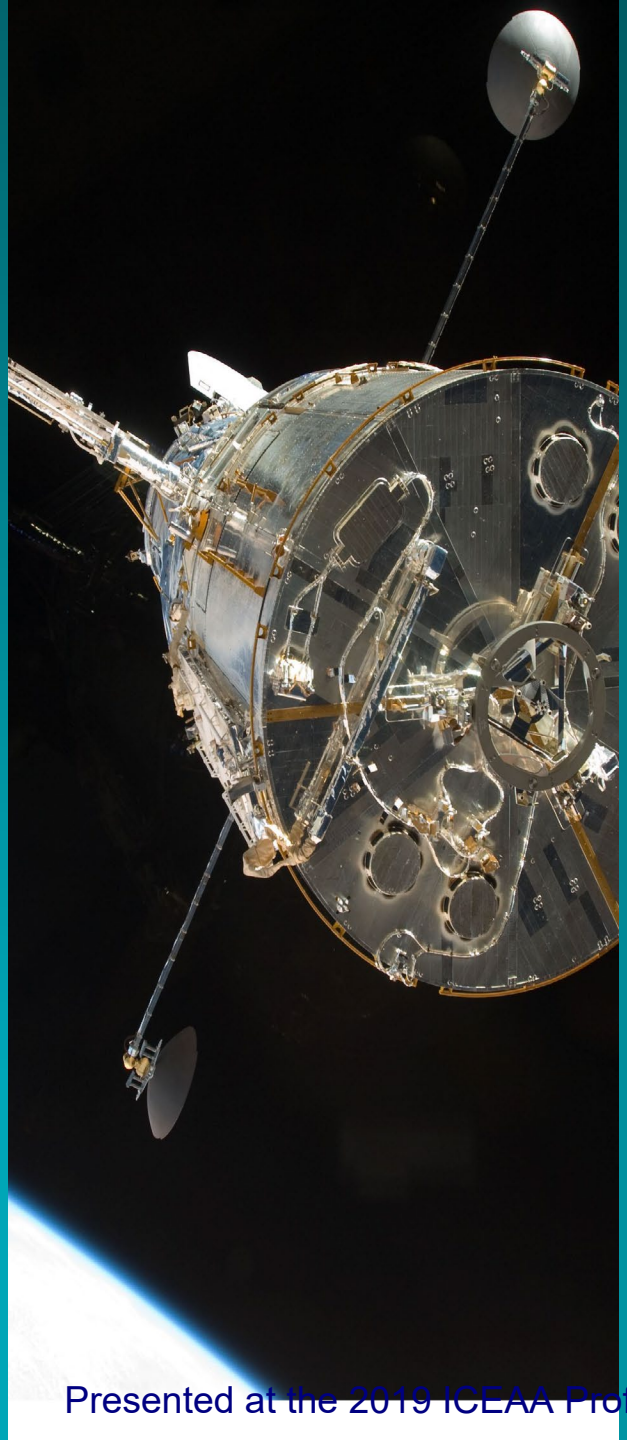


When is Less More?

Level of Detail in Cost and Schedule Risk Assessment

International Cost Estimating and Analysis Association

Laura Krepel and Zachary Pirtle

This presentation does not necessarily reflect the views of NASA or the United States Government.

MAY 2019

Presented at the 2019 ICEAA Professional Development & Training Workshop - www.iceaaonline.com

Intro & Objectives

In Cost and Schedule Risk Assessment (C)SRA, the level of detail in the analysis schedule(# of lines) drives amount of **time and effort** to build, validate, review, and understand the models.

(C)SRA models can be built with analysis schedules of 1-10,000s of lines. We will explore:

- Pros & cons of using a very detailed (1,000s of lines) versus or less detailed (1-500 lines) analysis schedule.
- Scenarios in which we'd recommend using a more or less detailed analysis schedule

Additionally we will cover:

- (C)SRA Definitions, Benefits, and Applications
- NASA's Experience with (C)SRA
- Recommendations for advancing the practice of (C)SRA

Representative References

Guidelines & Handbooks

A. Joint Agency Cost and Schedule Risk and Uncertainty Handbook (2014)

B. GAO Schedule Assessment Guide: Best Practices for Project Schedules (2015)

C. NASA Cost Estimating Handbook (2015)

D. NASA Schedule Management Handbook (2011)

E. DoD Integrated Program Management Report (IPMR) DI-MGMT-81861A (2012)

Articles and Books

1. **Hulett**, D. (2011). Integrated Cost-Schedule Risk Analysis. Farnham England: Gower Publishing Limited
2. **Hamaker**, J.W. (2010). Do More Details Imply Better Accuracy in Cost Estimates?. Parametric World
3. Pirtle, Z., Odenbaugh, J.,Hamilton, A. & Szajnfarber, Z. (2018). Engineering Model Independence: A Strategy to Encourage Independence Among Models. Techné: Research in Philosophy and Technology
4. Gilmer, G., & Druker, E. (2012). Analytical Program Management: an Approach for Integrating Cost, Schedule and Risk. Cost and Value
5. Wong, J.S. (2015). Integration of Probabilistic Costing and Scheduling. Delft University of Technology Thesis

We founded limited references to the level of detail in an analysis schedule in literature search. Content is based upon author's experiences with (C)SRA and peer input.

Laura Emerick Krepel PMP, EVP, PMI-SP

Cost and Schedule Risk Assessment Experience includes:

- NASA HEO ESD EM-1 (SLS, Orion & EGS) – a precursor mission to human exploration to Mars
- NASA James Webb Space Telescope
- DoD DTRA CTR – BSL-3 Laboratory Construction Overseas
- DoD Syrian Chemical Weapons Elimination Contingency Planning
- NRO Satellite Software Development Program
- DoD ACAT-1 Radar Systems Development
- VA & DHS Cybersecurity Implementation
- DoD ACAT-1 IT Systems Development and Implementation
- DoD Joint Strike Fighter (F-35)

- Senior Associate at Booz Allen Hamilton within their Strategic Innovation Group.
- Leads a team providing data-driven project management and business analytics with specialists in scheduling, integrated cost and schedule risk assessment (using Polaris software), and applying automation and artificial intelligence to the program management office.
- Supported projects in diverse industries including aerospace, construction, nuclear power, air traffic control, health, international engagements, software development, and nuclear/chemical weapons non-proliferation.
- Leads Booz Allen's Planning, Scheduling, and Risk Community of Practice of over 300 members including training and development
- Certified Project Management Professional, Earned Value Professional, and Scheduling Professional with a degree in Civil Engineering.

Zachary Pirtle, Ph.D

Cost and Schedule Risk Assessment Experience includes:

- NASA HEO ESD EM-1 (SLS, Orion & EGS) program integration engineer, 2010-2018
- Served as KDP-C liaison for SLS, Orion and EGS reviews
- NASA James Webb Space Telescope, Lead Programamtic Assessor, Standing Review Board (2016-present)
- Programmatic Tradeoffs Deliberation of Mars Exploration (ECAST, 2014)
- ESD Production and Operations Cost Study, 2014
- Human Exploration Framework Team Workforce sub-team, 2010

- Joined NASA in 2010 as a Presidential Management Fellow and spent 8 years working in the Human Exploration and Operations Mission Directorate.
- Exploration Portfolio Analyst (Operations Research) in NASA's Strategic Investments Division, a division of the Office of the Chief Financial Officer
- Supports and oversees NASA's Exploration Systems Development, Gateway, and emerging lunar lander programs.
- Education and awards include:
  - Bachelors degrees in Mechanical Engineering and Philosophy and Master's degree in Civil and Environmental Engineering from Arizona State University
  - Currently completing his Ph.D. in Systems Engineering at George Washington University.
  - Fulbright Scholar to Mexico
  - Mirzayan Fellow at the National Academy of Engineering

AGENDA

1. *Intros*
2. *Overview of (C) SRA*
   - Terminology
   - Ground Assumptions
   - Benefits
   - NASA's JCL Policy
3. *Analysis Schedules*
   - (C) SRA Steps
   - Building the Analysis Schedule
   - Levels of Detail
   - Pros and Cons
   - Scenarios
4. *Conclusions and Next Steps*

Cost and Schedule Risk Assessment

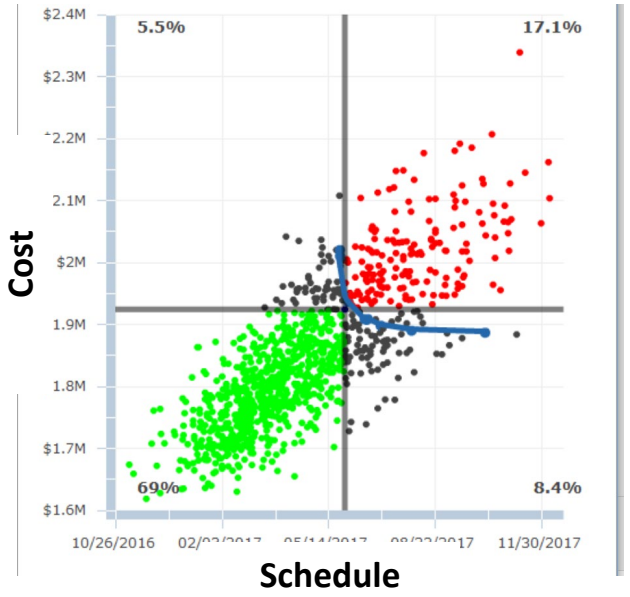
Cost and Schedule Risk Assessment is performed using the following artifacts:

- The program **schedule** (IMS or higher-level analysis schedule) with uncertainty bounds on task durations
- The quantified **risk register** (probabilities, cost and schedule impacts) where each risk is mapped to a task in the IMS
- The **cost** estimate with uncertainty bounds that map to the schedule at any level
  - Time Dependent costs
  - Time Independent costs

Monte Carlo Simulation

Joint Confidence Level (JCL)

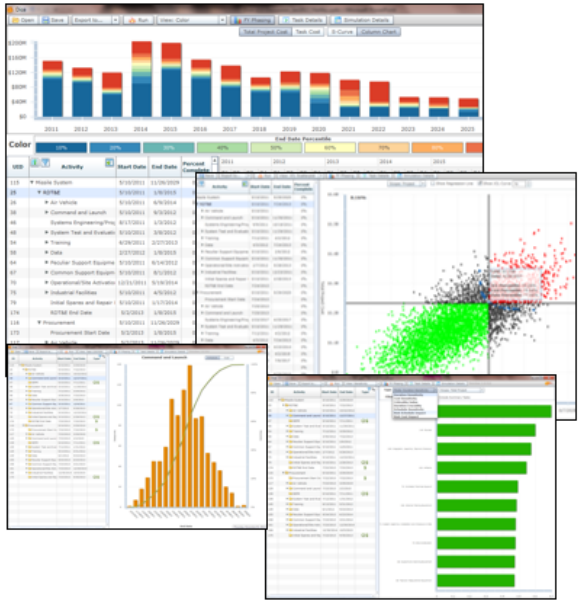
Integrated Cost & Schedule Risk Assessment



Cost and Schedule Risk Assessment (C)SRA: Approaches, Definitions, and Caveats

(C) SRA refers to any of three of these approaches:

1. **Schedule Risk Assessment (SRA)**– Analysis schedule with duration uncertainty and/or schedule impact of risks
2. **Joint Confidence Level (JCL)** a.k.a. Integrated Cost and Schedule Risk Assessment. Requires a cost-loaded schedule
3. **Cost Informed by SRA** (CISRA): Probabilistic cost informed by schedule uncertainty. Does not require an integrated model. Could involve joining a cost and schedule parametric model together



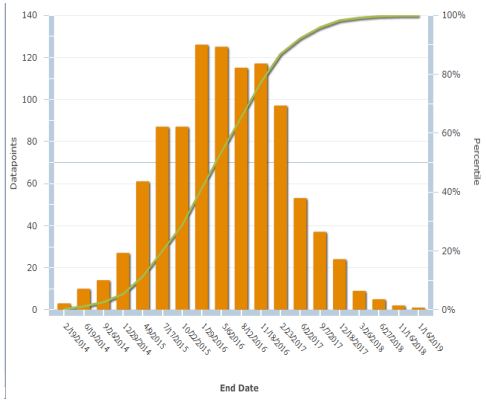
Integrated Master Schedule (IMS) here will refer to the program's detailed schedule(s) for day to day management

Cost and Schedule Risk Assessment provide management insights and statistically backed confidence in outcomes; however this does not replace **the need for and emphasis on the detailed program and contractor Integrated Master Schedules**

This presentation assumes that the programs are managing work to a detailed Integrated Master Schedule with a valid critical path

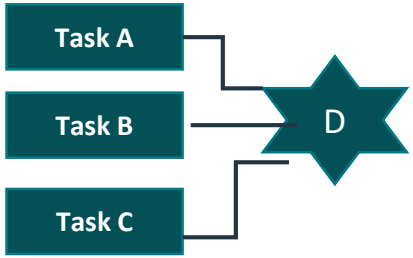
Benefits of (C)SRA

1. **Range of cost and schedule forecasts**
   - Probability of completing on time/budget
   - Range of cost & schedule
   - Bound & aggregate the uncertainty
   - Quantifies the need for program reserve
2. **Program Insights**
   - Clarify program drivers, tasks and risks most impacting cost and schedule
   - Identify areas of greatest unknown and sensitivity
   - Quantify & evaluate the impact of potential & unofficial delays
3. Quantifies the risk of parallel paths
4. Review drives improvements to program artifacts – schedule, cost, and risk



Risk of Parallel Paths

If Tasks A, B, C each have a 75% chance of completion by 1/1,…



Then what are the chances that MS D will complete by 1/1?

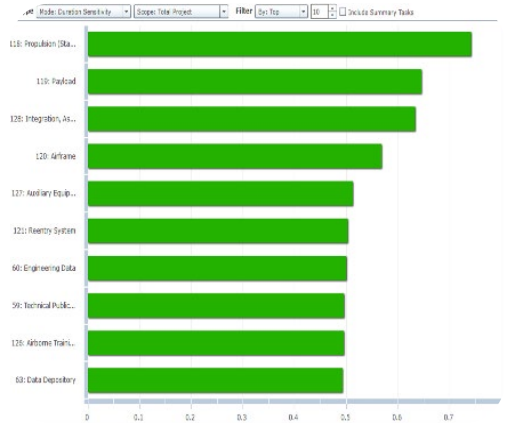
When should you conduct (C)SRA?

In support of:

1. Mandatory requirements from NASA (JCL) or EVMS*
2. **Impact (delay) analysis and what-if scenarios**
3. Releasing SOW or project scoping
4. Validating the project plan

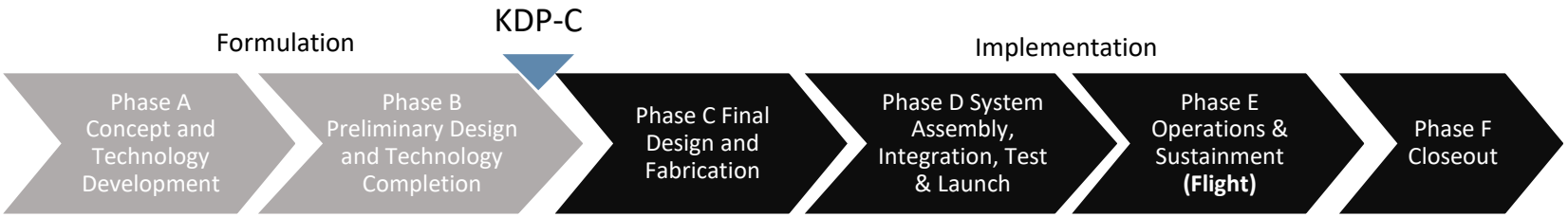
**Note: DoD does not currently require integrated, programwide SRAs including all government & contractor work to meet objectives.*

Cost and Schedule Ranges



Tornado or sensitivity chart of drivers

NASA Establishes Program Cost & Schedule Baseline at KDP-C



- NASA establishes the Agency Baseline Commitment (ABC) at Key Decision Point (KDP)-C, which is:
  - Reported to OMB & Congress
  - An integrated set of project requirements, cost, schedule, technical content
- Prior to 2000s, NASA primarily developed primarily point estimates with parametric assessments
- **NASA was pressured to enhance cost control in the 2000s** due to:
  - Championship from NASA Administrator Griffin "to avoid the pattern of finger-pointing for cost overruns and schedule slips that have plagued the industry in the past[1]"
  - GAO reports beginning in 2002 describing the major causes of NASA Program cost growth including incomplete cost-risk assessment and flawed initial program planning[1].

In 2009, NASA established the JCL Policy; requiring a a resource-loaded schedule and risk-informed probabilistic analysis as the basis of Agency Baseline Commitment[2]

(1) NASA Cost Estimating Handbook Version 4.0 Feb 2015
(2) Additional requirements for JCLs & SRAs at CDR,

AGENDA

1. *Intros*
2. *Overview of (C) SRA*
   - Terminology
   - Ground Assumptions
   - Benefits
   - NASA'S JCL Policy
3. *Analysis Schedules*
   - (C) SRA Steps
   - Levels of Detail
   - Pros and Cons
   - Scenarios
4. *Conclusions and Next Steps*

(C)SRA Steps

Author's time estimates include these steps

- Detailed IMS
- Risks
- Cost
- Performance Data
- Expert Opinion

- **Analysis Schedule**
- Duration Uncertainty
- Risks
- Costs

- Ensure results match expectations and make sense
- Confirm: risk adjusted schedule, probabilistic critical path, drivers, areas of sensitivity are appropriate

- Basis
- Results
- Drivers
- Recommended Actions
- Messaging

- Program Manager
- Leads & SMEs
- Project Controls Staff: Schedule, Risk, Cost
- Establishes credibility

- Senior Executives and Stakeholders
- Completes actions

Developing the **analysis schedule** from the IMS typically involves going line by line and:

1. Evaluating (near) critical paths and drivers
2. Correcting or accounting for "preferred" logic versus "hard" logic. *Can the team perform workarounds?*
3. Correcting for "Just-in-Time" delivery and "window of opportunity" durations versus required duration – *What could be accelerated?*
4. Summarize the IMS via deleting tasks and/or rolling up detailed work to a longer duration
5. Validating logics

The more detailed the analysis schedule (# of lines), the longer it takes

Analysis Schedule – Level of Detail Definitions

On a large program, the detailed IMS may contain 10,000s of lines.

A detailed analysis is rarely performed on the full IMS due to difficulty; however a quick analysis using templated uncertainty would showcase the risk due to parallel paths.

Typically the analysis schedule would be 1-1,000s lines…

	1-10s of lines	100s of lines	1,000s of lines
Typical Content	• Program duration and uncertainty • Program phases (requirements, design, build, test, accept)	• Critical path items and near critical path items • Major external dependencies • Major program milestones and hand offs between groups	• All program scope and risks to some level of detail • Major and minor interdependencies
Time	**Fastest**	**Faster**	**Most time consuming**

- Model may include the full Program scope or just a portion (next milestone, single project)
- (C)SRA model may vary by either:
  a) Starting high-level and then become more detail or;
  b) Becoming less detailed as you have confidence in the true drivers

Key Content!

Pros & Cons of Detail in Analysis Schedules

	1-10s of lines	100s of lines	1,000s of lines
Typical Content	• Program duration/uncertainty • May include program phases	• Critical path items and near critical path items • Major dependencies	• All program scope and risks to some level of detail • Major and minor interdependencies

Pros	• Can adjust model or what-if analysis in real-time
	• May be sufficient for Cost Informed by SRA
	• **Model & inputs are easier to understand & review, driving acceptance & action**
		• **Typically exclude non-critical path items which reduces validation time**
		• Evaluate potential delay factors such as external dependencies and risks
		• Greater ability to model time-dependent costs
			• Typically required for resource/cost loading (JCL)
			• **Comprehensiveness:**
			  ○ **Implies credibility**
			  ○ Validates all drivers
			  ○ Drives additional insights and enhancements to program artifacts

Cons	• Typically does not provide insights into key drivers & areas of sensitivity • Typically excludes discrete risks (but includes uncertainty) • **May lose some credibility with stakeholders as being perceived as too high level**	• Without modeling all scope, may miss potentially important logic ties • **Still perceived credibility challenges due to smaller size**	• **Inhibits review and understanding "Lose the forest for the trees." Opaque** • Most error likely & difficult to validate • **Accuracy may not necessarily improve**
Use when:	• Quick analysis & What-if scenarios • Undefined scope /reqm'ts	• When critical path drivers are known for sure	• Cost loading • Validating complete IMS & all potential drivers
Time to Build & Validate	**Fastest** • Hours for a simple model with available inputs & SMEs	**Faster** • Weeks to a few months for an SRA	**Most time consuming** • A new JCL can take 1-4 FTEs, 2-8 months on a large program

Audience Participation: Scenarios & Recommendations

Given the scenario, would you recommend a more or less detailed analysis schedule? Or both? Any caveats or additional recommendations?

1. **Unknown/Changing Scope**: Early in lifecycle, ill-defined, or during major shifts.
   - Less detailed
2. **Budget Impact:** Work is deferred or accelerated based upon available funding
   - Less detailed
3. **Advocacy Bias**: Overly optimistic forecasts
   - Use of both can help tease out inconsistencies. More detailed or with objective performance data allows for deeper assessment.
4. **Poor Program Artifacts** (Schedule, risk, cost)
   - Both: Less detailed for initial results, then migrate to a more detailed analysis to drive enhances to primary artifacts
5. **Schedule Concurrency:** Running multiple activities in parallel
   - More detailed will reveal the combined impacts of parallel paths and potential drivers
6. **Risks & Technical Challenges**
   - More detailed approach load risks and to understand combined cost/schedule impacts

AGENDA

1. *Intros*
2. *Overview of (C) SRA*
   - Terminology
   - Ground Assumptions
   - Benefits
   - NASA's JCL Policy
3. *Analysis Schedules*
   - (C) SRA Steps
   - Building the Analysis Schedule
   - Levels of Detail
   - Pros and Cons
   - Scenarios
4. *Conclusions and Next Steps*

Summary: Pros & Cons of Analysis Schedules at Various Levels of Detail

	1-10s of lines	100s of lines	1,000s of lines
Typical Items Included	• Program duration • May include program phases	• Critical path items and near critical path items • Major dependencies	• All program scope and risks • Major and minor interdependencies

Pros	• Can adjust model or what-if analysis in real-time
	• May be sufficient for Cost Informed by SRA
	• **Model & inputs are easier to understand & review, driving acceptance & action**
		• **Typically exclude non-critical path items which reduces validation time**
		• Evaluate potential delay factors such as external dependencies and risks
		• Greater ability to model time-dependent costs
			• Typically required for resource/cost loading (JCL)
			• **Comprehensiveness:**
			  ○ **Implies credibility**
			  ○ Validates all drivers
			  ○ Drives additional insights and enhancements to program artifacts

Cons	• Typically does not provide insights into key drivers & areas of sensitivity • Typically excludes discrete risks	• Without modeling all scope, may miss potentially important logic ties • **May lose some credibility with stakeholders as being perceived as too high level**	• **Inhibits review and understanding "Lose the forest for the trees."** • Most error likely & difficult to validate • **Accuracy may not necessarily improve**
Use when:	• Quick analysis & What-if scenarios • Undefined scope /reqm'ts	• When critical path drivers are known for sure	• Cost loading • Validating complete IMS & all potential drivers
Time to Build & Validate	**Fastest** • Hours for a simple model with available inputs & SMEs	**Faster** • Weeks to a few months for an SRA	**Most time consuming** • A new JCL can take 1-4 FTEs, 2-8 months on a large program

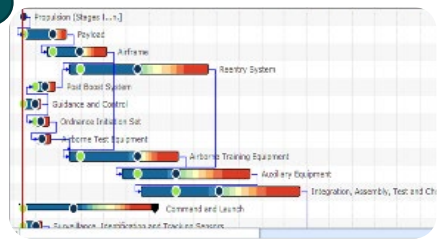
Next Steps & Recommendations

The authors would be interested in additional <u>data</u> and analysis around around:

1. **Does the level of accuracy of a (C)SRA increase with more detail?**
   - When can the use of multiple models (one of high fidelity, one of low fidelity) be helpful in increasing accuracy?

2. **What are the cost and benefits of conducting a JCL versus Cost Informed by SRA (CISRA)?**
   - What is the additional time & resources to develop a fully integrated JCL with a cost-loaded schedule versus a CISRA where probabilistic cost informed by schedule uncertainty. (Does not require an integrated model)?
   - What are the additional benefits of a JCL over CISRA?

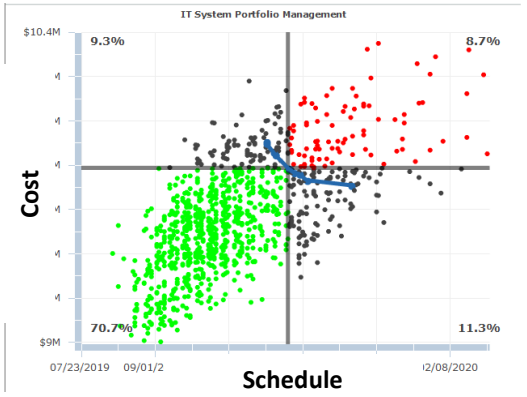
1



Schedule Risk Assessment

2

Probabilistic Cost Estimate informed by SRA



JCL or Integrated Cost & Schedule Risk Assessment

Point of Contact

Laura Emerick Krepel

Booz |Allen | Hamilton
Senior Associate
Krepel_Laura@bah.com
Washington DC Metro Area
https://www.boozallen.com/s/product/polaris.html

Zachary Pirtle

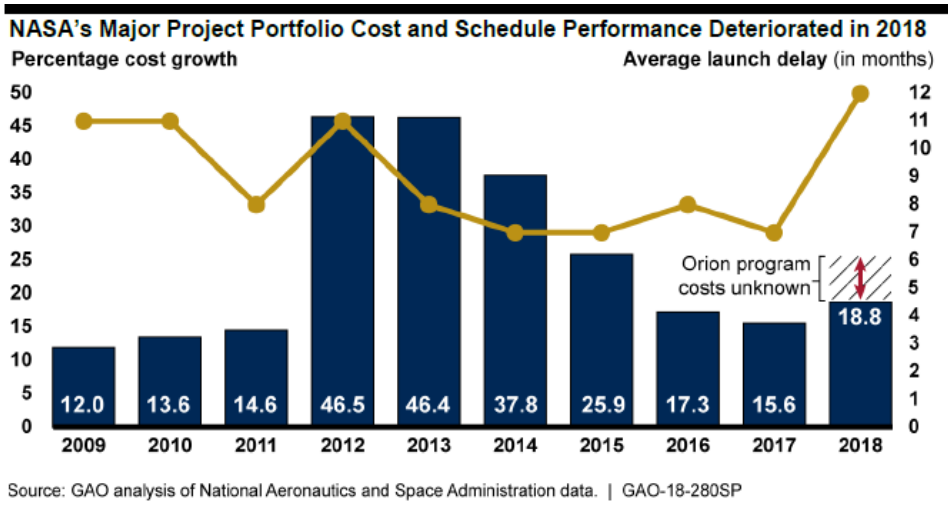
NASA Headquarters
Washington, DC
zpirtle@nasa.gov

Backup

Benefits & Outcomes of NASA's JCL Policy

The JCL Policy has not definitely reduced cost & schedule overruns

as evaluated by GAO and Andy Prince's 2019 ICEAA presentation



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-18-280SP

However, Program Managers & NASA Leadership describe JCLs as a valuable management tool[1]:

- Forcing function for good program management
- Integrated analysis
- Drivers & insights

Culture and other drivers impact cost & schedule targets

In 2019, NASA expanded requirements for JCL at KPD-B and CDR for $1B+ programs

(1) Joint Confidence Level Requirement: Policy and Issues by Fred Kuo and Steve Wilson – Constellation Program Office July 2011

DoD SRA Requirements

- EVMS IMPR requires contractor developed SRA with:
  - IBR. An SRA is required prior to an IBR.
  - OTB/OTS. An SRA is required before processing an OTB or OTS.
  - Single Point Adjustment. An SRA is required before implementing a significant cost and schedule reset, also referred to as a single point adjustment.
  - Milestone Target. The Government will determine the milestone target(s) for the SRA based on contract events
- EVMS IMPR SRA must contain 3 point duration estimates (min/max/most likely)
  - Does not require incorporation of discrete risks
- **DoD does not currently require integrated, programwide SRAs including all government & contractor work to meet objectives.**