

Conditioning the Schedule for Quantitative Risk Analysis

Cost and Schedule Symposium
NASA Glenn Research Center, 27 August 2026

David T. Hulett, Ph.D., FAACE

Keith D. Hornbacher, M.B.A.

Hulett & Associates LLC

Integrated Cost Schedule Risk Analysis (ICSRA) with Monte Carlo Simulation

David Hulett, Ph.D., FAACE, Principal



Contact: +1.310.283.3527
david.hulett@projectrisk.com

- Leads Hulett & Associates, LLC project management consultants
- 30+ years of risk analysis and management experience supporting clients in the US, Canada, South America, SE Asia, Middle East and Europe.
- Oil and gas (refineries platforms, pipelines, oil-sands, LNG), pharmaceuticals, vertical construction, aerospace.
- Clients are commercial, foreign national oil companies and US Government agencies including NNSA, GAO, GSA, NASA .
- AB at Princeton, Ph.D. at Stanford in Economics.
- Instructor in Economics at Harvard, economic analyst at the Federal Reserve Board of Governors, management positions at Office of Management and Budget and Department of Energy. Worked in strategic planning at Tosco and TRW.
- Active in AACE International with the DRM community, conference papers. Authored or co-authored 6 recommended practices and 11 articles in Cost Engineering
- Moved to the Denver Area, still upgrading the house, have a German Shepherd 85 lbs. named Sundar (“beautiful” in Hindi)

IMS Should Follow Important Best-Practices* Scheduling

The IMS supports its purposes:

- An IMS is used to show how the contract can be met.
- The IMS supports managing and progressing the project.
- Usually this requires scheduling at the lowest level possible.

Does the IMS also support the ICSRA based on Monte Carlo simulation of the CPM model?

*See NASA Schedule Management Handbook, 2024 (NASA Schedule Handbook), NASA Cost Estimating Handbook Version 4.0 & Appendix J, 2015 (NASA Cost Handbook), and the GAO Schedule Assessment Guide, 2015 (GAO Schedule Guide).

Some Scheduling Best Practices say that Lags may be OK if they are “Minimized and Justified”

Lags between activities. Positive lags placed on logical links act as a delay between activities. This creates a “ghost” activity

- During regular IMS updates the duration of lags placed in the IMS to account for the predecessor’s taking more than planned time can be shortened by the amount of the predecessor’s slips.
- In an SRA, lags hold their duration during simulation. Hence, they can overestimate risk impacts by double-counting the work of the ICSRA.

During Monte Carlo simulation (MCS):

- A lag’s duration cannot be affected by risks
- Recommend convert the lag into an activity if it reflects work, otherwise delete it

Some Best Practices say that Date Constraints may be OK if they are “Minimized and Justified”

Date constraints disrupt flow in logical systems. Constraints can override logical inter-dependencies.

- The objective for the IMS is to eliminate or replace all “hard” or “rigid” constraints with logical structure.
- Backward pass constraints do not affect the risk analysis since simulation only looks at forward pass dates.
- Fixed dates may be crucial to model risk in ***special cases***. Examples are spaceflight missions (launch windows) and maritime shipping (sail away dates).
- These constrained dates should be used for comparison with the scheduled or risk-informed results BUT NOT DRIVE the schedules dates in simulation. If risks cause these special dates to be missed, that is information the program / mission needs to know.

The IMS May not Contain Work that is Performed by Others since that is Out of the Contractor's Scope

- The schedule that is ready for Monte Carlo simulation needs to represent ALL THE WORK AND PRODUCTS required for the complete scope.
- “The Integrated Master Schedule (IMS) is the “when” of P/p scope. It supports all internal NASA P/p and all external contractor activities, when applicable. The purpose of an IMS is to provide a time-phased plan for performing the P/p’s approved total scope of work and achieving the P/p’s goals.”
- The IMS may represent receiving that equipment but may not represent the work and risks that might delay the project’s prime contractor’s receipt

Analysis of a Contractor-Provided Schedule During Execution

If the project is slipping behind schedule, the IMS may have to change to hold milestones to the project contract dates even if no longer supported by the original logic and duration of the project plan

- The IMS may be required to place some activities in parallel (S-S, F-F) that should be, and will actually be, in series (F-S)
- The scheduler may be required to use durations that are “as short as possible,” claiming “that could happen, right?”(this inserts malpractice in the estimates)

Requiring that the IMS matches the contract’s dates may affect the unconstrained total float or even the identity of the critical path.

Scheduling Best Practices vs. the IMS Conforming to the Contract

Using practices such as constraints and lags that may be best-practice permissible if “minimized and justified” and not showing out of scope work would make the IMS an imperfect source as the platform of the project risk analysis effort.

Adjusting the risk analysis schedule if it does not agree with the IMS represents starting the analysis with an unrealistic schedule

The IMS milestone dates may be inconsistent with the contract unless constraints are used

Will the IMS reflect missing a flight window if the logic and activity duration indicate this?

Consequences of Creating a Schedule to Support Simulation

A schedule being produced to support ICSRA using realistic not-biased durations and complete / correct logic containing all required work but without lags and constraints:

- May show a deterministic (before ICSRA) overrun that would differ from the finish date of the IMS.
- Focus on the “negative float” paths indicating problems and leading to potential de-scoping
- May also show different critical path, total float from IMS

Get the IMS schedulers involved in resolving these issues and the fit-for-purpose schedule risk analysis results.

- Need to certify that the schedule used for ICSRA represents the project suitable for that purpose even if its pre-ICSRA results differ from those of the IMS

Credible Risk Analysis Platforms

Guidance to Conditioning Schedules for Quantitative Risk Analysis (QRA) using Monte Carlo Simulation (MCS)

Source References to Risk Drivers and Risk Models, AACE International Recommended Practices (RPs):

- *RP 57R-09 Integrated Cost and Schedule Risk Analysis using Risk Drivers and Monte Carlo Simulation of a CPM Model (“RP 57R”)*
- *RP127R-23 Choosing Among Strategic Alternatives Using Branching Concepts In Decision Modeling (“RP 127R”)*

Keith Hornbacher, M.B.A., Sr. Associate



Contact: +1.612.269.8398
keith@hornbacherassociates.com

- 40+ years of risk analysis and management experience with clients in the US, Canada, Mexico, SE Asia, Middle East, Portugal, and Denmark; a Raytheon Program Risk Manager (WAAS); aerospace / defense, and commercial CapEx mega-projects, including the Canadian offshore platform in iceberg alley (Hibernia); water infrastructure mega-project (Pacific Northwest)
- Co-founded MN certified veteran owned small business *HORNbacher & ASSOCIATES* with Kristin Hauser, RMP, in 1993 after being VP/Managing Consultant, and Risk Analysts (Log/an, Inc., Los Angeles)
- Engagements include USAF advanced tactical fighter (stealth), oil and natural gas (refineries, platforms, pipelines, oil sands); US agencies including GAO, DOE, NASA, AOC, and NAVFAC (vertical construction)
- Affiliated Faculty, Univ. Pennsylvania, Organizational Dynamics Graduate Studies (15+ years); BSc (IA State Univ.), MBA (MN State Univ.)
- Co-authored RP 127R, revision to RP 57R AACE International; contributed to the *Application Guide for Systems Engineering in the Infrastructure Domain*, and *SEBoK*, International Council on Systems Engineering (INCOSE), Risk SME
- Played string bass during university competition at the Notre Dame Jazz Festival; USMC jet attack (A6 Intruder), airline (B727/B707) pilot

Establish Purposes of the Quantitative Risk Analysis (QRA)

Given: technically healthy schedules & cost estimates, credible QRAs are useful to analyze*

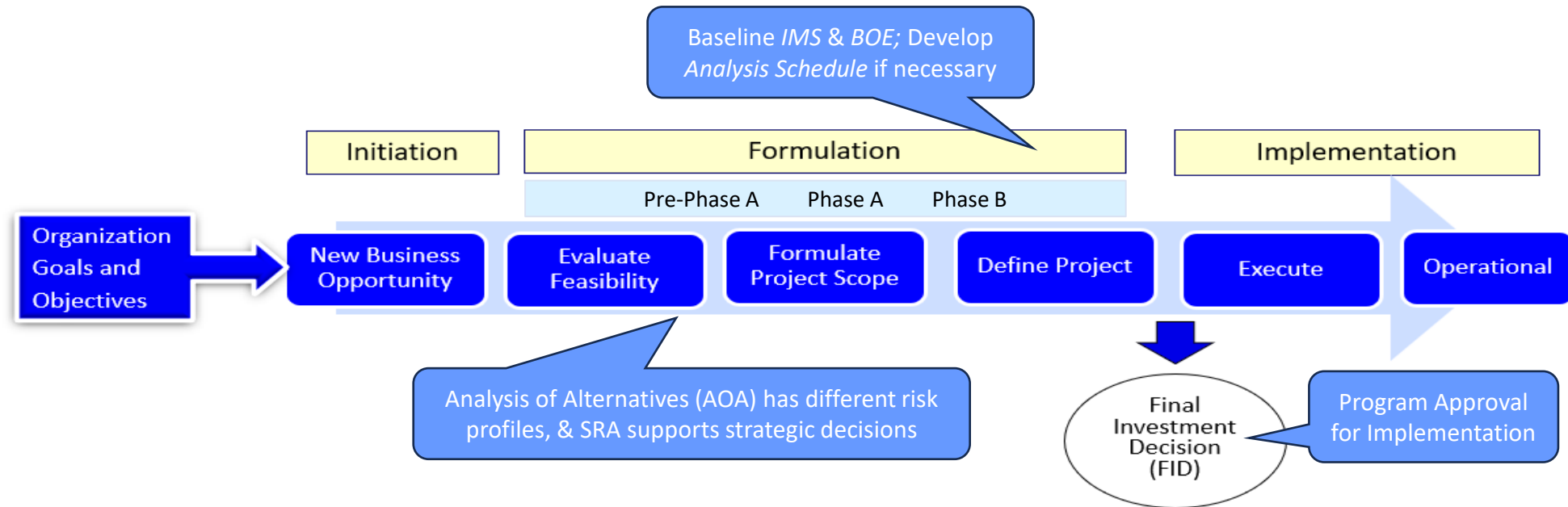
- Alternatives
- Stochastic Critical Paths
- Risk Sensitivity/Prioritization
- Confidence Level/Completion Ranges
- Joint Confidence Level (JCL) of cost and schedule [will not be discussed today]
- Margin Allocation and Sufficiency
- Funding/Reserves [will not be discussed today]
- Risk-based Trends [will not be discussed today]

➤ Communicate realistic findings to P/p Decision Makers, Executive Stakeholders, and US Congress

* See NASA Schedule Handbook, paragraph 6.3.2.5.3, p255.

Purpose & Level of Detail Varies with P/p Life Cycle Phase

Schedule Risk Analysis (SRA) and Integrated Cost Schedule Risk Analysis (ICSRA) need enough detail to apply Risk Drivers* for the benefit of *risk informed decision-making*.



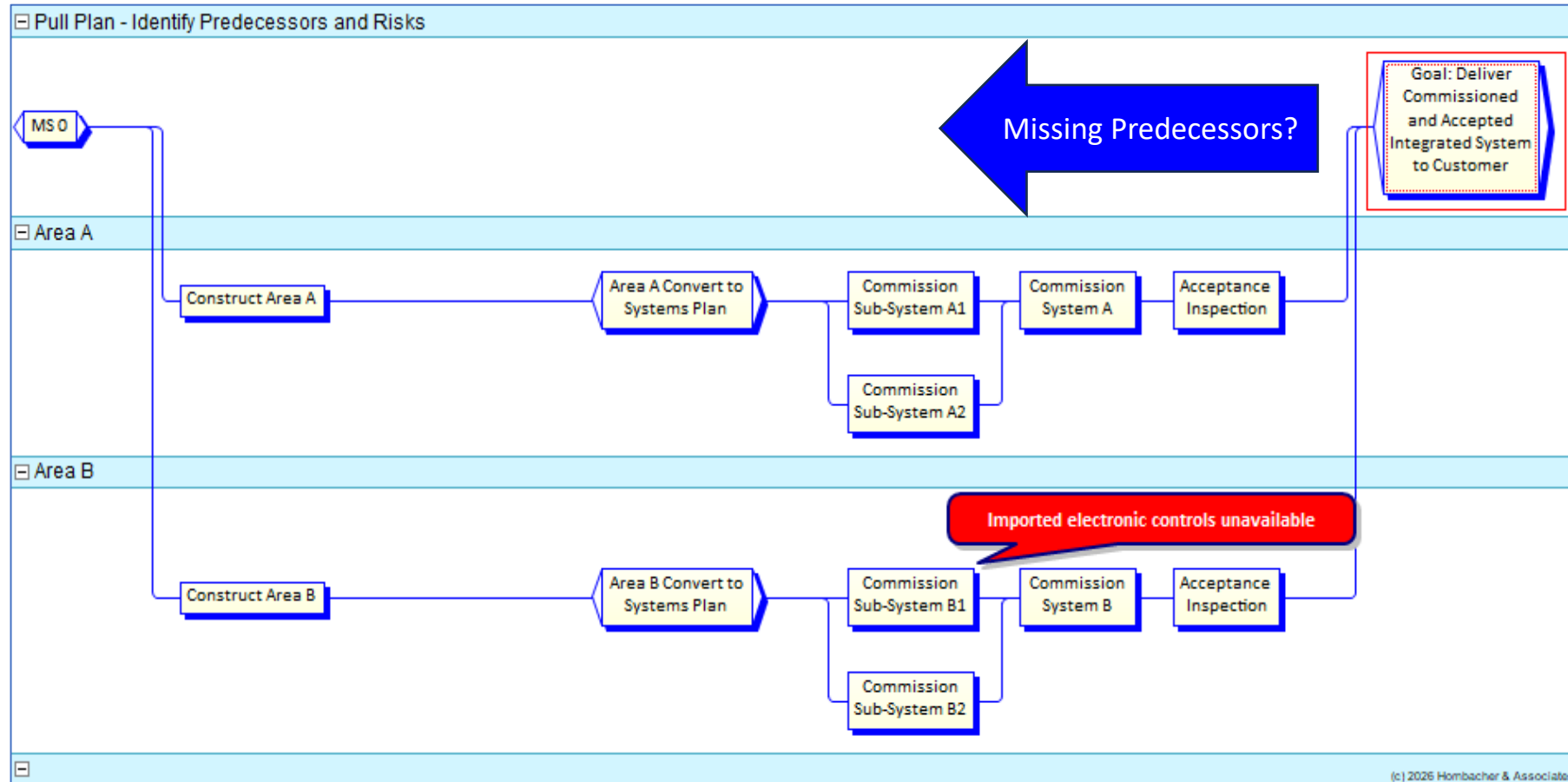
Aligned with Fig. 5-9, Schedule BoE maturity requirements by P/p phase according to NPR 7120.5, NASA Schedule Management Handbook, 2024, p75; *See RP 127R; RP 57R

➤ Level of detail is governed by phase, analytical needs, availability of input data, and utility of results

High Fidelity Logic: Retain Possible Critical Paths

- Summarize? Roll-ups that span related groups of activities can be OK . . . **IF**
 - Impacts of *mapped* risks apply to *each activity in the rolled-up group* as % of durations (Risk Drivers) and Important logic is preserved at merge points
 - Likelihood of nearly critical paths becoming critical during schedule risk analysis
 - “*Merge Bias*”, converging paths increase schedule risk (two or more paths are predecessors to an activity or milestone and drive that succeeding path)
 - Latest path drives the merge point (latest finish date delays successor’s earliest start date)
 - Which paths will become critical and why?
 - The roll-up might destroy logic with paths outside of the roll-up
 - Execution Schedules may have excessive detail (reporting, other purposes)
 - Analytical needs drive choices (MCS software capabilities should not be the constraint)
- Manage *Merge Bias*. Validate risk drivers of each converging path: “Pull Planning” can help

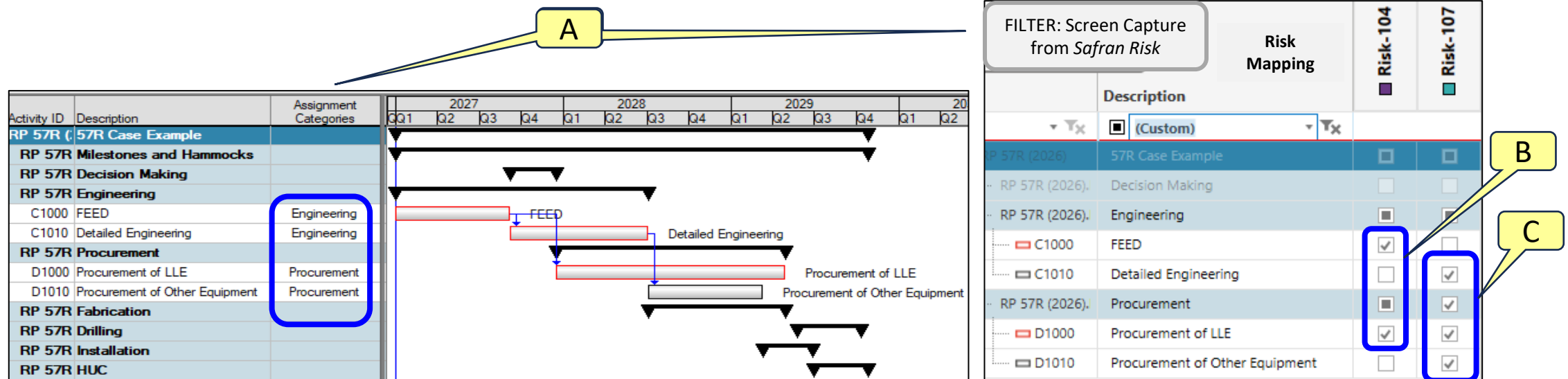
Team Collaborates with Pull Planning to Validate Logic, Risks



- Credibility: **Validate logic flow from right to left.** Look for missing drivers, risks.

SRA: Essential to Map Risks to WBS (category, groups, phases)

- Create Field Codes in Schedule to build the Analysis Schedule/Risk Model
- Assign impacts of risks selectively to multiple risks by categories (multiplicative Risk Drivers*)
- Use column and risk mapping filters: Examples (A) - Engineering, Procurement
- Map (✓) impacts of (B) Risk-104 and (C) Risk-107 to activities specified by their categories
- Codes can be selected to assign Risk Drivers to many phase activities and/or individual activities



*Source: RP 57R

➤ SRA Model is an entrance criterion to building an ICSRA Model

ICSRA - Map Risks to Activity's WBS/CBS Interface

Clarification of Two Methods: Resource/cost loaded (classic) or Cost Linked (alternate)*

Activity attributes (duration, cost and resource type, risk mapping) are constant in examples

- R-1 Labor: Time Dependent (TD), \$120K, 100% “variable”; linked directly to activity duration
Cost varies with Schedule Risk, uncertainty; and Cost Risks (e.g., labor market competition, or productivity that affects burn rates)
- R-2 Material: Time Independent (TI), \$80K, 100% “fixed”; linked to activity
Linked to activity occurrence (moves with dates for cash flow, may have unique and systemic risks, uncertainties)
- Risk-105 Mapped to Activity E1020 *Fabricate CPP Topsides*

Classic
Resource/Cost
Loaded Activity

Activity ID	Description	Assigner Categories	Total Cost (\$000)	2028 Q3	2028 Q4	2029 Q1	2029 Q2
RP 57R	57R Case Example		200,000				
RP 57R	Fabrication		200,000				
E1020	Fabricate CPP Topsides	Fabrication	200,000				

Resource	Planned Cost
R-1 - Time Dependent (Labor)	120,000.0
R-2 - Time Independent (Material)	80,000.0

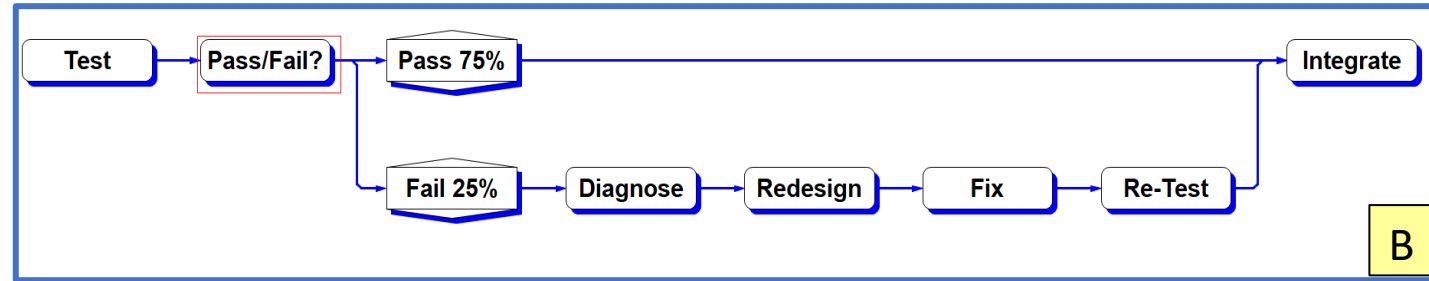
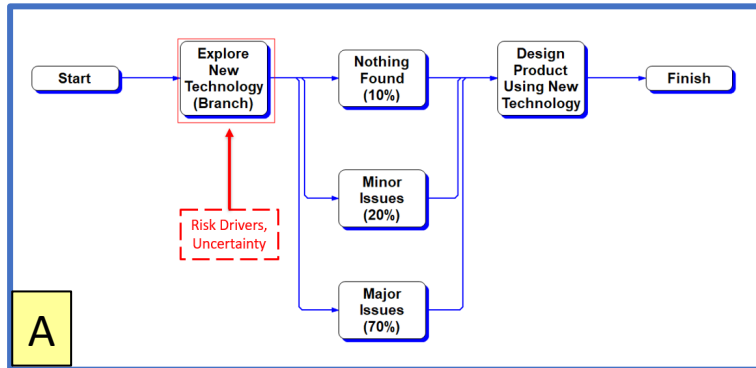
Risk Filter: 105		Risk Mapping	
Id	Description		
RP 57R (2026)	57R Case Example	☐	
RP 57R (2026)	Fabrication	☐	
E1000	Fabricate Drilling Topsides	☐	
E1010	Fabricate Drilling Jacket	☐	
E1020	Fabricate CPP Topsides	☒	
E1030	Fabricate CPP Jacket	☐	

Alternate
Cost Linked
Activity

Safran Risk Cost Module		Resource Cost		Cost Uncertainty	Schedule Connection	Time Dependent or Independent		Risks
Description		Base	Base Distribution		Activity	Fixed	Variable	
☒ FAB CPP TOPSIDES		=	☒					
☒ Cost R1 FAB CPP TOPSIDES Labor		120,000	Triangle(85% ; 105% ; 125%)	☒	100% E1020 - Fabricate CPP Topsides	0	120,000	Risk-105
☒ Cost R2 FAB CPP TOPSIDES Material		80,000	Triangle(85% ; 105% ; 125%)	☒	0% E1020 - Fabricate CPP Topsides	80,000	0	Risk-105

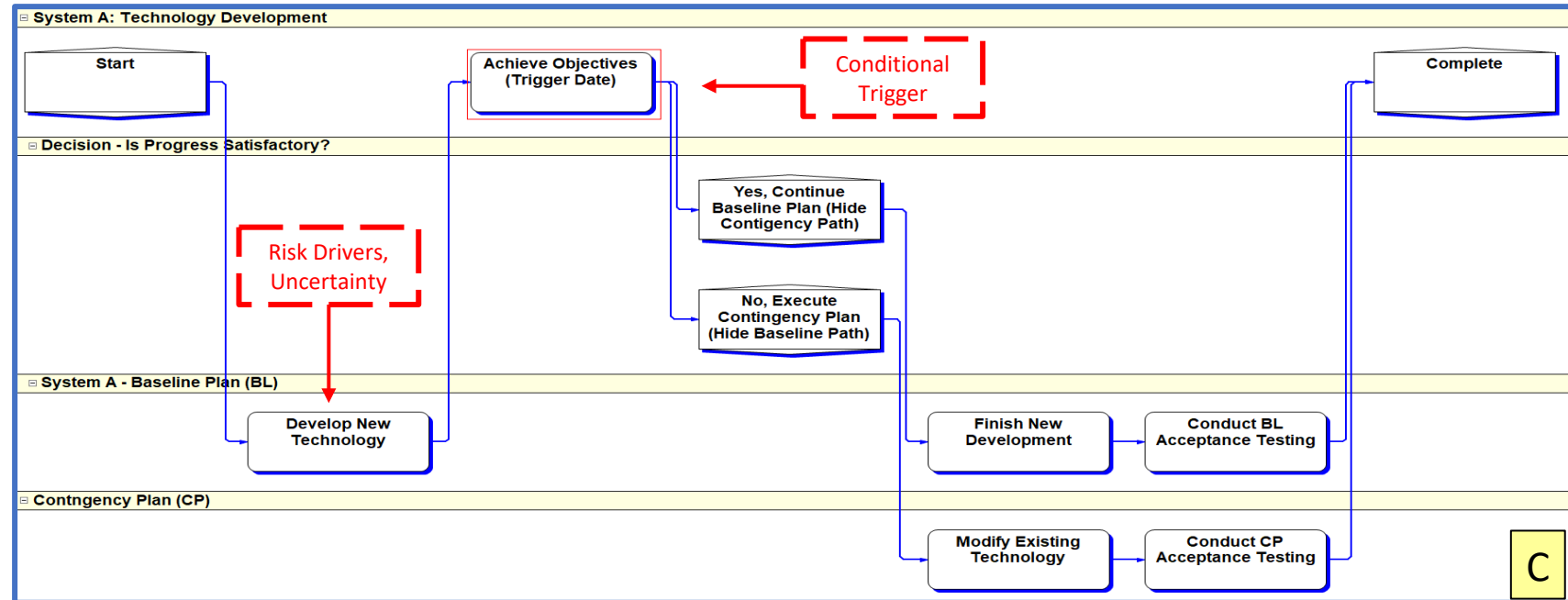
*See NASA Schedule Handbook, Section 6.3.2.4, p230 ff & RP 57R (as revised)

Stochastic Paths are Special Cases (decision-making)



Probabilistic (A, B) Execute One of probable paths

Conditional (C)
If, then . . . Contingency plan



➤ Deterministic schedules are not designed to answer stochastic questions.

Summary: Adopt Systems Approach, Plan for Change

- IMS and AS models may differ because of different purposes
- Implement best practices to create and maintain schedules, use tools fit for purpose; eliminate lags; unconstrain milestones to benefit from the conclusions of valid logic. If schedule shows overrunning a launch window, find the cause, do not adjust the schedule
- Collaborate with team, IMS and Risk Analysis Schedule (AS) authors, to understand and communicate what the differences represent and their unique purposes
- Validate predecessor logic by starting with delivery of completed system at transfer of care, custody, control; use pull planning, work from right to left to discover missing or invalid logic; include all work, especially work from suppliers and interfacing P/p driving inputs
- Condition the IMS to include provisions for stochastic logic
- Implement the “Risk Drivers” multiplicative method in the project risk model so risks can be assigned to multiple activities/control accounts and their sub-sets

References: NASA

US National Aeronautics and Space Administration (NASA) Handbooks

<https://www.nasa.gov/ocfo/ppc-corner/ppc-guidance-documents/#EVMHandbooks>

- NASA Schedule Management Handbook, 2024.

<https://www.nasa.gov/ocfo/ppc-corner/ppc-guidance-documents/#ScheduleManagementHandbook>

- NASA Cost Estimating Handbook Version 4.0, 2015.

<https://www.nasa.gov/ocfo/ppc-corner/ppc-guidance-documents/#CostEstimatingHandbook>

Appendix J: Joint Cost and Schedule Confidence Level (JCL) Analysis, See especially section *J.2. Integrated Schedule*, pages J-20 through J-22

- NASA Space Flight Program and Project Management Handbook, 2022 (2024).

<https://ntrs.nasa.gov/citations/20220009501>

References: NASA (continued) and GAO

US National Aeronautics and Space Administration (NASA)

- NASA Risk Management Handbook: Version 2.0, Part 1 & Part 2
<https://ntrs.nasa.gov/citations/20240014019> & <https://ntrs.nasa.gov/citations/20240014326>
- NASA Common Leading Indicators Detailed Reference Guide, 2021
https://nodis3.gsfc.nasa.gov/OCE_docs/OCE_52

US Government Accountability Office (GAO)

- GAO Schedule Assessment Guide, GAO-16-89G, 2015
<https://www.gao.gov/products/gao-16-89g>
- GAO Cost and Estimating Assessment Guide, GAO-20-195G, 2020
<https://www.gao.gov/products/gao-20-195g>

References: Recommended Practices (RPs) AACE* International

RP 57R-09 Integrated Cost and Schedule Risk Analysis using Risk Drivers and Monte Carlo Simulation of a CPM Schedule (being revised)

RP127R-23 Choosing Among Strategic Alternatives Using Branching Concepts In Decision Modeling

RP 26R-21 Developing or Revising a Scheduling Specification

RP 37R-06 Schedule Levels of Detail – As Applied in Engineering, Procurement, and Construction

RP 49R-06 Identifying the Critical Path

RP 61R-10 Schedule Design – As Applied in Engineering, Procurement, and Construction.

RP 91R-16 Schedule Development

RP 132R-23 Schedule Risk Analysis Maturity Model

RP 133R-23 Using Decision Analysis Methodologies to Enhance Decision Quality

RP 135R-24 System Dynamics Modeling to Demonstrate Entitlement to Project Disruption Costs

*Association for the Advancement of Cost Engineering (AACE), est. 1956. <https://web.aacei.org/resources/recommended-practices>

Conditioning the Schedule for Quantitative Risk Analysis

Cost and Schedule Symposium
NASA Glenn Research Center, 27 August 2026

David T. Hulett, Ph.D., FAACE

Keith D. Hornbacher, M.B.A.

Hulett & Associates LLC

Integrated Cost Schedule Risk Analysis (ICSRA) with Monte Carlo Simulation