Technomics
Better Decisions Faster

Using TRLs to Predict the Future of Nuclear Weapons

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MEET THE AUTHORS

Our team is a mix of two contractors and one federal employee working to support the National Nuclear Security Administration (NNSA) Office of Cost Estimating and Program Evaluation (CEPE). Established in 2014, CEPE provides the NNSA Administrator with independent cost estimates for major programs, program evaluation support, and data collection & sharing, and policy counsel.

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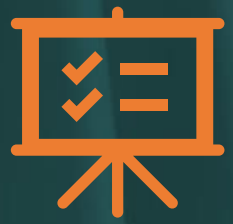
AGENDA

- What is a TRL?
- What do they mean in the NNSA?
- Schedule Estimating using TRLs
- Data/Methodology
- Results
- Future Work

What is a TRL?

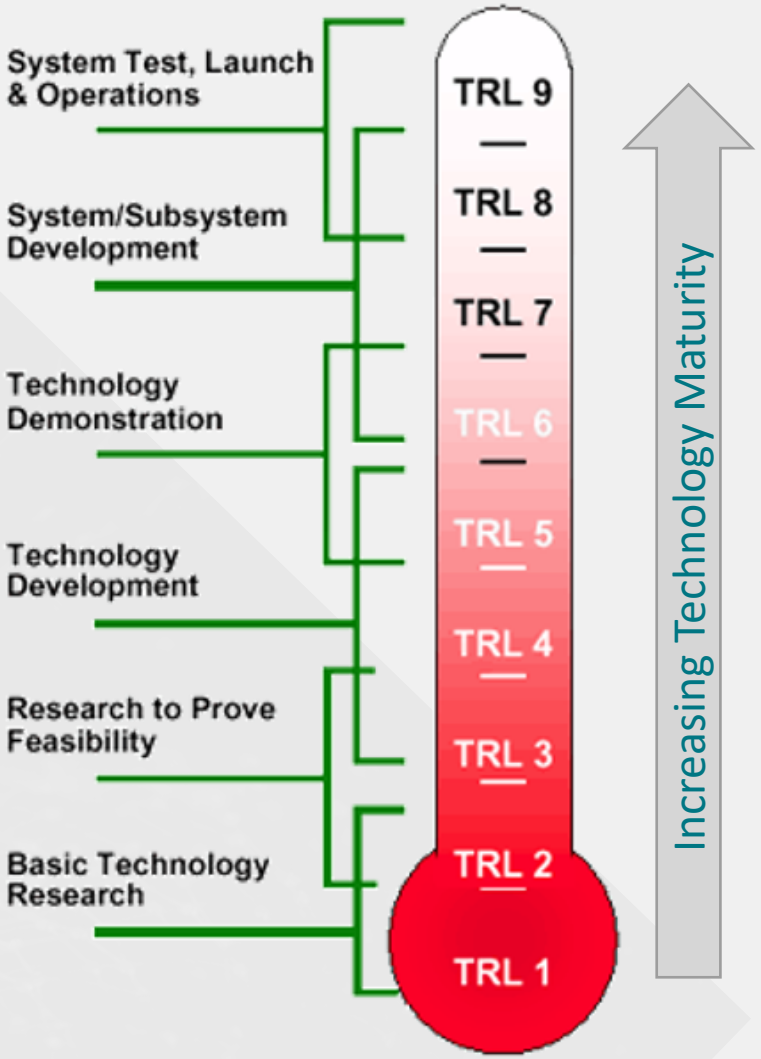


Technology Readiness Levels (TRLs) are a method for estimating the maturity of technologies prior to incorporating them into a system and ideally prior to significant funding

Good TRL analysis can prevent program managers from selecting technologies that unnecessarily increase program risk (technical, schedule, and cost)

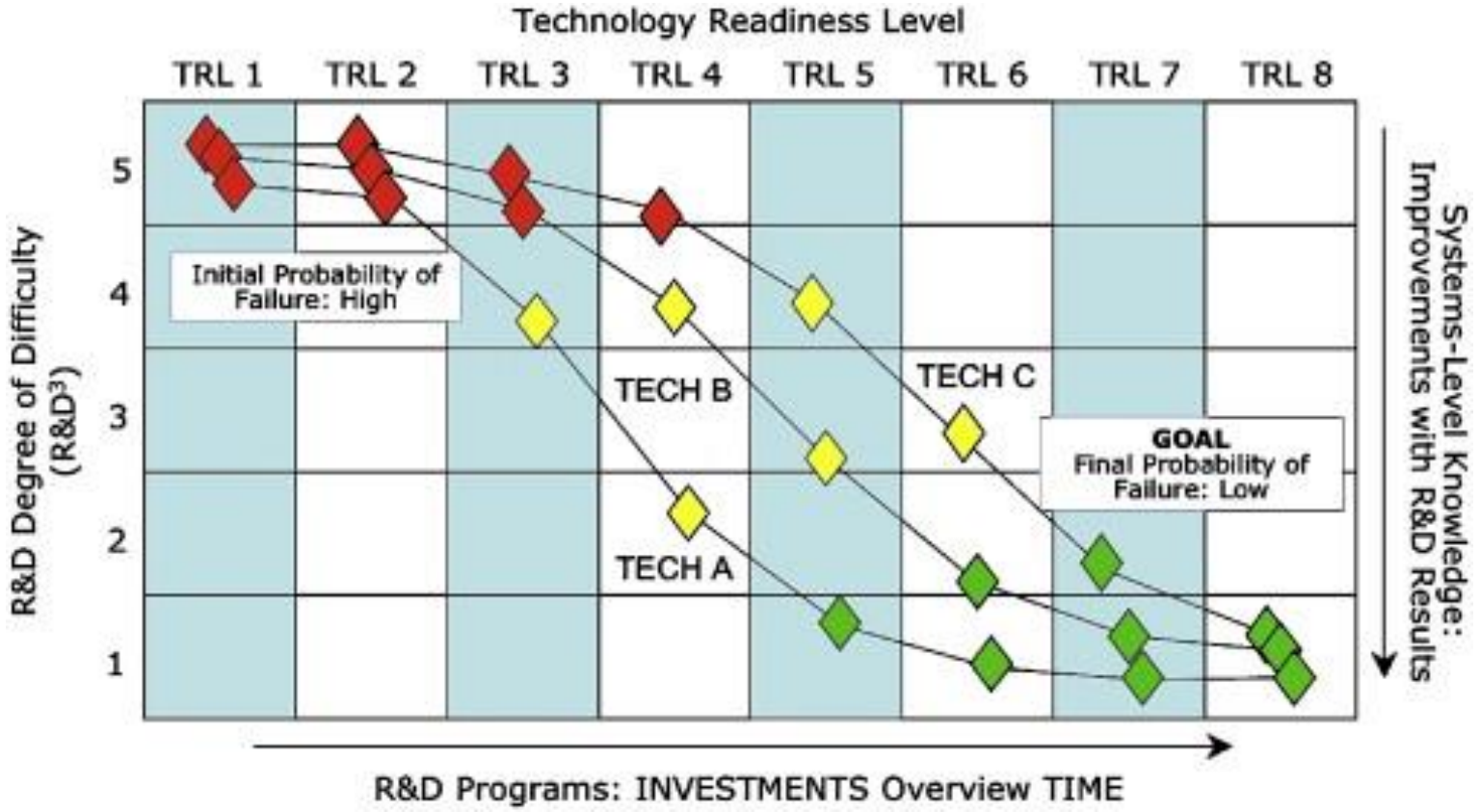
TRLs also help communicate to decision makers the technical risk a program is facing in a consistent manner

Defining TRLs

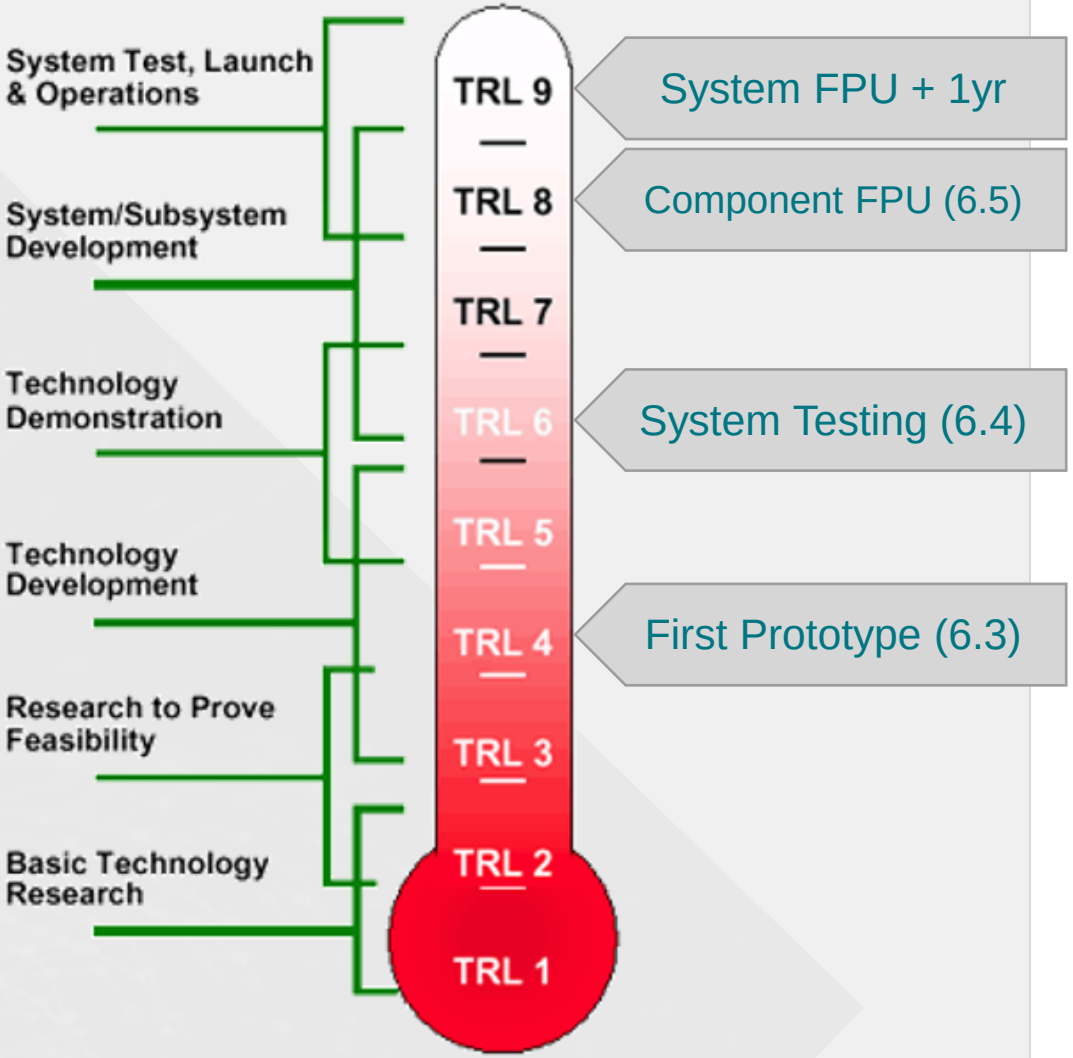


- TRLs provide a rubric, most often graded 1 through 9, that standardize the measure of maturity for a technology, component, process, or system
- Each TRL has a defined set of criteria for entry and exit, demonstrating progression; guides for TRL definition exist from GAO, NASA, DoD, NNSA, and other organizations
- Collecting the TRL also allows us to build a data-informed risk assessment of a program's schedule while accounting for the scope of technology maturity

TRLs are not an Indicator of Difficulty

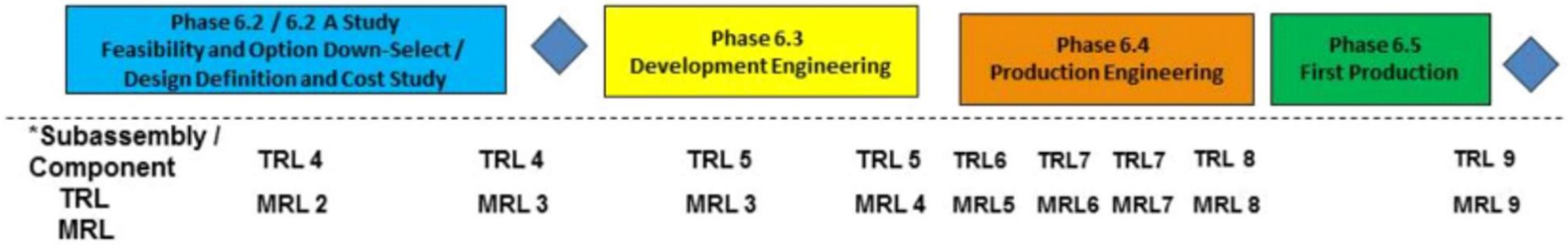


The NNSA and TRLs



- The National Nuclear Security Administration (NNSA) is charged with:
  - maintaining the nuclear deterrent
  - advancing nuclear nonproliferation
  - promoting International nuclear safety
  - providing Naval reactor fuel
- In the NNSA, TRLs are most widely used in the weapons programs; they are assessed using a Technology Readiness Assessment (TRA) and re-evaluated as the program reaches major milestones
- Assessment was previously managed by the Management & Operating (M&O) contractors, but the Systems Engineering office within Defense Programs has instituted new requirements for TRL definition and progression

The 6.X Process



* Exceptions may exist in early phases for Nuclear Explosive Package subassembly

The 6.X process – NNSA's acquisition policy – uses TRLs to inform major milestones; These are ideal states rather than requirements

Schedule Estimating using TRLs

Technique developed for an upcoming early-stage weapons program

Relies upon prior work populating a database of component TRLs over time for ongoing and completed weapons programs

Provides more detail and rigor than prior early-stage estimates based on top-level milestones

Requires potential technologies to be defined and assessed

Historical Data: Process

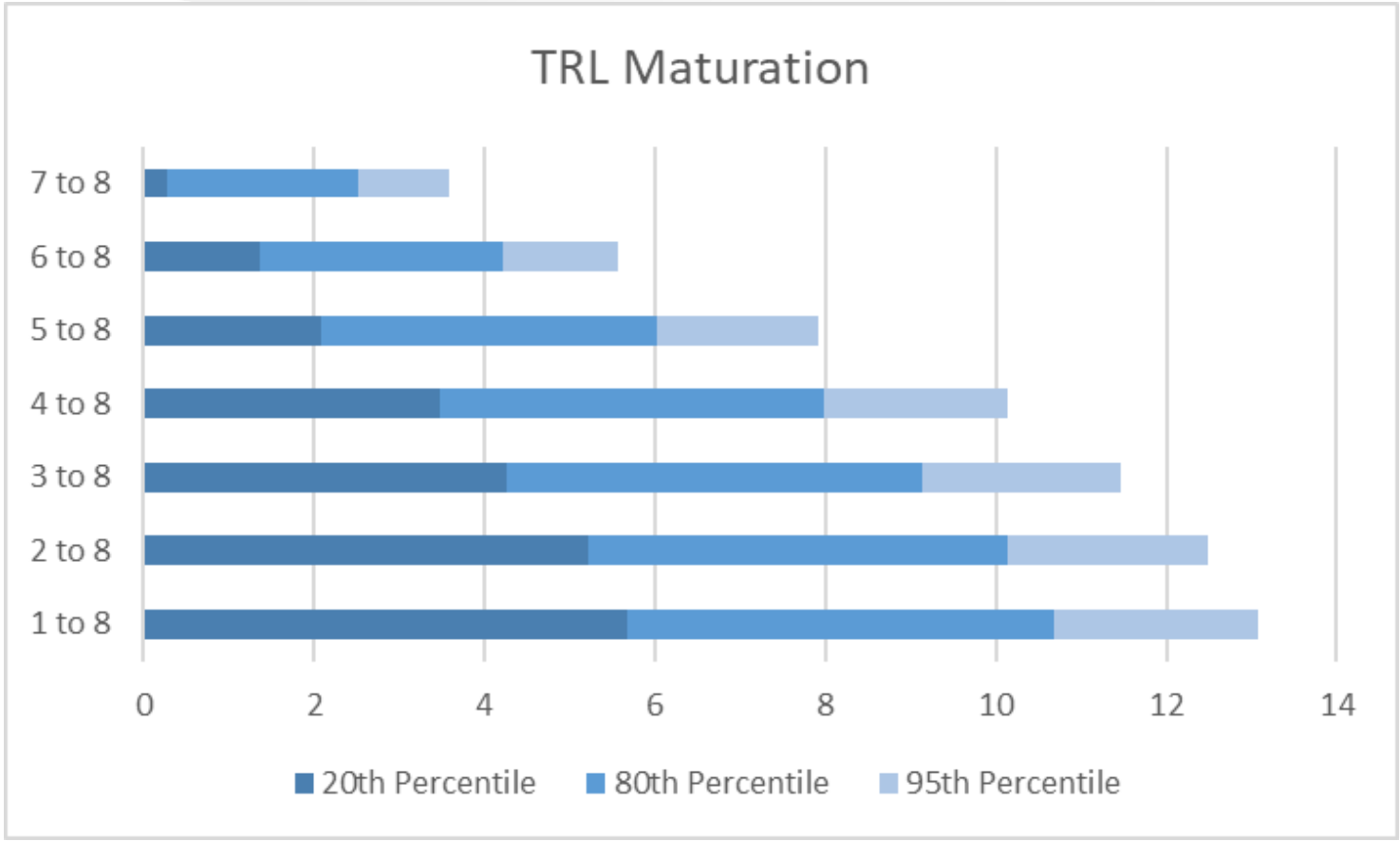
TRL (quarter reached)	1	2	3	4	5	6	7	8	9
Pit									22
Case					22	23	24	25	
Capacitor					22	24			
Enviro. Sensor		22	24	25	32	36	41	46	50
Radar				22	27	32	32	35	
Electronics		22			31	36	41	46	50

TRLs (quarters to complete)	1	2	3	4	5	6	7	8	9
Pit									
Case						1	1	1	
Capacitor						2			
Enviro. Sensor			2	1	7	4	5	5	4
Radar					5	5	0	3	
Electronics						5	5	5	4

- Defined primary data sources (site schedules, weapon design reports, CARDs) and filled in holes using secondary sources (program reviews, NIMS)
- Collected TRL actuals and projections from ongoing and completed weapons programs by component for over 400 components
- Filled gaps (see red numbers) and defined to complete each TRL for each component

Historical Data: Analysis and Results

- Using filled component data, determined mean time between each TRL
  - Sample size of 3 to 70 components for each TRL step
- Applied normal distributions on progressions to simulate time from each starting TRL to TRL 8 (component FPU)
- Determined percentage of components complete by year for each progression

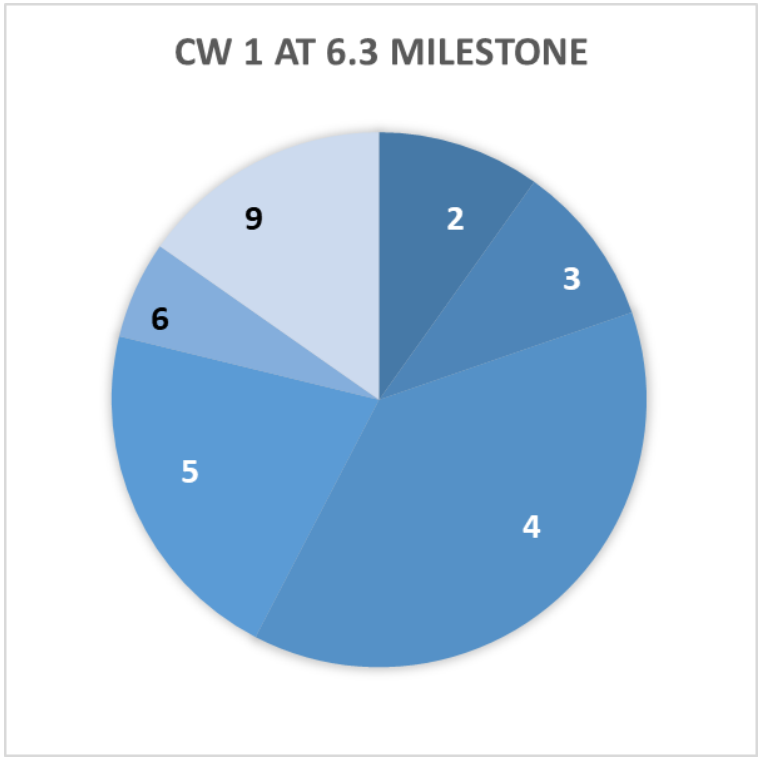


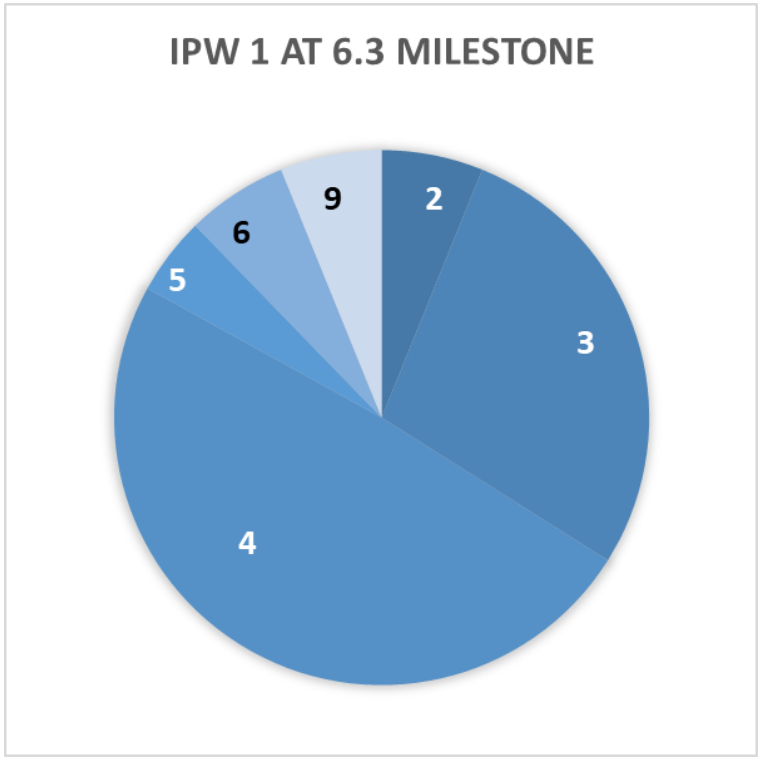
Clearly demonstrates the schedule risk of using immature technologies

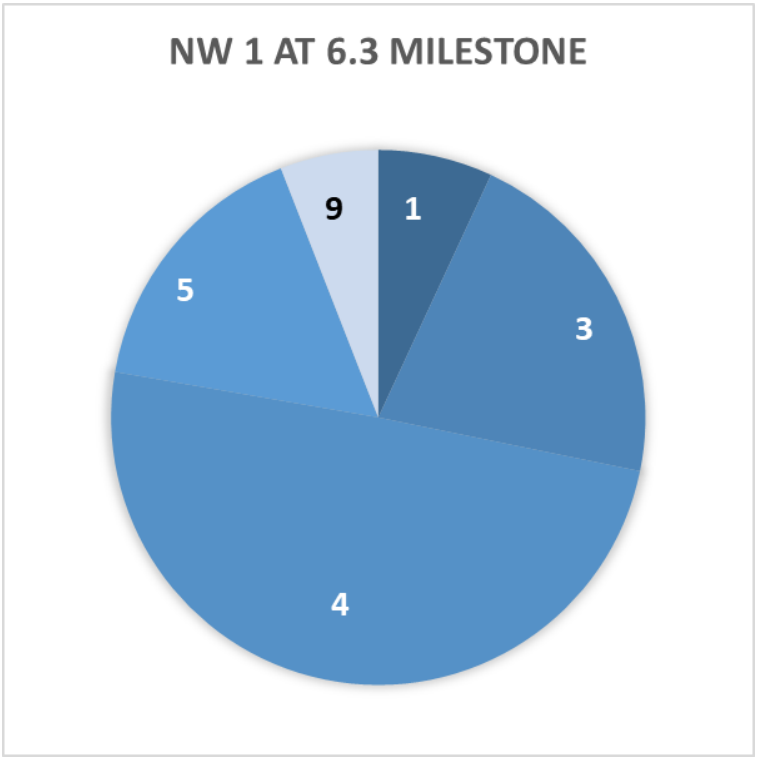
Comparing TRLs Across Programs at their Respective 6.3 Milestones

Data has been sanitized and program names have been changed to:

- Completed Warhead (CW)
- In-Progress Weapon (IPW)
- New Weapon (NW)





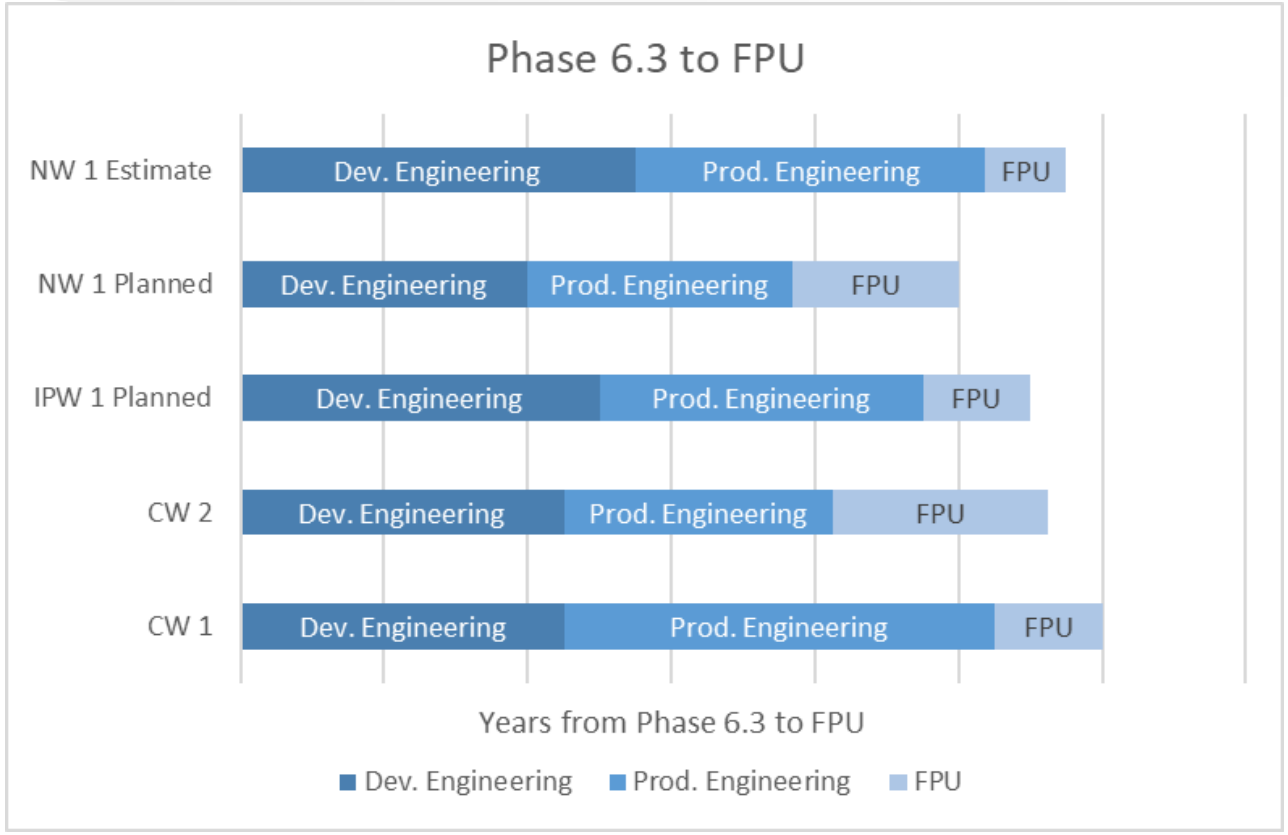


Legacy programs appear more mature at design definition than upcoming programs
Causes include: more rigorous TRL assessment, insertion of new technologies

Results and Comparison to History

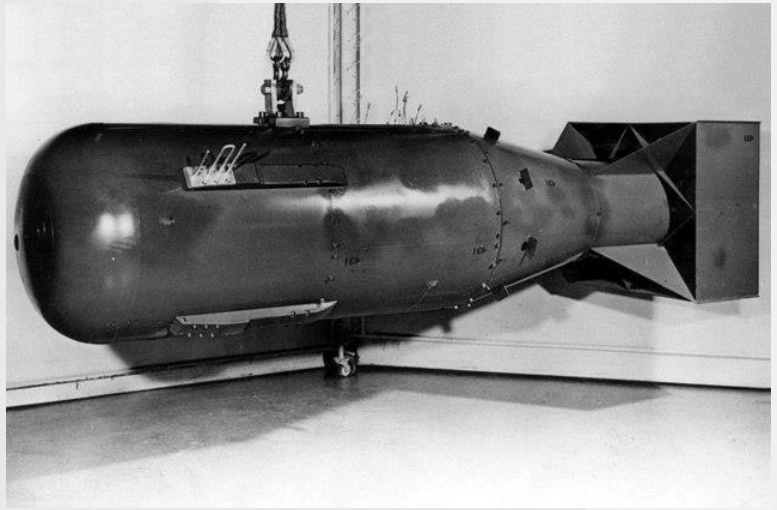
Using Projected TRLs to estimate Milestones

- Set the completion of Development Engineering for when 80% of components hit TRL 6
- Set the completion of Production Engineering for when 80% of components hit TRL 8
- Considered completion of Program FPU when 95% of components hit TRL8



Our estimate shows that NW 1 will require more time than planned for both Development Engineering (Phase 6.3) and Production Engineering (Phase 6.4) based on starting maturity

Advantages of this Analysis



Does not rely on a critical path analysis or an IMS

Allows for early program analysis before critical path or schedule is defined

Other metrics like milestones are internal and not tied to specific technical, production, or other achievements

Programs can take out “liens” on items that have faced technical or schedule risk

Clearly demonstrates the impact of the outliers in technology maturation

It doesn't matter if 80% of components are complete; if one component is incomplete the program cannot proceed

Limitations

- Due to the small size of the database, we are unable to draw conclusions about type of component or design organization
- Data is limited to the weapons modernization programs
- Currently the data skews to a shorter maturation timeline due to the age of the data and the programs
  - These programs tend to span over a decade from initial inception to Last Production Unit (LPU)
  - Components that have completed will populate high TRLs first
- We don't consider the likelihood that a component fails design or is de-scoped from the program
- This methodology is best used for an early-stage estimate before a baseline is established

Future Analysis Opportunities

- Understand the impact of more rigorous assessment
- Understand the tie between tests and TRL levels
  - What tests need to be performed to certify a TRL level?
  - What documentation needs to occur?
- Test the relationship between the milestones and TRL levels
  - What percentage of components pass TRL 6 before the 6.4 milestone?
- Discover correlations between components and define parent-child relationships rather than treat each component as equal

Future Interest: Other Readiness Levels

- Manufacturing Readiness Levels
- Production Technology Readiness Levels
- System Readiness Levels
- Integration Readiness Levels
- Producibility

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