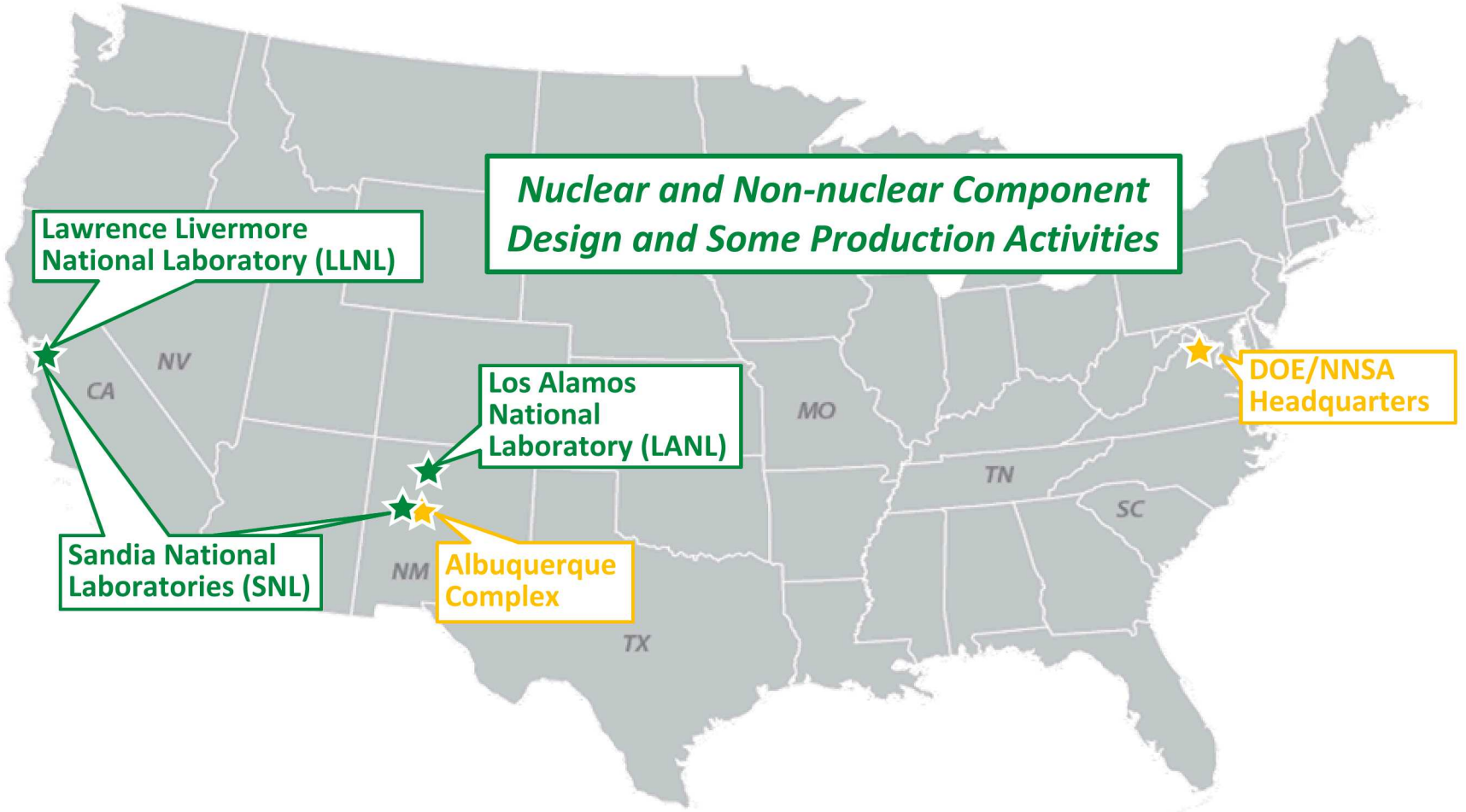

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★ National Security Laboratories

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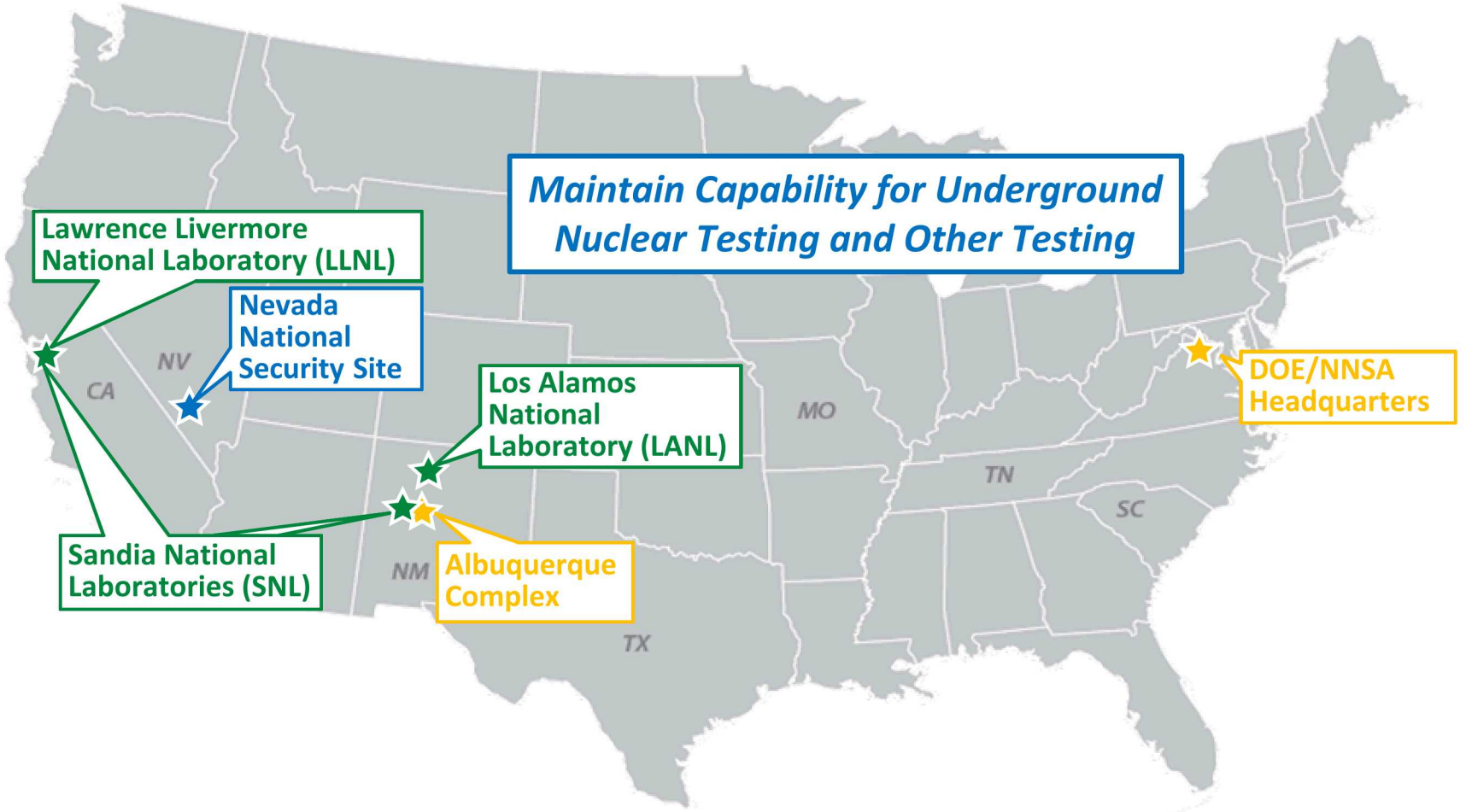

★ Headquarters

★ National Security Laboratories

★ National Security Site

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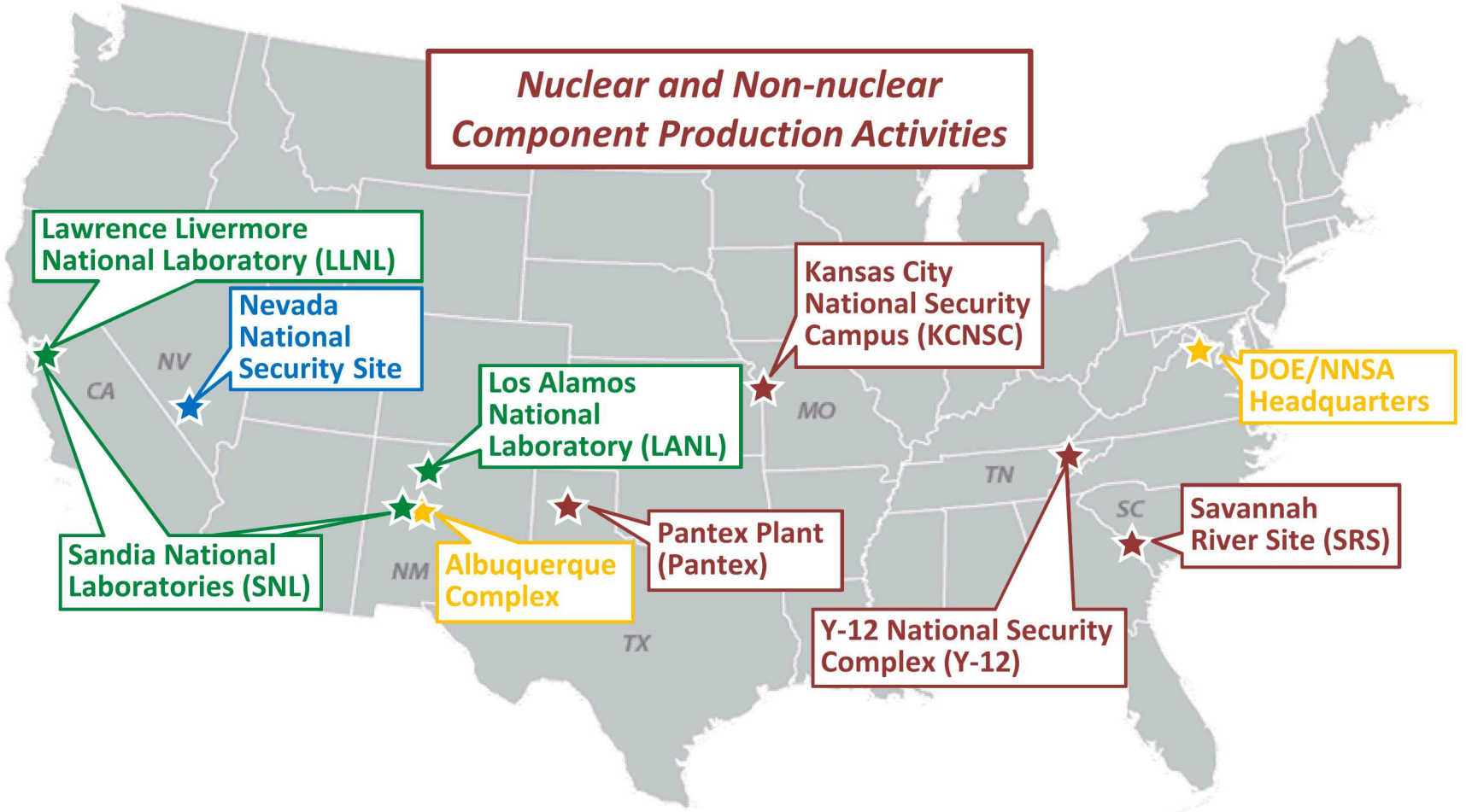

★ Headquarters

★ National Security Laboratories

★ National Security Site

★ Nuclear Weapons Production Facilities

https://www.energy.gov/sites/prod/files/2018/10/f57/FY2019%20SSMP.pdf

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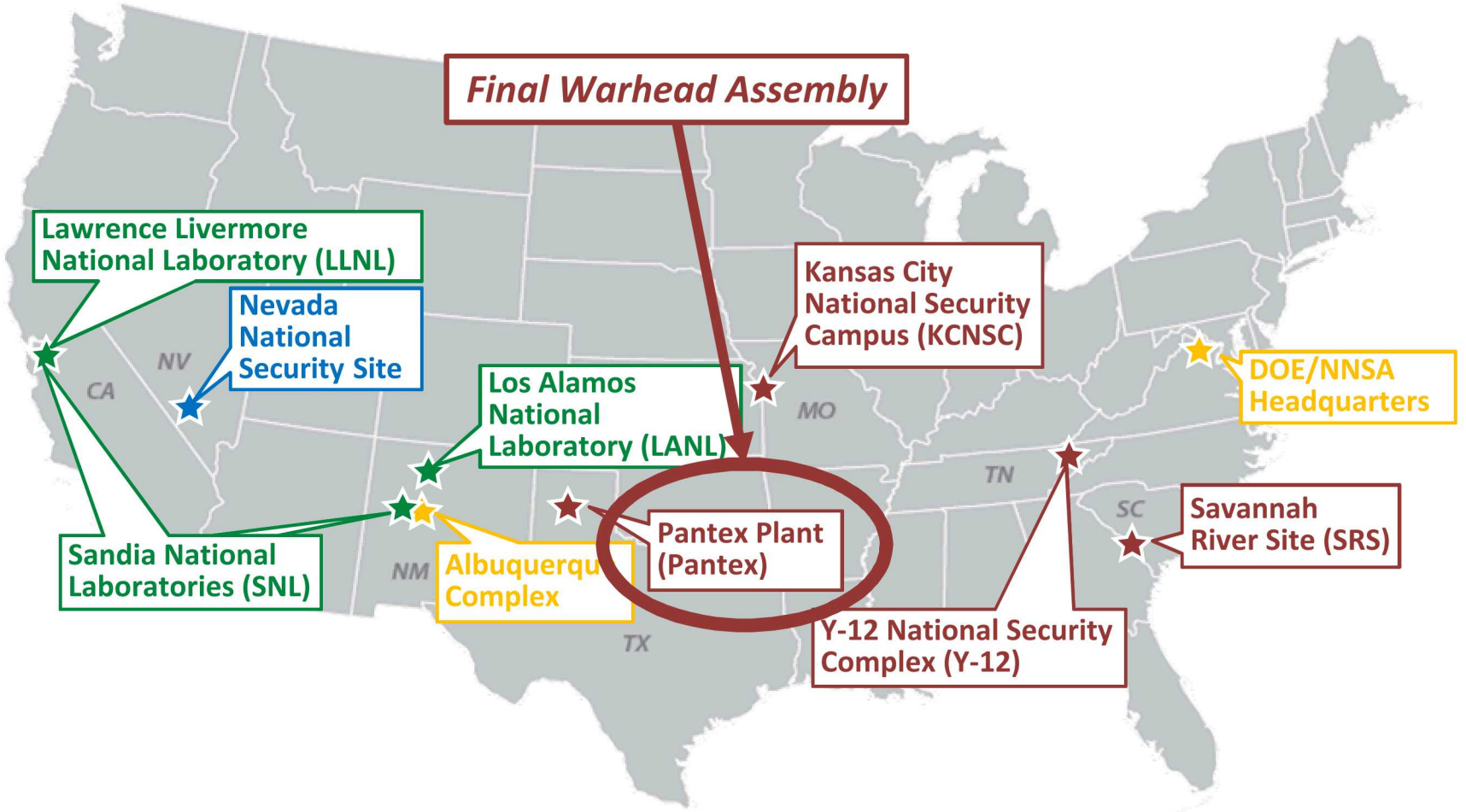

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★ National Security Laboratories

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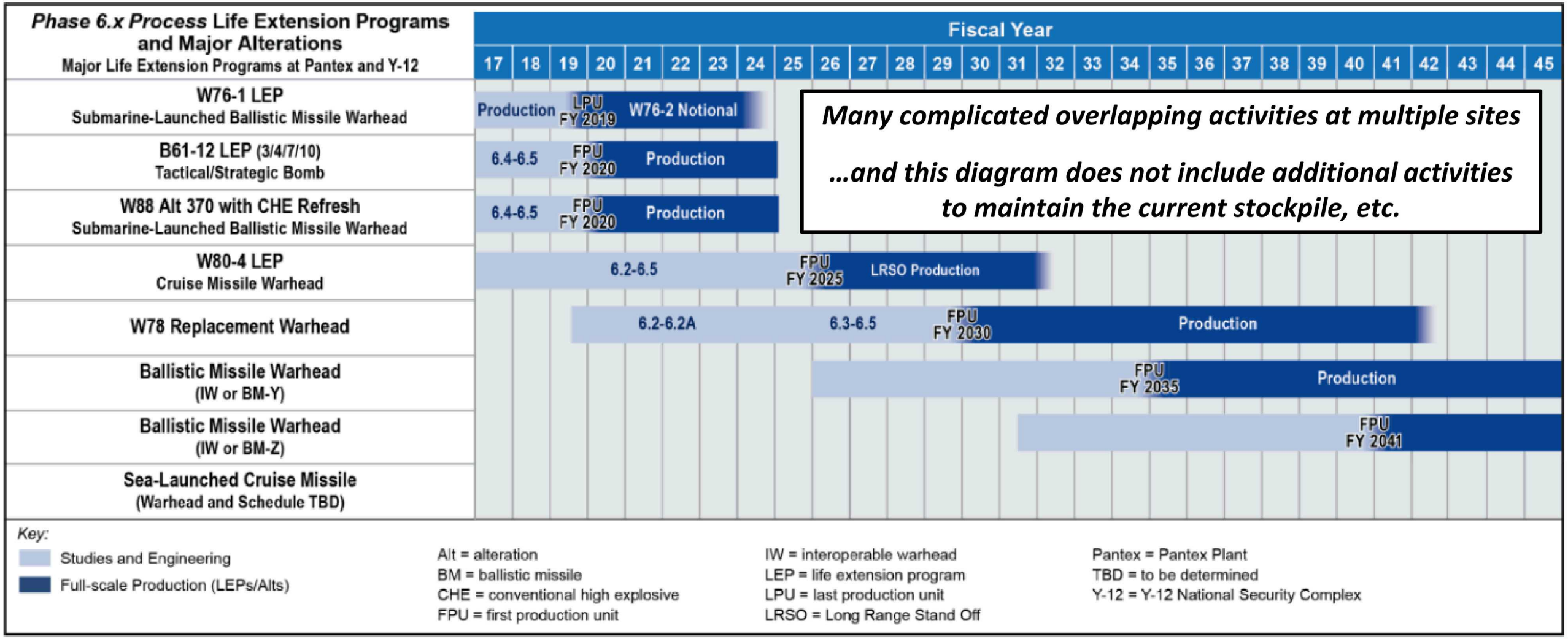
National Nuclear Security Administration Warhead Activities Overlap



2019 Stockpile Stewardship Management Plan (SSMP) Program of Record (POR)

https://www.energy.gov/sites/prod/files/2018/10/f57/FY2019%20SSMP.pdf

Stockpile Optimization Under a Resource Constrained Enterprise (SOURCE) Model Allows Us to Analyze the Integrated View

Many details must be captured to ensure all aspects of the integrated schedule are executable

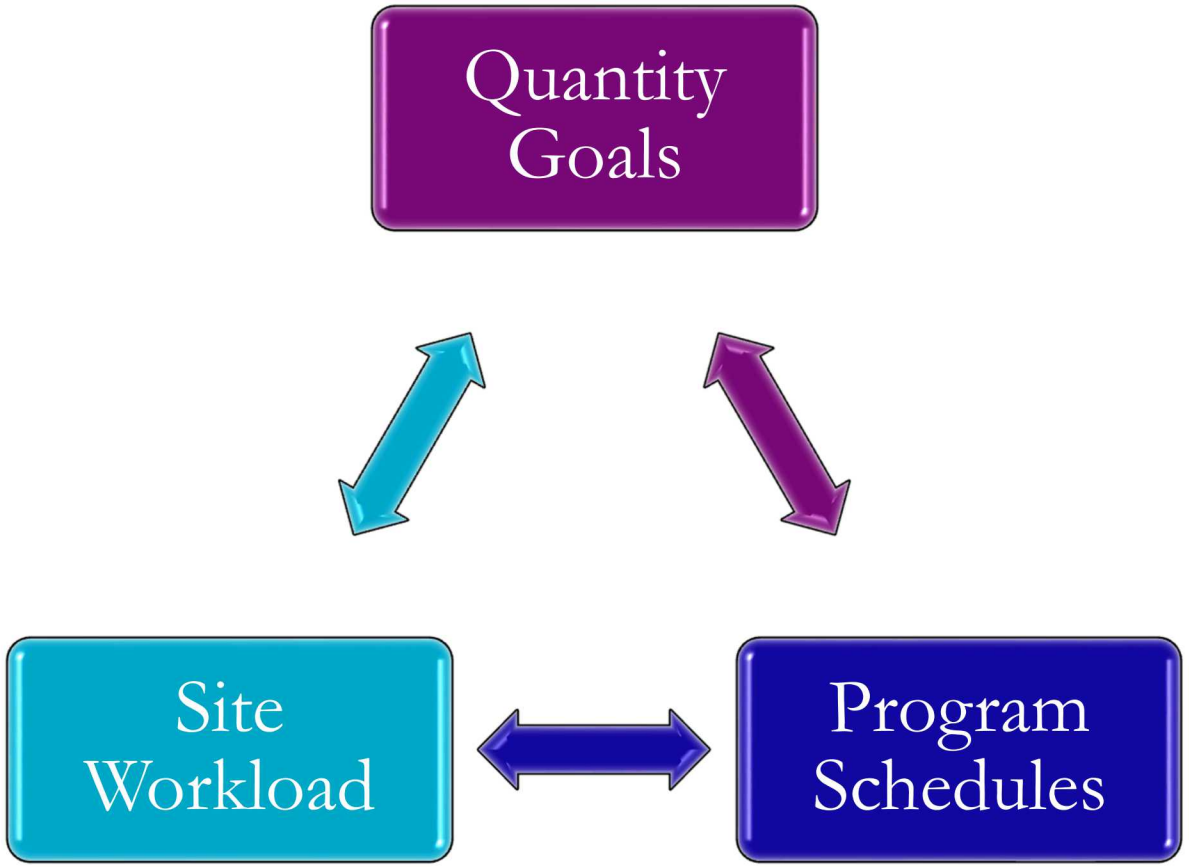
- DOD requirements
- Treaties
- Technical designs
- Ability to produce products
- Ability to execute a schedule

Given this complexity, we developed an optimization model to analyze and propose alternative stockpile plans

- Mixed-integer linear program
- Sixty-four unique constraints were identified to model the problem space

Stockpile plans must balance three major objectives

Major Model Objectives



Slide 11

SJN10 removed two modes

Samberson, Jonell Nicole, 6/3/2019

SOURCE Identifies a Schedule

Model selects first production unit (FPU) year, last production unit (LPU) year, and production quantities for systems and components subject to a variety of constraints.

FPU and LPU dates are binary decision variables that define the allowable production window

- Activities at production facilities continue until production is completed
- The number of concurrent lines can be limited at facilities, which makes this a difficult problem to solve

Sample Schedule

Notional Data

	Fiscal Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
System A	6.X Schedule																				
	System	20	20	20	20	20									20	20	20	20	20	20	20
	Component 1	63	63	56	55	54								67	66	65	68	82	82	82	82
	Component 2	20	20	20	20	20								20	20	20	20	20	20	20	20
	Component 3	20	20	20	20	20								20	20	20	20	20	20	20	20
System B	6.X Schedule																				
	System						15	15	25	25	15	15	15								
	Component 1						51	51	51	51	41	39	37								
	Component 2						15	15	15	15	15	15	15								
	Component 3						25	30	30	15	15	15	15								
System C	6.X Schedule																				
	System																10	10	10	10	10
	Component 1																				
	Component 2																10	10	10	10	10
	Component 3																				

System and Component Production Dates are Selected Simultaneously

LEGEND

- Phase 6.1-6.5
- Phase 6.6
- System Production
- Production Development
- Production Facility W
- Production Facility X
- Production Facility Y
- Production Facility Z

Stockpile Quantity Goals and Age Limits Drive SOURCE Workload

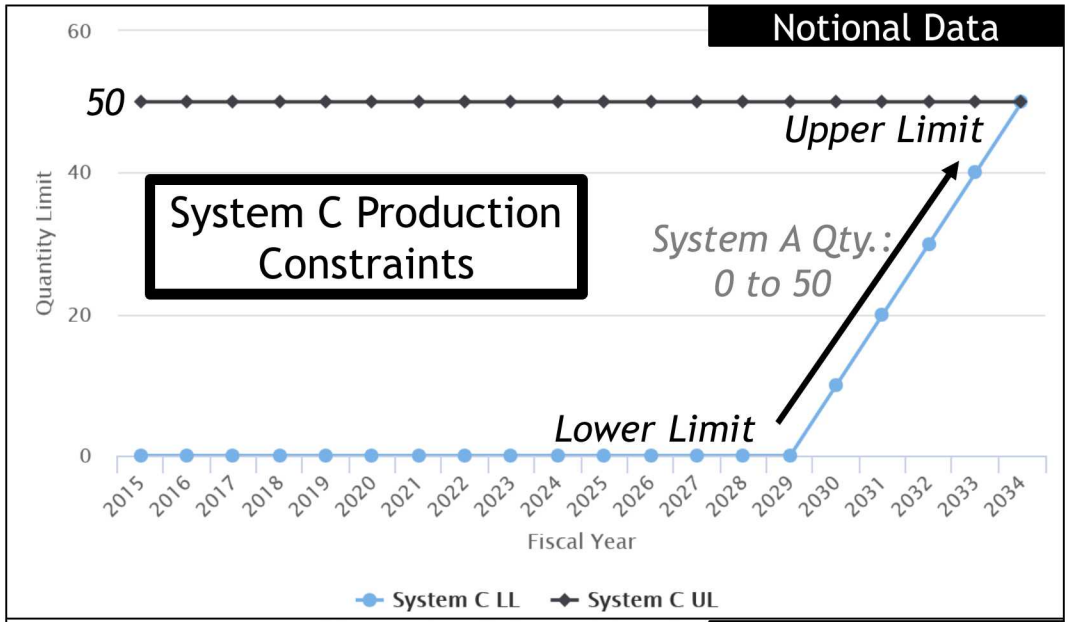
Work in the model is driven by:

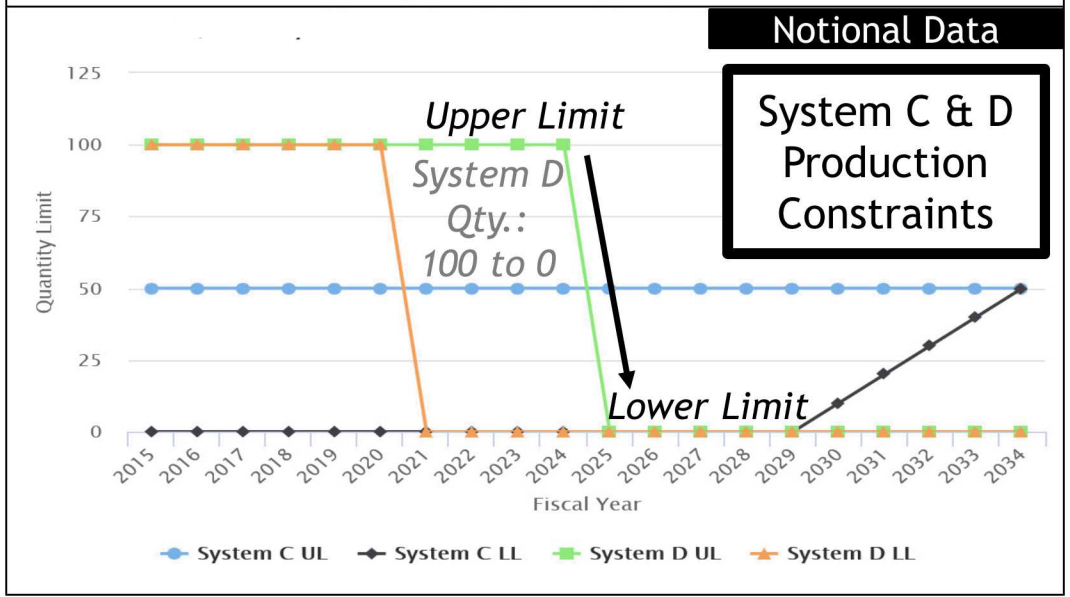
- **Quantity goals:** Upper and lower limits on system quantities for a period of time
- **Age limits:** Maximum number of years a system can be in the inventory before being dismantled or updated

The model is able to best explore alternate schedules when goals are not overly specific

If all modeling constraints are not met simultaneously, a penalty is applied

Example Quantity Goals



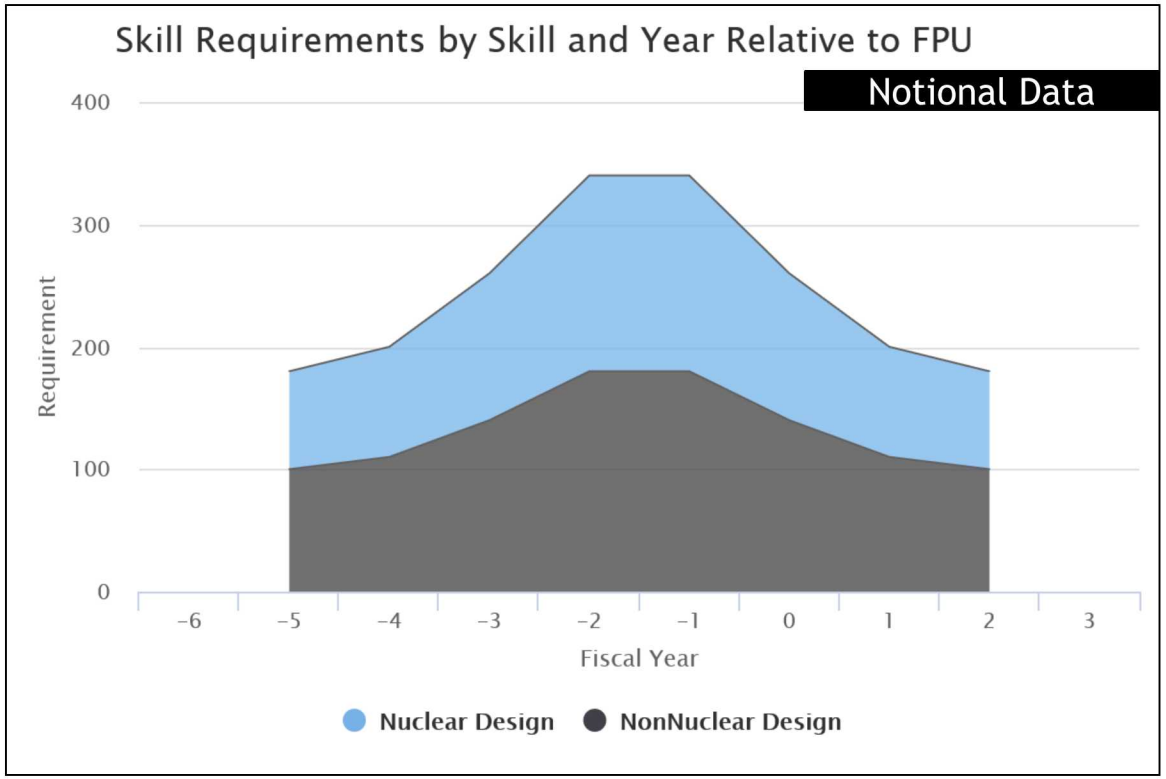


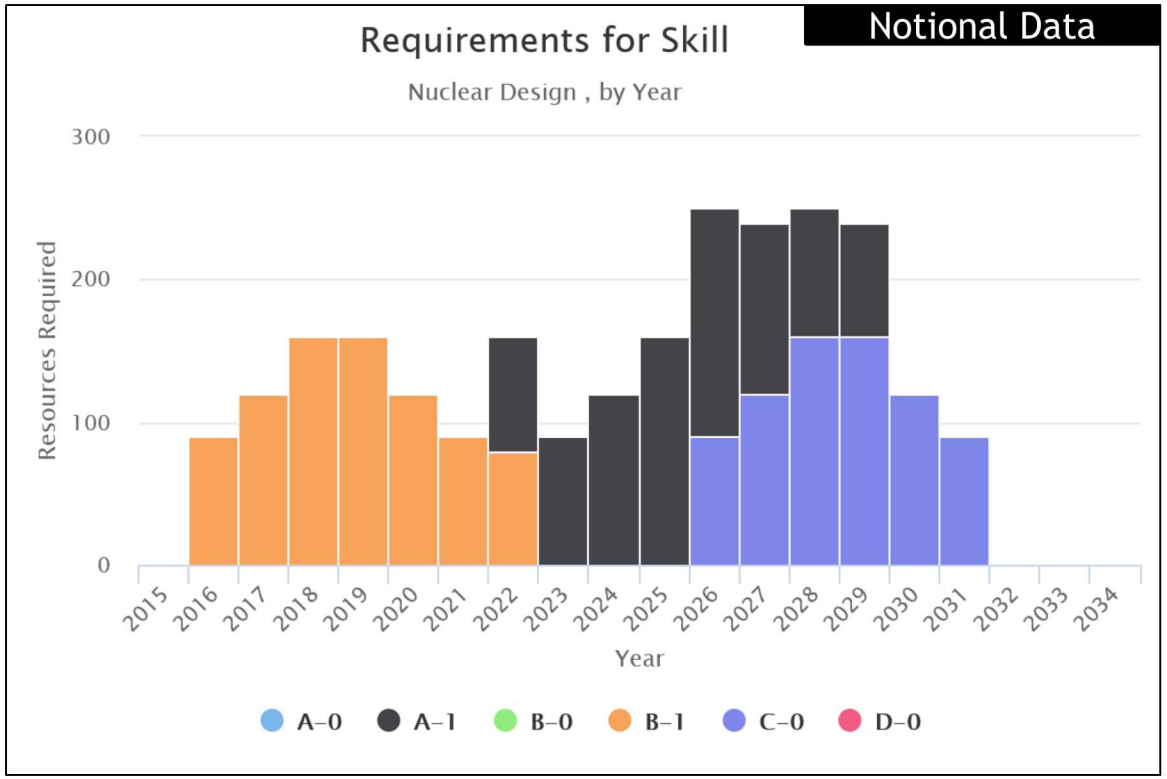
SOURCE Models Design Agency Utilization

As input, users identify skill requirements relative to FPU for each new system

- Multiple types of skills can be considered
- No assumptions made about the units that are used for skills

The model captures skill requirement workload per system once a FPU date is determined





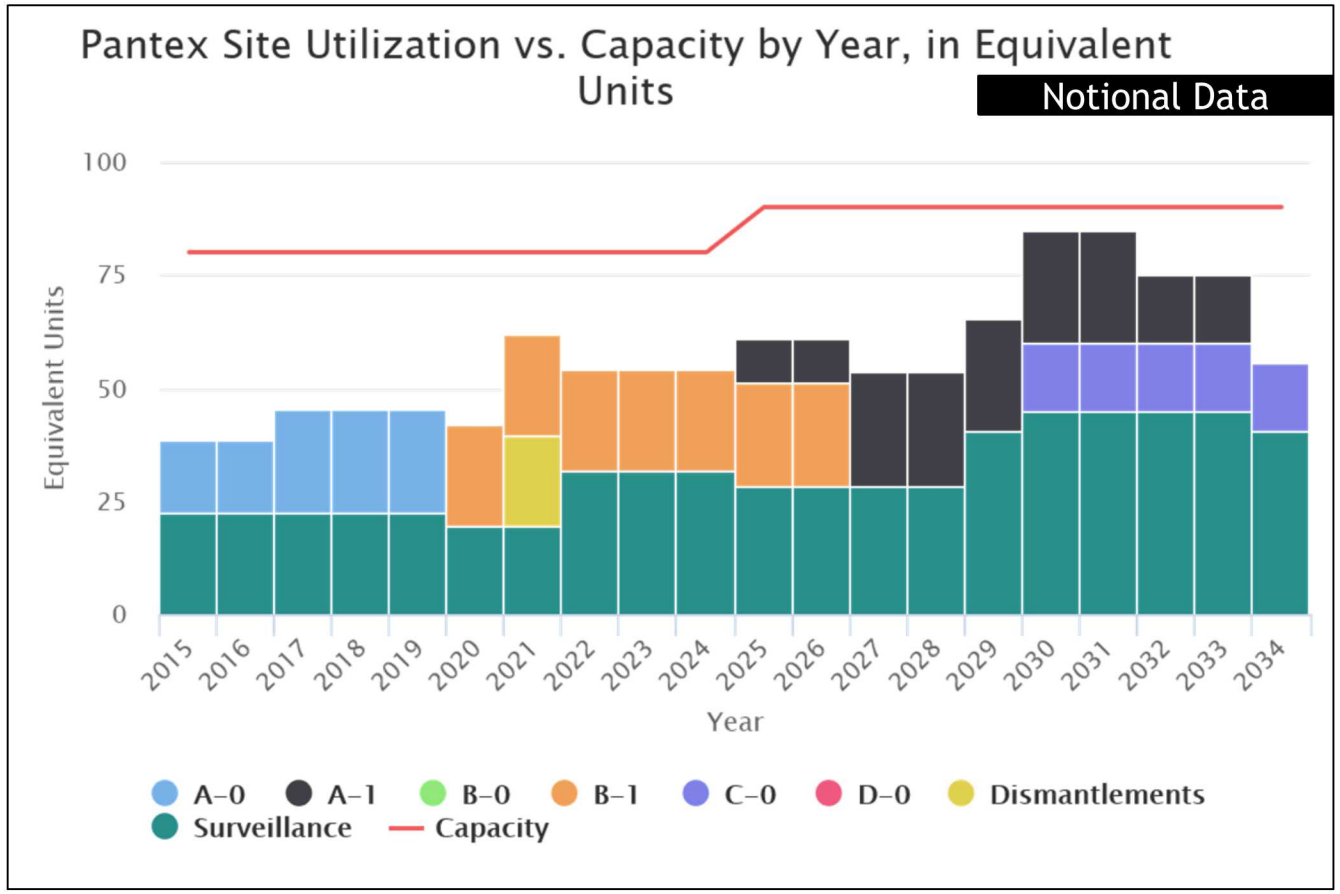
SOURCE Models Production Facilities

SOURCE contains data driven sub-models of production facilities (e.g., Pantex or component)

- Necessary for integrated enterprise analysis
- Contains enough detail about each site to ensure that model outputs are executable

Production workload and constraints modeled

- Prebuilds
- Production
- Overbuilds
- Dismantlement
- Surveillance
- Annual site capacities
- Production leveling
- Concurrent line limits
- Gaps/overlaps between batches
- Production ramps



SOURCE Model Structure

Minimize: Goal violations + Schedule deviations + Lifetime limit violations

+ Facility capacity violations + Facility leveling violations

Subject to:

- System/component continuity constraints
- System/component lifecycle constraints
- Upper and lower stockpile quantity constraints*
- Target FPU and LPU constraints*
- System lifetime constraints*
- Production facility and design agency capacity constraints*
- Workload leveling constraints*
- Other site operating constraints

** Violations of these constraints are penalized in the objective function*

Source Model Solution Approaches

Objective weights can be modified to solve model in one of two modes

1. Resource requirements: Identify necessary resources given a fixed schedule
   - Increase penalties for schedule, goal, and lifetime violations, decrease penalties for facility capacity violations
2. Resource constrained: Identify FPU/LPU dates given fixed resources
   - Decrease penalties for schedule, goal, and lifetime violations, increase penalties for facility capacity violations

Two solutions procedures:

1. Solve model in a single instance: Can be slow in resource constrained mode
2. Two step procedure: Deactivate leveling initially
   - Leveling is typically a site level concern and key dates will not be missed to accommodate leveling
   - First step solves for binary variable (FPU and LPU dates)
   - Second step fixes schedule dates and then finds the best possible schedule from the site perspective

SOURCE Modeling and Analysis **Integrates** Multiple Data Sources

Baseline Schedule

Defined Excursions to the Baseline

Analysis Driven Excursions

Example Areas of Uncertainty Analyzed by Varying Model Parameters:

- Warhead Types
- Warhead FPU/LPU
- Production Quantities
- Facility Capacity
- Warhead Design
- Component Design

Summary and Conclusions

Stockpile Optimization Under a Resource Constrained Enterprise (SOURCE) model is a large-scale mixed-integer linear program has enabled stakeholders to analysis strategic plans with an integrated view of the Nuclear Security Enterprise (NSE)

SOURCE integrates key constraints from multiple development & production entities while balancing three user-defined objectives:

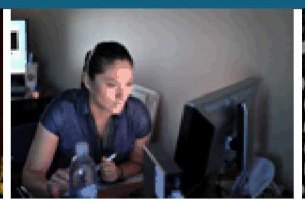
- (1) stockpile quantity goals with upper and lower limit
- (2) program schedules with desired start and end timeframes
- (3) entity workload constraints

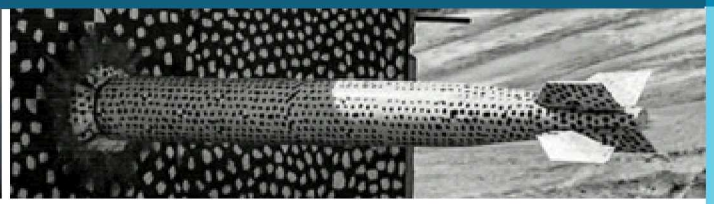
SOURCE generates program schedule solutions based upon optimization and determines expected workload for each entity using two analysis modes or a combination of both:

- (1) Resource requirements
- (2) Resource constrained

SOURCE results have been used to inform stockpile stakeholders about the feasibility of the current plan and impacts of alternative schedules and strategic plans

Analysis of Alternative Optimized Nuclear Weapon Stockpiles under a Resource Constrained Enterprise





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Related Presentation:
Chad E. Davis

Simple Strategic Planning Visualization Tool

Wednesday, June 19
Fairchild Hall, 4D62
11:30 AM

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