SAND2020-5542C

An Expert Elicitation Method for Estimating Probabilistic Schedule Risk During Conceptual System Design

PRESENTED BY

Robert Pedersen and Jarret Lafleur, PhD

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One Challenge: Nuclear Modernization Design Decisions

Joint DOE/DoD Phase 6.X Process

6.1	6.2	6.2A	6.3 Development Engineering	6.4 Production Engineering	6.5	6.6
Concept Assessment	Feasibility Study & Option Down-Select		Design Definition & Cost Study		First Prod.	Full Scale Production

Military Need

However, cost and schedule risk can be **most strongly influenced** during design concept generation and downselection – **before schedule risk is formally assessed.**

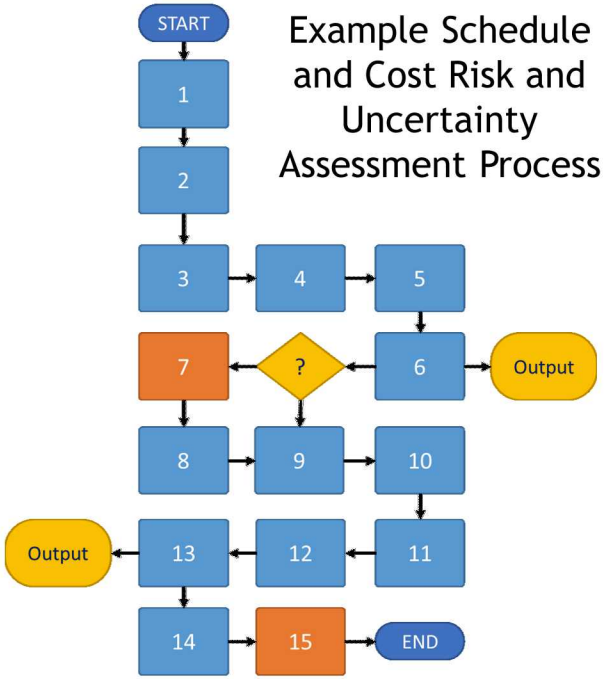
How can we **quickly and quantitatively assess schedule risk to enable defensible risk-informed design downselection during conceptual design?**

Weapon Design & Cost Report (WDCR)

Recent Example:

- >1 year effort
- >100 contributors across 40 component teams
- Schedule, cost, risk, and uncertainty estimates produced for 40,000 activities
- Baseline design option already selected

Example Schedule and Cost Risk and Uncertainty Assessment Process



Example Problem

You are a project manager.

Product committed for delivery in 8 years that captures both the development engineering and production engineering periods.

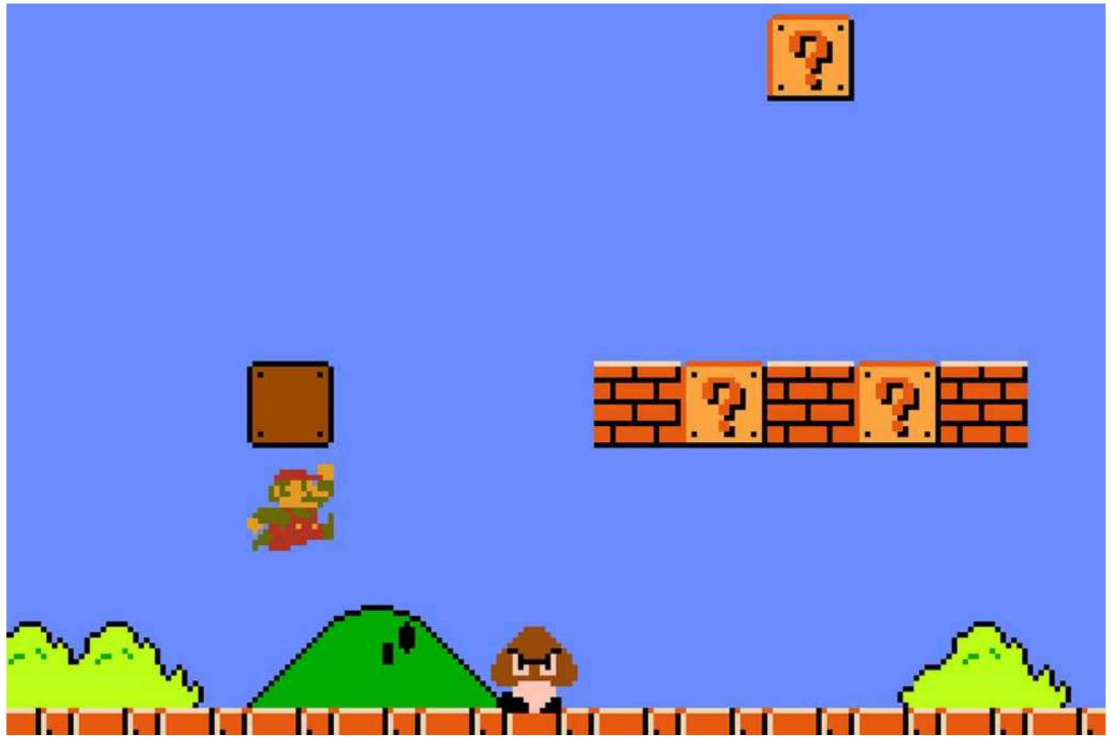
Contains three components, two with multiple design options.

Each component design option differs not only the time that engineers expect for realization, but also in schedule delay risk (for instance, due to its technology readiness).

You can't find statistical data on schedule expectations or delays for prior or similar products.

Your executive management wants to know in one week which product options are most likely to meet the given 8-year delivery commitment.

What Does This Methodology Accomplish?



From https://www.newyorker.com/culture/cultural-comment/how-video-games-changed-popular-music

Expert elicitation methodology

Versus

From https://boingboing.net/2015/09/14/super-mario-maker-levels.html

Detailed schedule risk analysis

Developing the Methodology

Developing the Methodology

Develop Survey

Subject Matter Expert Elicitation and Wagers

Set Up Distribution

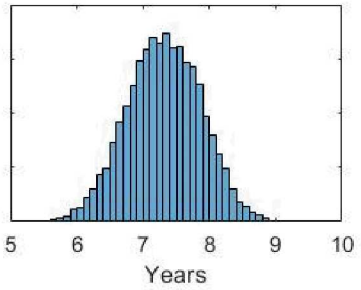
Convert SME Estimates to Subsystem Probability "Building Blocks"

Set up Monte Carlo

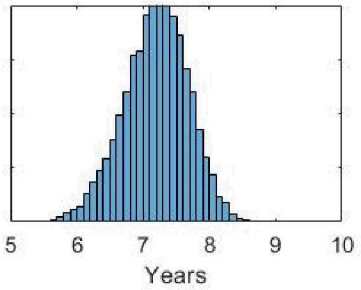
Simulate full system option schedules

Results

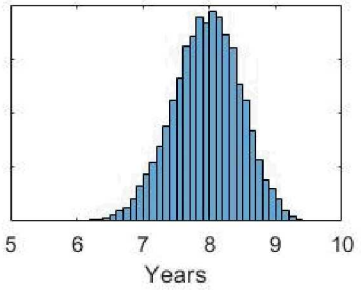
Option 1



Option 2



Option 3



… and so on

Develop Survey

The value of this methodology is increased when a well-thought out, holistic survey calibrates a respondent's mindset:

- Identify key product features (Do they already exist? Are they new?)
- Identify historical trends (Has a particular component or process delayed past schedules?)
- Identify process factors (How will a quality assurance timeframe affect overall results? TRL/MRL?)
- Identify external factors (Are components dependent upon an external organization's timely completion?)

Question set is scalable across multiple, independent benchmarks/iterations (TRL, MRL, for example)

Develop Survey

After reviewing questions in the survey, a respondent has more data points on the mind in order to make a better 'wager' on an accurate timeframe for a specific system/product's subcomponent

Component Schedule Confidence: Distributing 100 poker chips across different bins to assess a level of confidence, use the tables below to indicate how long the component will most likely take to complete during Phase 6.3 and 6.4 of the Phase 6.X cycle? Consider component development uncertainty but exclude major unforeseeable external factors like government shutdowns, Nuclear Weapons Council ordered pauses, or abnormally lengthy budget Continuing Resolutions.

Phase 6.3 Component Development Completion

Range (years)	Chips
Below 0.5	
0.5 to 1	
1 to 1.5	
1.5 to 2	
2 to 2.5	
2.5 to 3	
3 to 3.5	
3.5 to 4	
4 to 4.5	
More than 4.5	

Phase 6.4 Component Development Completion

Range (years)	Chips
Below 0.5	
0.5 to 1	
1 to 1.5	
1.5 to 2	
2 to 2.5	
2.5 to 3	
3 to 3.5	
3.5 to 4	
4 to 4.5	
More than 4.5	

Set Up Distribution

Wagering Distribution

Range (years)	Chips
Below 0.5	0
0.5 to 1	0
1 to 1.5	0
1.5 to 2	0
2 to 2.5	0
2.5 to 3	0
3 to 3.5	10
3.5 to 4	30
4 to 4.5	40
More than 4.5	20

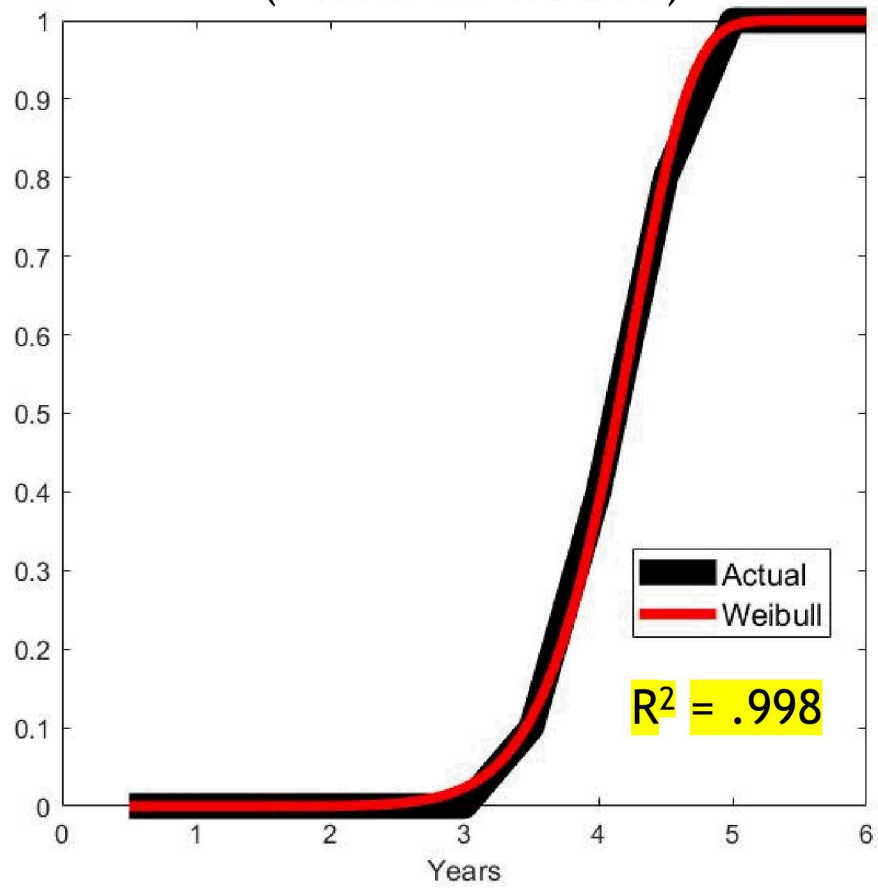
CDF

Converting to Cumulative Distribution Function

Range (years)	CDF
Below 0.5	0
0.5 to 1	0
1 to 1.5	0
1.5 to 2	0
2 to 2.5	0
2.5 to 3	0
3 to 3.5	.1
3.5 to 4	.4
4 to 4.5	.8
More than 4.5	1

Least Squares Fit to Weibull Distribution

Cumulative Distribution Functions (Actual vs. Weibull)



$$f(t) = \begin{cases} 1 - e^{-(x/\lambda)^k} & t \geq 0 \\ 0 & t < 0 \end{cases}$$

$$f(t) = \begin{cases} 1 - e^{-(x/4.288)^{10.453}} & t \geq 0 \\ 0 & t < 0 \end{cases}$$

Set Up Distribution

Design Options	
1	$A + B_1 + C_1$
2	$A + B_1 + C_2$
3	$A + B_1 + C_3$
4	$A + B_2 + C_1$
5	$A + B_2 + C_2$
6	$A + B_2 + C_3$

Option 4

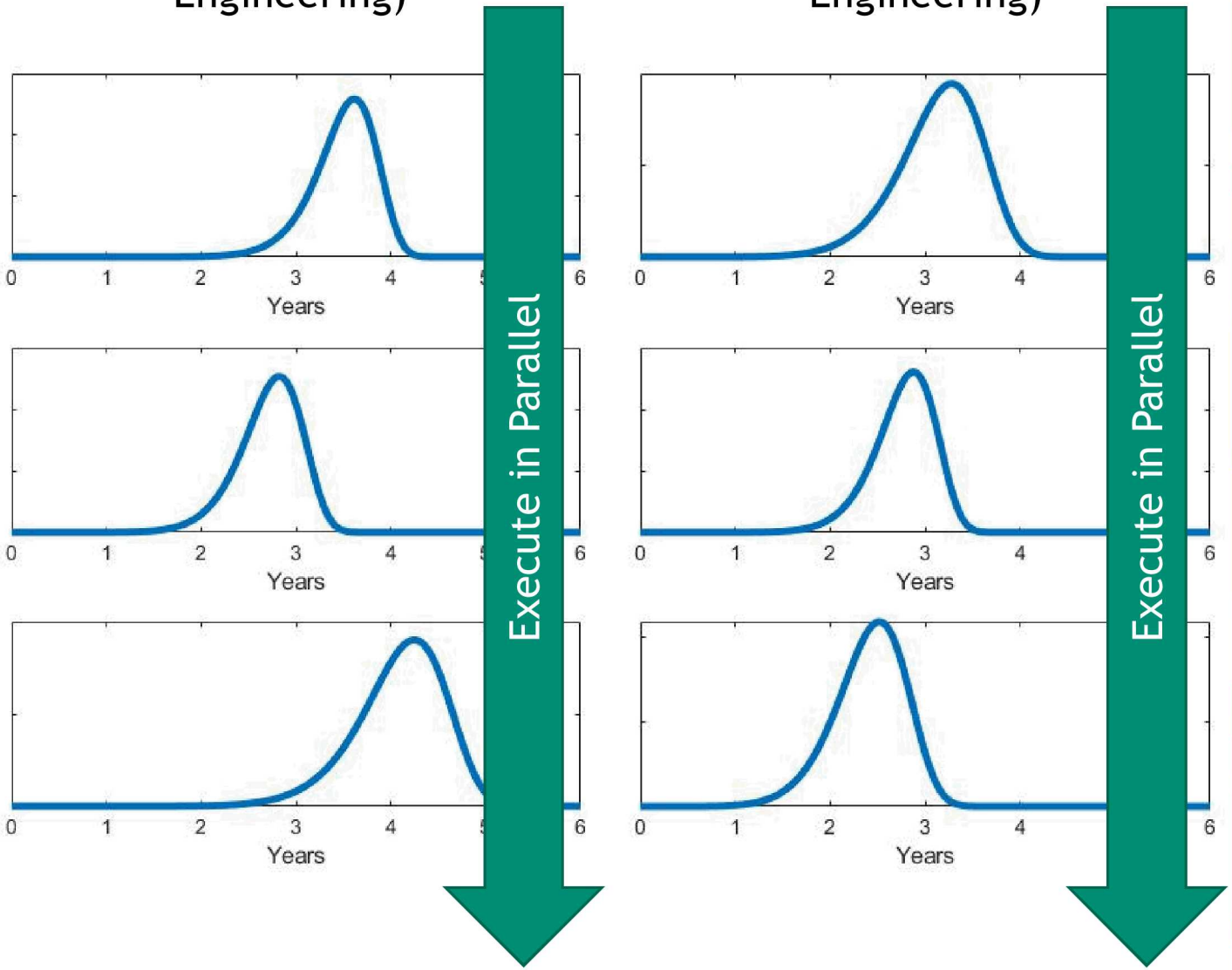
Component A

Component B_2

Component C_1

Phase 6.3 (Development Engineering)

Phase 6.4 (Production Engineering)



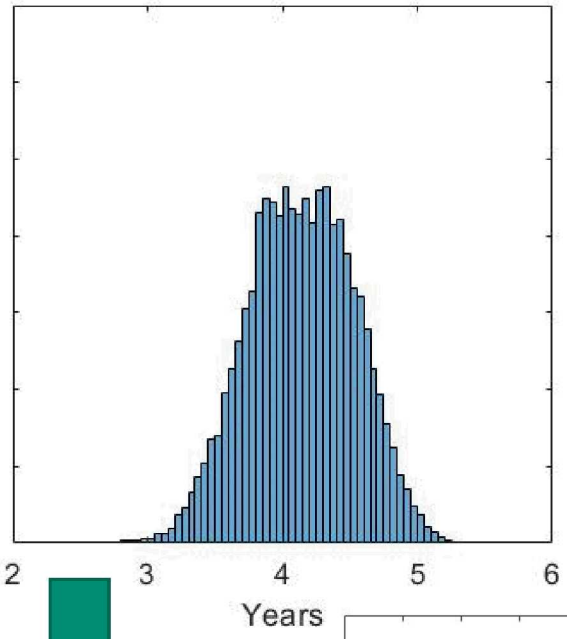
Set Up Monte Carlo

Option 4

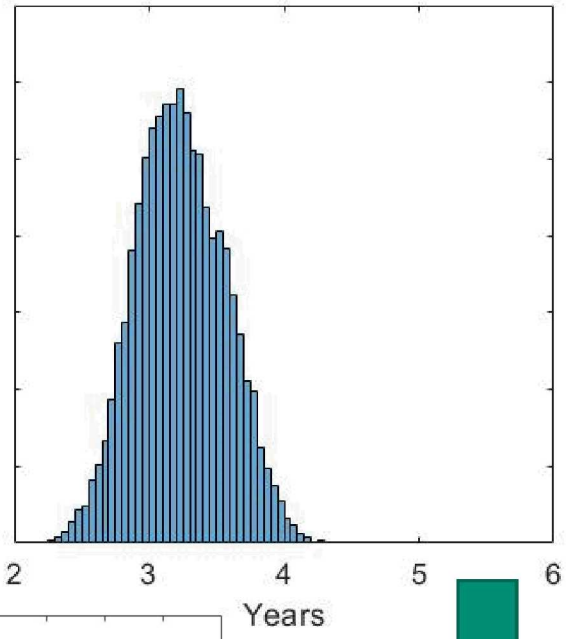
Design Options	
1	$A + B_1 + C_1$
2	$A + B_1 + C_2$
3	$A + B_1 + C_3$
4	$A + B_2 + C_1$
5	$A + B_2 + C_2$
6	$A + B_2 + C_3$

System Time (maximum time of option's component combination)

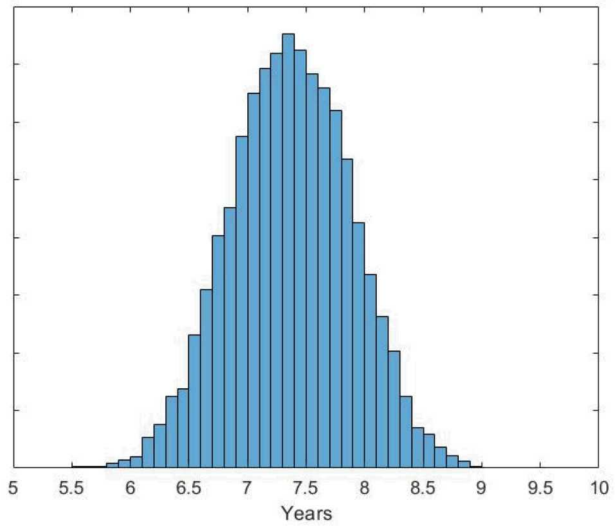
Phase 6.3 (Development Engineering)



Phase 6.4 (Production Engineering)

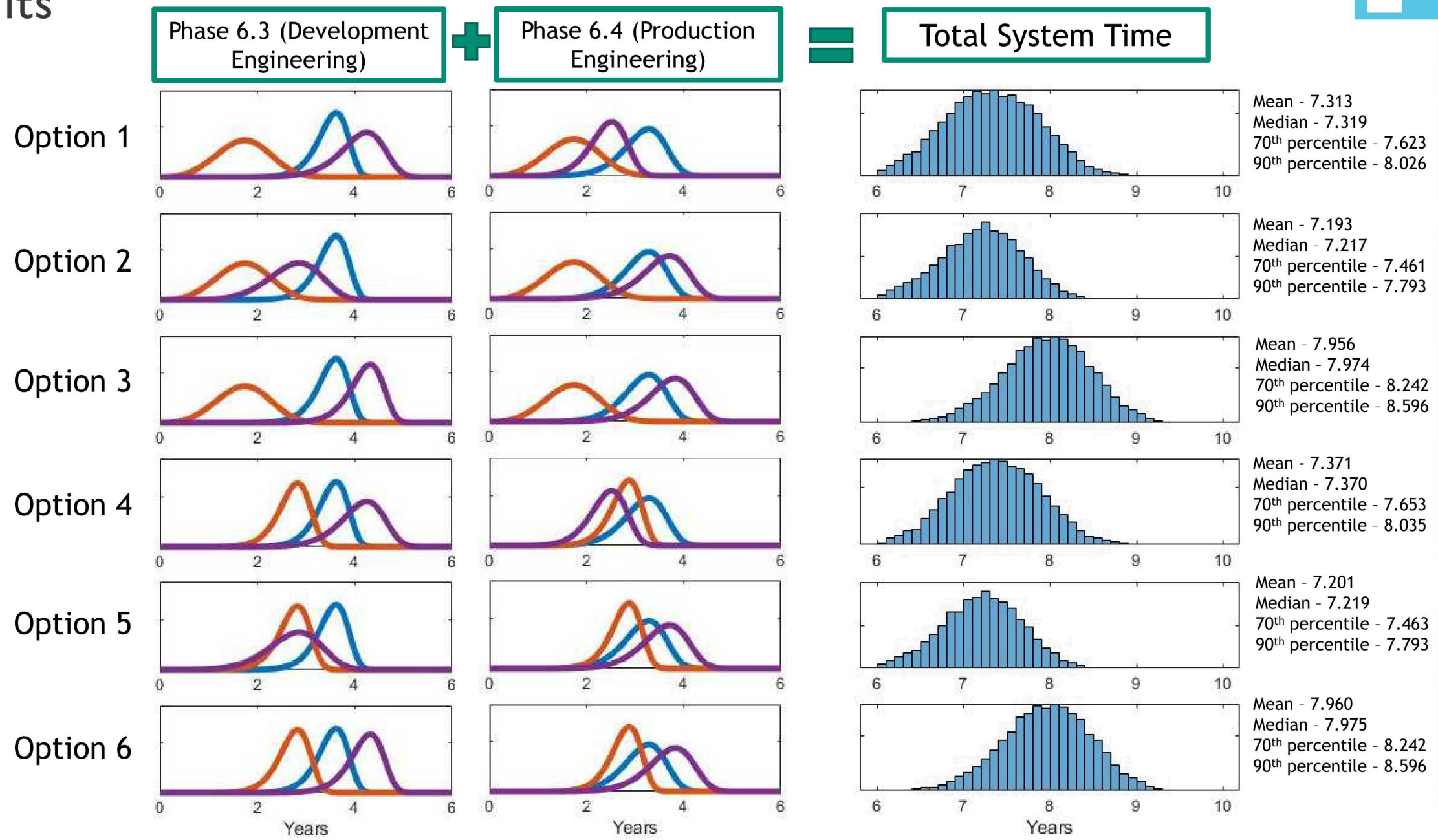


Option 4
Total Time (6.3 + 6.4)



Results

Results



Legend

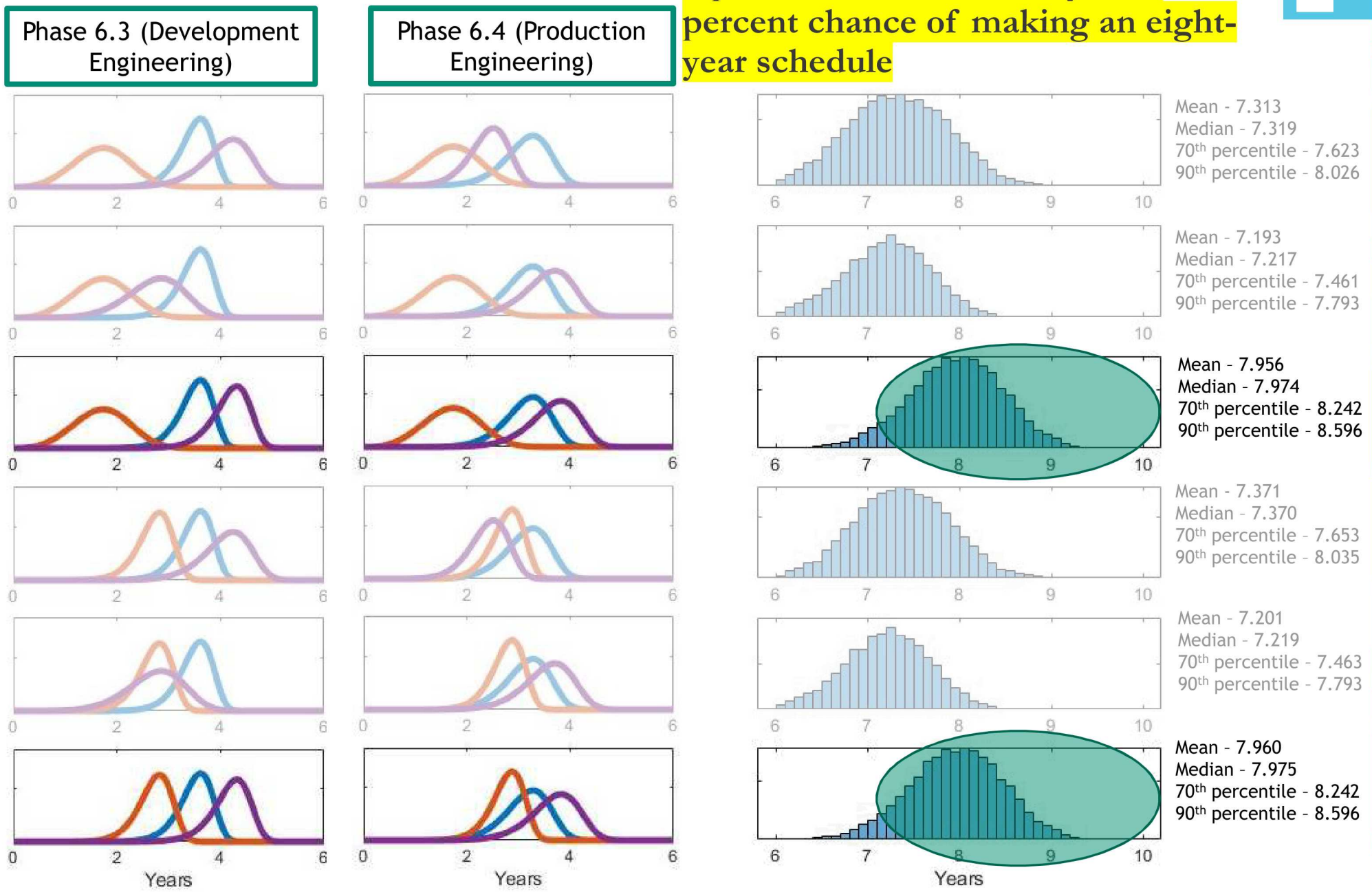
Component A

Component B

Component C

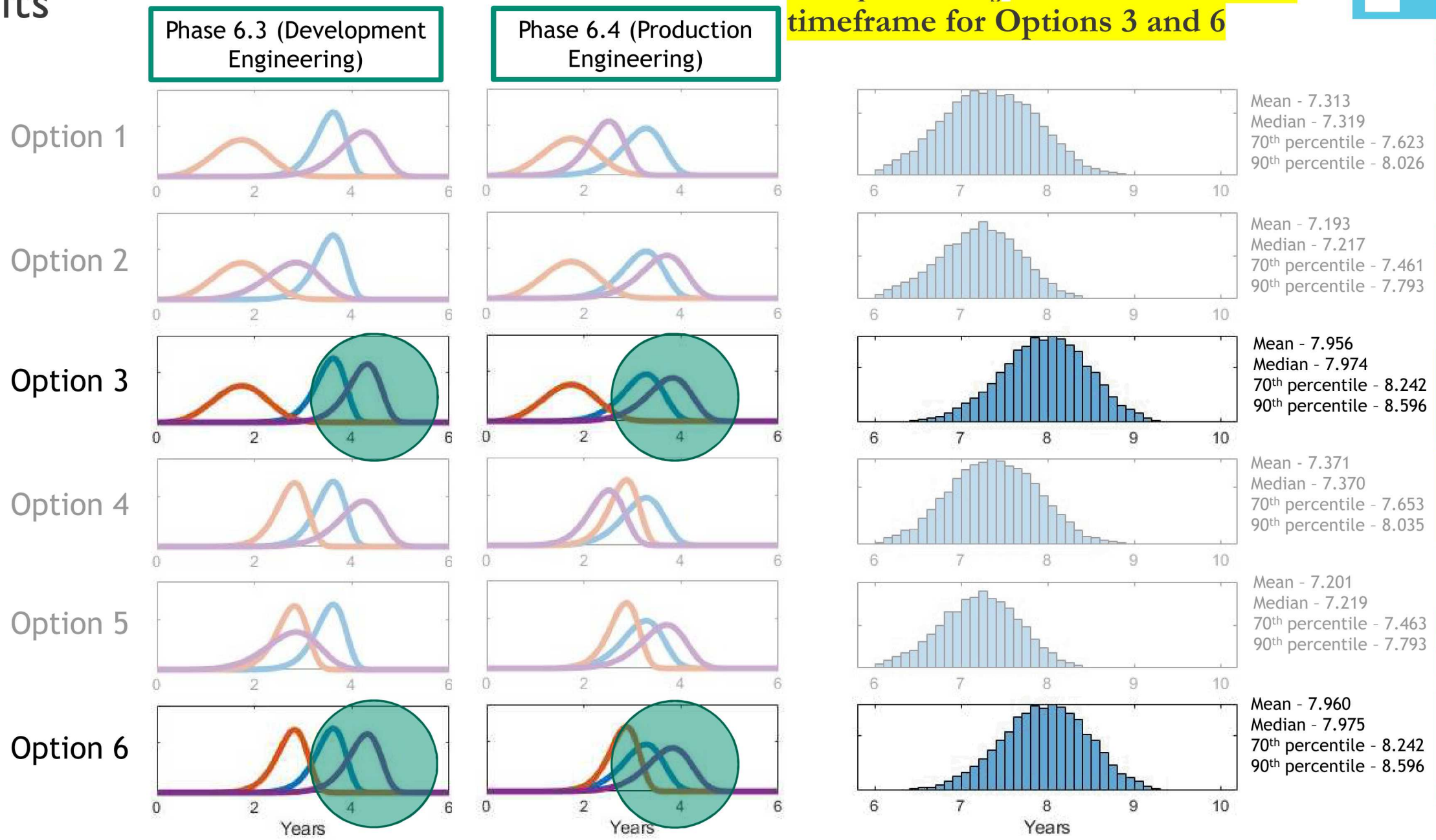
Results

Options 3 and 6 have only a 48 percent chance of making an eight-year schedule



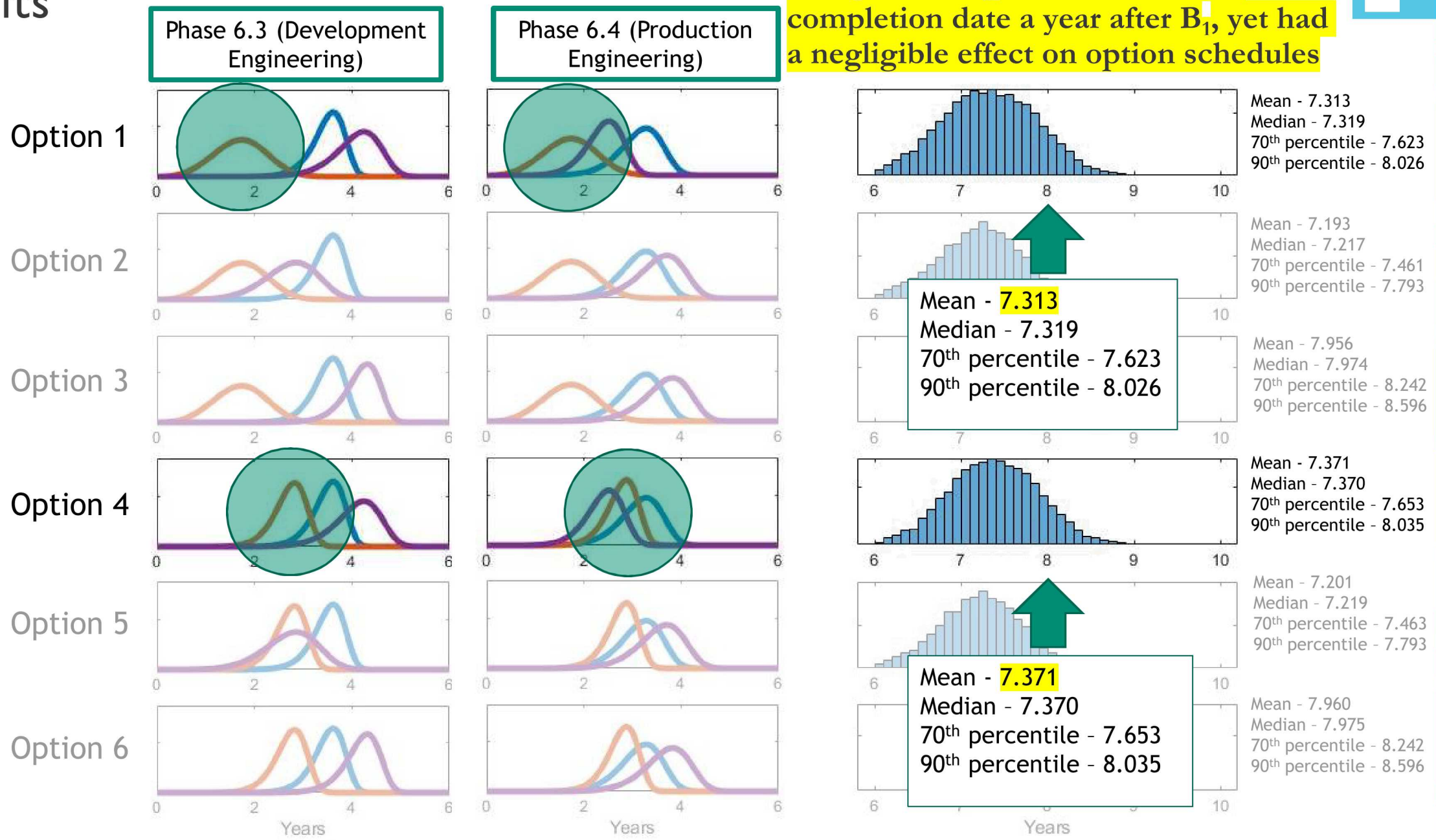
Results

Component C_3 extends deliverable timeframe for Options 3 and 6



Results

Component B_2 had an estimated completion date a year after B_1, yet had a negligible effect on option schedules



How Can These Results Assist With Decision-Making?

Identify infeasible options

- Example: Options using C_3 have only a 48 percent chance of making schedule (CDF for C3)

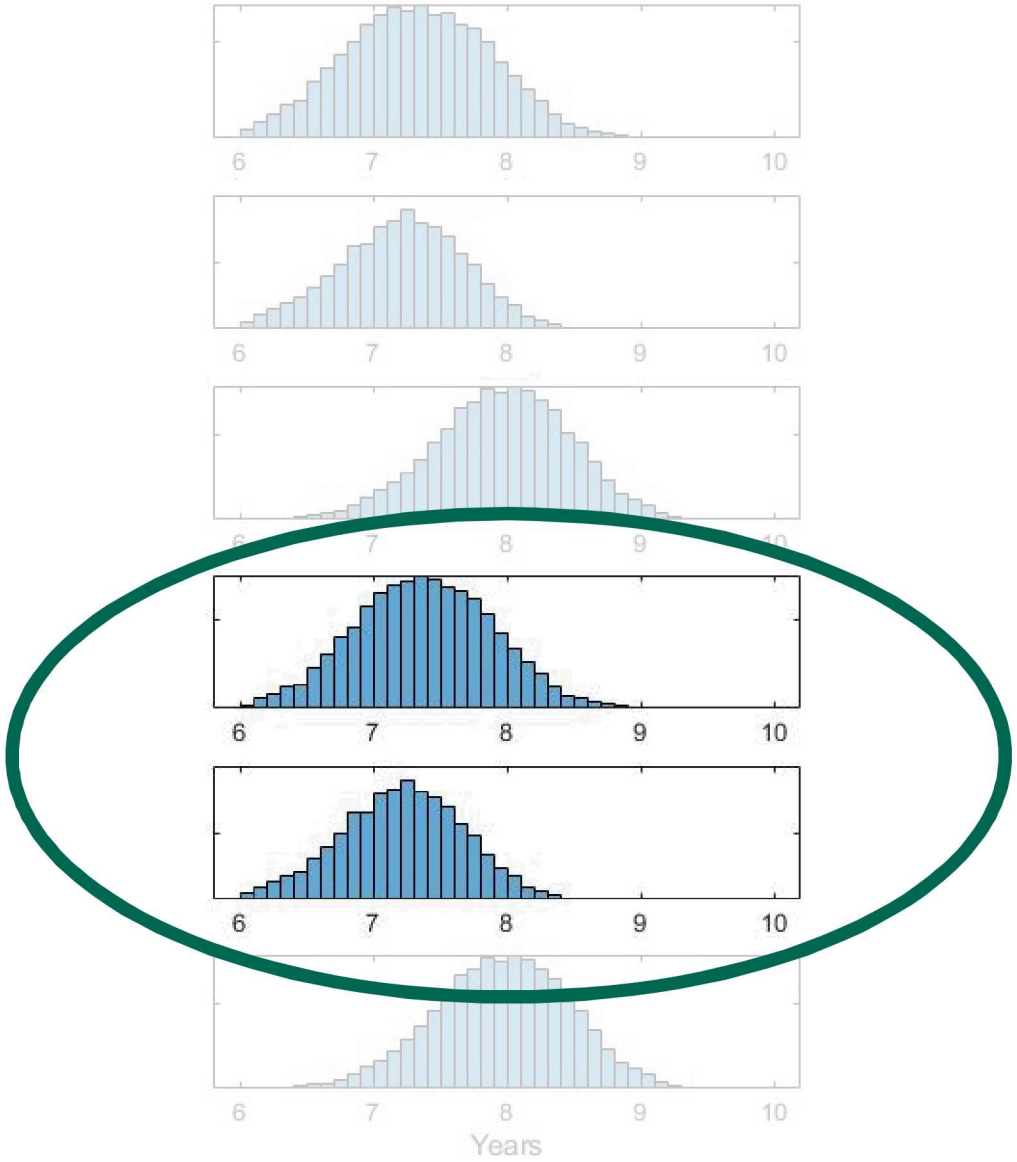
Identify schedule drivers

- Example: Options using C_3 extends schedules between 7 – 9 months

Identify options with negligible schedule impact

- Example: Even though B_2 was higher-risk than B_1, B_2 delivery had negligible effect on overall option schedules

Considering the information above, what are our viable options?



Summary and Next Steps

This is a quick process that:

- Gets information to decision-makers before formally assessing schedule risks
- Provides transparency
- Provides results that take advantage of anchored SME understanding of options
- Identifies magnitude of schedule risks of design options introduced
- Enables more informed selections that lead to detailed, formal studies

Limitations and next steps:

- Requires SMEs for input
- Potential for uncorrected SME bias
  - Next step – compare SME estimate to empirical, historical data
  - Next step – survey multiple SMEs for same component
- Challenging to validate, especially for any single program
- Coupling with qualitative approaches