NASA JCL: Process and Lessons

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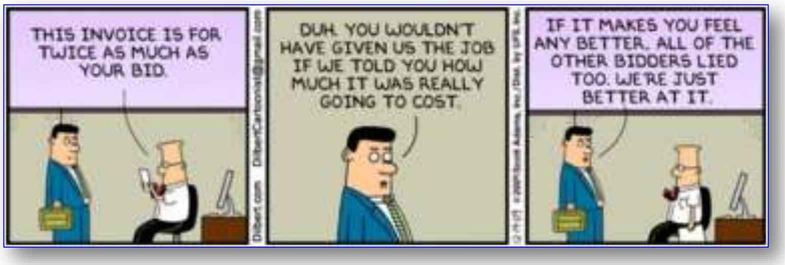
To ICEAA: June 12, 2014

NASA JCL: Process and Lessons
Agenda

- What/Why/How of NASA JCL
- Lessons from Constellation
- Lessons From Orion
- Lessons from Commercial Crew
- Poetic Epilogue

Decision Support and Policy

- **Form follows function: NASA should fully understand root causes for growth and develop policies to address them.**

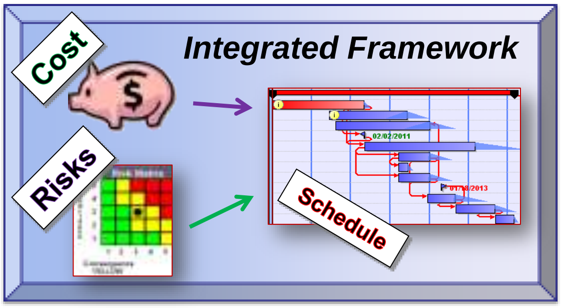

THIS INVOICE IS FOR TWICE AS MUCH AS YOUR BID.
DUH. YOU WOULDN'T HAVE GIVEN US THE JOB IF WE TOLD YOU HOW MUCH IT WAS REALLY GOING TO COST.
IF IT MAKES YOU FEEL ANY BETTER, ALL OF THE OTHER BIDDERS LIED TOO. WE'RE JUST BETTER AT IT.
Dilbert.com DilbertCartoonist@gmail.com

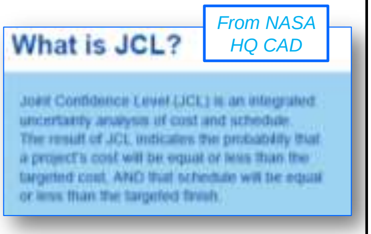
Lesson: If we want projects to meet cost and schedule commitments, we must understand their risks and fund them at a level commensurate with the amount of risk we are willing to accept.

What is JCL?

Confidence Level Definition

- **Confidence Level % denotes the likelihood a project can achieve a milestone (e.g. a launch) on time and under budget.**
- **Example: Given**
  - A budget of $100 billion
  - A target initial launch date of January 2020
  - …Project X has 50% chance of being able to afford the development and production for launch AND perform that work on time.
- **Key ingredients for Integrated Analysis: Cost + Schedule + Risks**


Integrated Framework
Cost
Risks
Schedule
02/02/2011
01/18/2013


From NASA HQ CAD

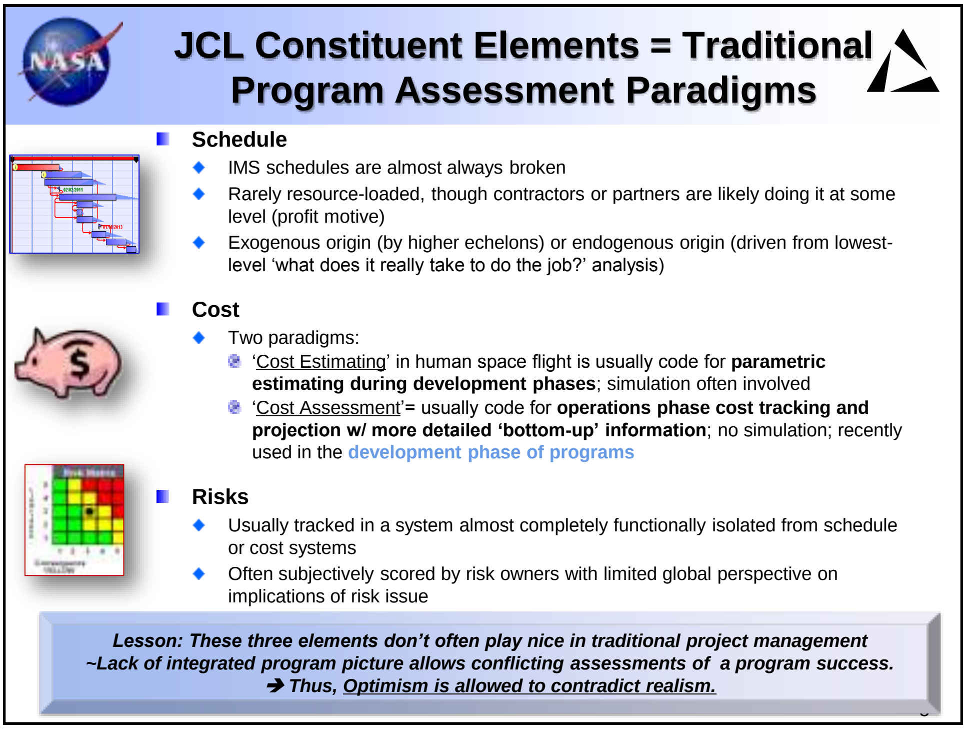
What is JCL?

Joint Confidence Level (JCL) is an integrated uncertainty analysis of cost and schedule. The result of JCL indicates the probability that a project's cost will be equal or less than the targeted cost AND that schedule will be equal or less than the targeted finish.

Merges the stovepipes of cost, schedule, and risks, capturing the dynamics of the inter-relationships.

Provides a cohesive and holistic picture of the project ability to achieve cost and schedule goals and to help the determination of reserves (schedule and cost).

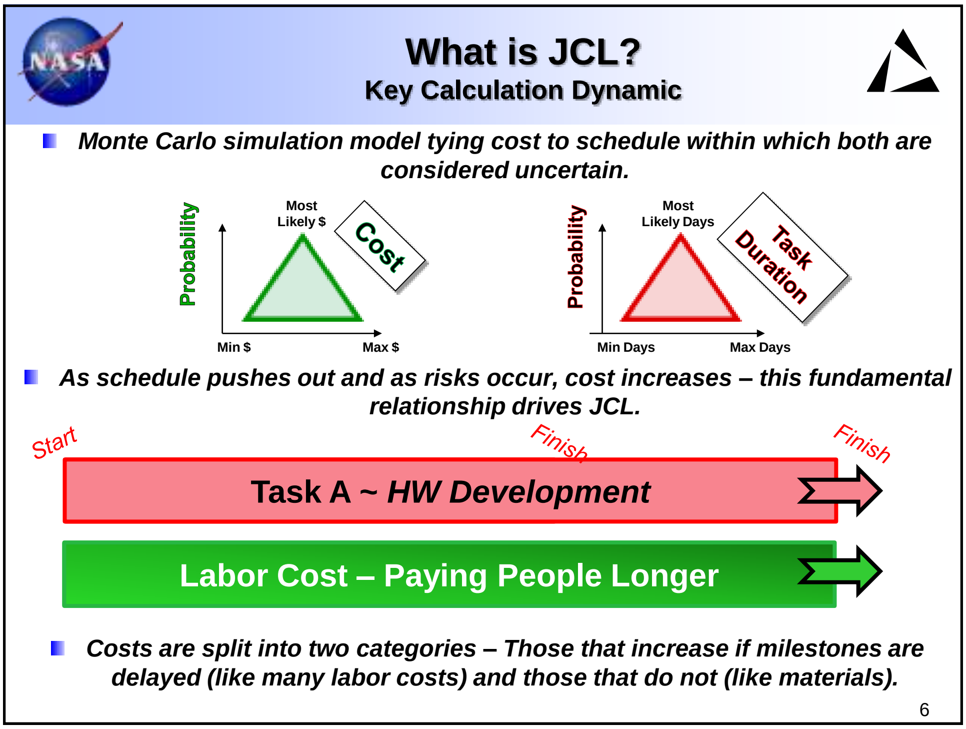
Facilitates transparency with stakeholders on expectations and probabilities of meeting those expectations.



JCL Constituent Elements = Traditional Program Assessment Paradigms

- **Schedule**
  - IMS schedules are almost always broken
  - Rarely resource-loaded, though contractors or partners are likely doing it at some level (profit motive)
  - Exogenous origin (by higher echelons) or endogenous origin (driven from lowest-level 'what does it really take to do the job?' analysis)
- **Cost**
  - Two paradigms:
    - 'Cost Estimating' in human space flight is usually code for **parametric estimating during development phases**; simulation often involved
    - 'Cost Assessment'= usually code for **operations phase cost tracking and projection w/ more detailed 'bottom-up' information**; no simulation; recently used in the **development phase of programs**
- **Risks**
  - Usually tracked in a system almost completely functionally isolated from schedule or cost systems
  - Often subjectively scored by risk owners with limited global perspective on implications of risk issue

Lesson: These three elements don't often play nice in traditional project management
~Lack of integrated program picture allows conflicting assessments of a program success.
➔ Thus, Optimism is allowed to contradict realism.



What is JCL?
Key Calculation Dynamic

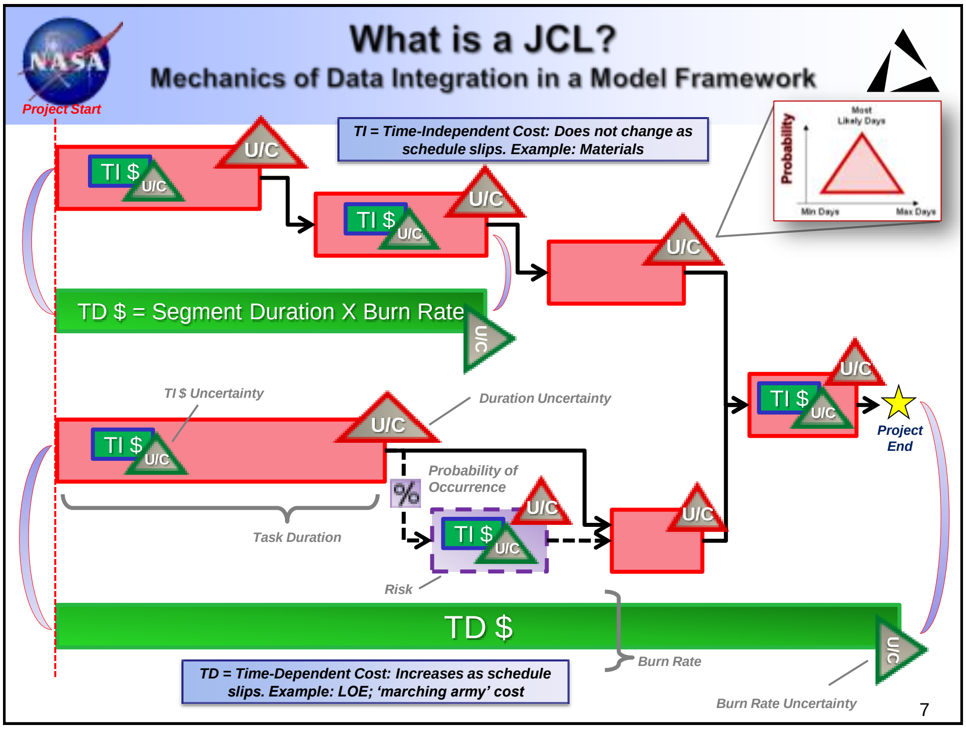
- ***Monte Carlo simulation model tying cost to schedule within which both are considered uncertain.***

- ***As schedule pushes out and as risks occur, cost increases – this fundamental relationship drives JCL.***

Task A ~ *HW Development*

Labor Cost – Paying People Longer

- ***Costs are split into two categories – Those that increase if milestones are delayed (like many labor costs) and those that do not (like materials).***



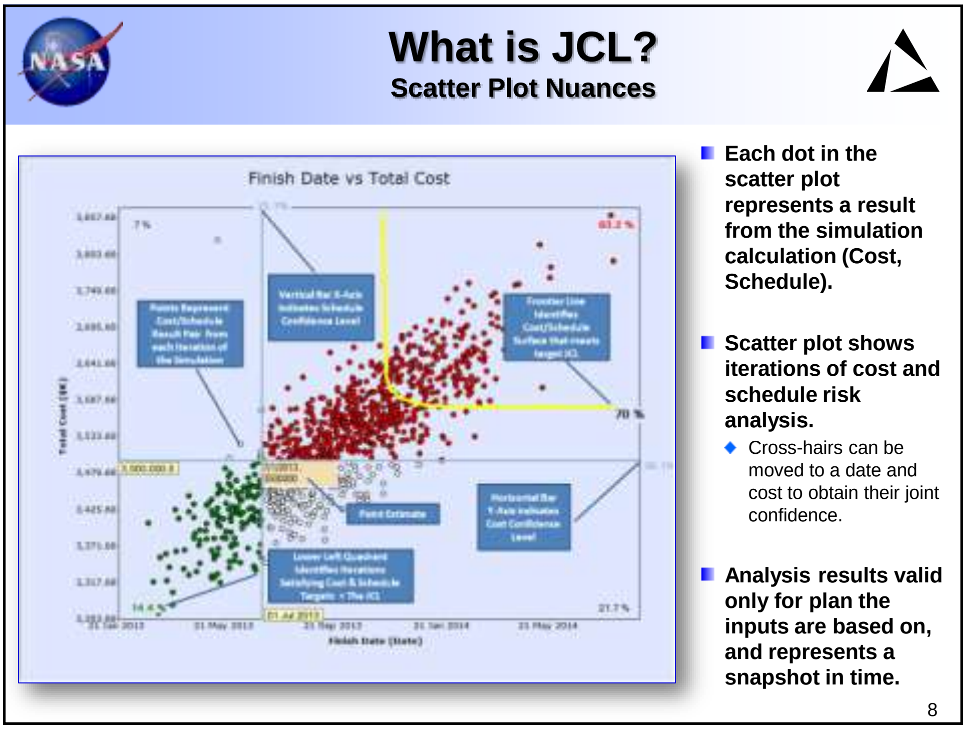
What is a JCL?

Mechanics of Data Integration in a Model Framework

TI = Time-Independent Cost: Does not change as schedule slips. Example: Materials

TD = Time-Dependent Cost: Increases as schedule slips. Example: LOE; 'marching army' cost

Project Start
U/C
TI $
TD $ = Segment Duration X Burn Rate
Most Likely Days
Probability
Min Days
Max Days
TI $ Uncertainty
Duration Uncertainty
Probability of Occurrence
%
Task Duration
Risk
TD $
Burn Rate
Burn Rate Uncertainty
Project End



What is JCL?

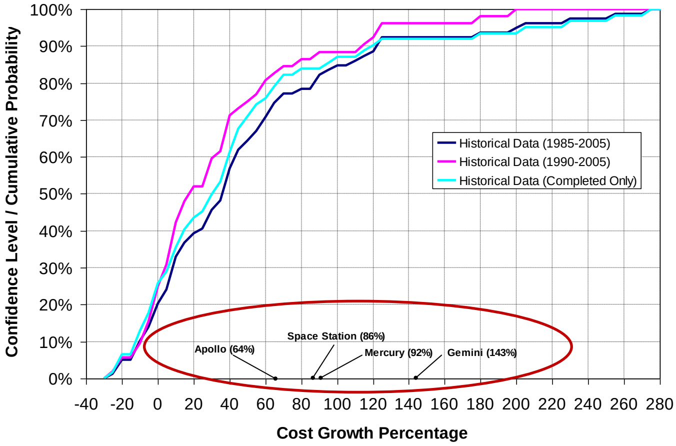
Scatter Plot Nuances

- **Each dot in the scatter plot represents a result from the simulation calculation (Cost, Schedule).**
- **Scatter plot shows iterations of cost and schedule risk analysis.**
  - Cross-hairs can be moved to a date and cost to obtain their joint confidence.
- **Analysis results valid only for plan the inputs are based on, and represents a snapshot in time.**

Why conduct a JCL?

Growth

Lesson, sort of: NASA has a long history of Cost Growth.



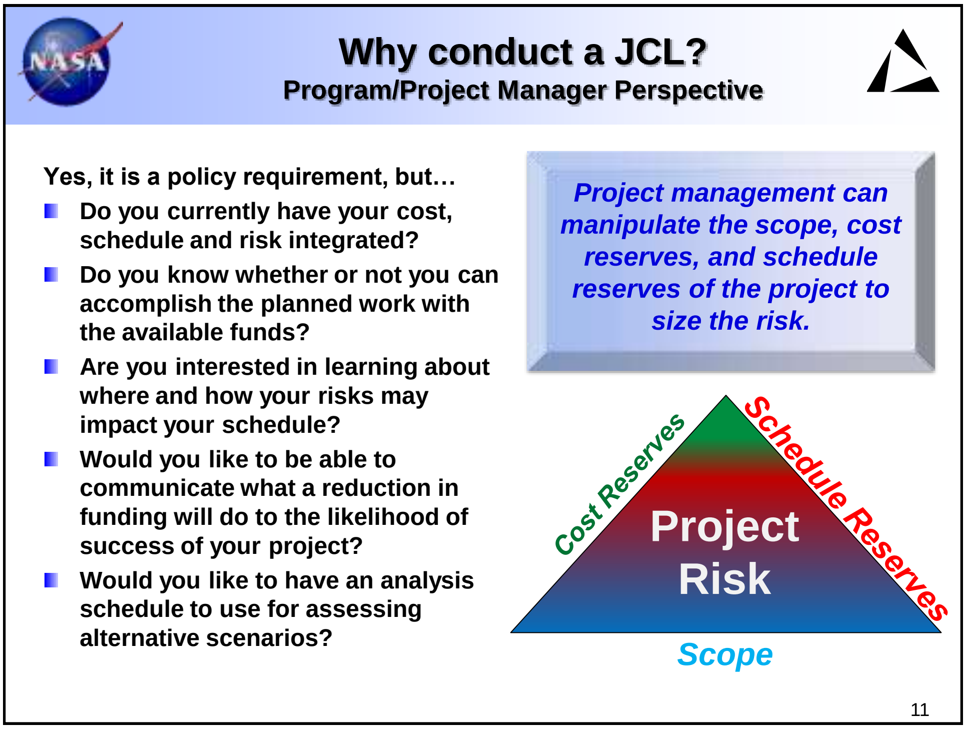
Why conduct a JCL?

NASA has a long history of Cost Growth.

- **Why have 80% of major NASA projects programs overrun their budgets?***
  - (Relentless) GAO reports support this statistic
- **Why have almost 100% of projects over schedules?***
- **….And continue to do so? (JWST)**

One major reason for many projects: Lack of an integrated picture at the beginning and throughout the life cycle

*Source Available



Why conduct a JCL?

Program/Project Manager Perspective

Yes, it is a policy requirement, but…

- Do you currently have your cost, schedule and risk integrated?
- Do you know whether or not you can accomplish the planned work with the available funds?
- Are you interested in learning about where and how your risks may impact your schedule?
- Would you like to be able to communicate what a reduction in funding will do to the likelihood of success of your project?
- Would you like to have an analysis schedule to use for assessing alternative scenarios?

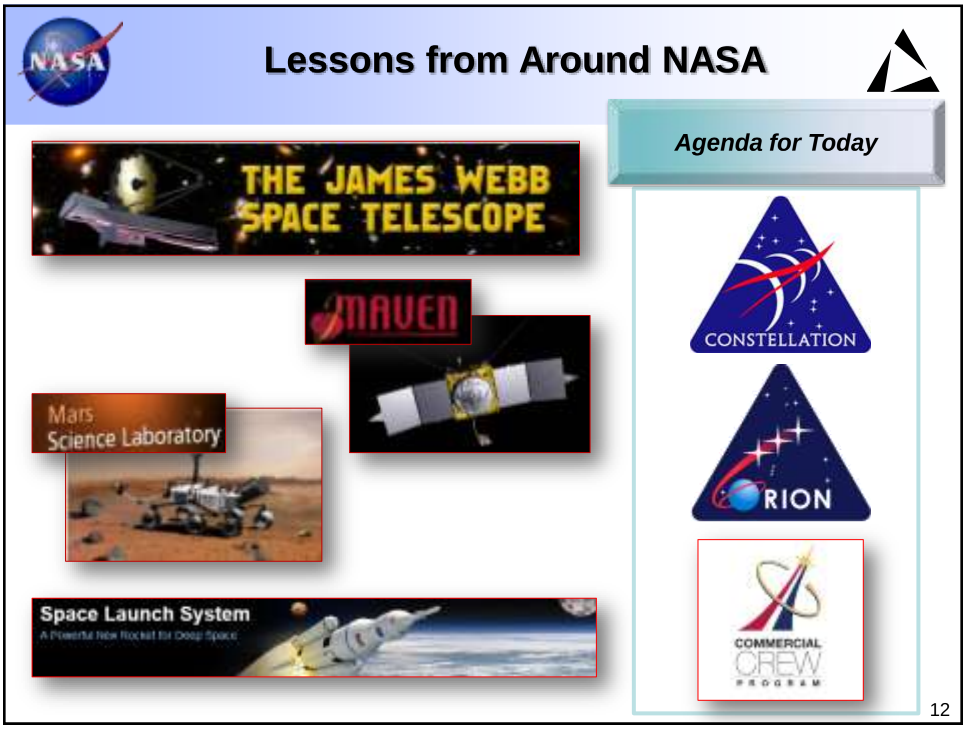
Project management can manipulate the scope, cost reserves, and schedule reserves of the project to size the risk.

Cost Reserves

Schedule Reserves

Project Risk

Scope



Lessons from Around NASA

Agenda for Today

THE JAMES WEBB SPACE TELESCOPE
MAVEN
Mars Science Laboratory
Space Launch System
A Powerful New Rocket for Deep Space
CONSTELLATION
ORION
COMMERCIAL CREW PROGRAM

Constellation JCL

Overview

- NASA's $98B* failed attempt to reach the moon coined 'JCL' terminology for first time in US Gov and pioneered the methodology.
- Augustine Committee concluded that Cx was 'unsustainable'; Cancelled by Obama administration in 2010
- JCLers were not surprised: 0% confidence of meeting schedule and budget rendered many months earlier
- Benefit: JCL was a major part of the program's story to external stakeholders: ESMD, HQ, Congress
- Benefit: Told story of a program in trouble, which was corroborated by the Standing Review Board and Augustine

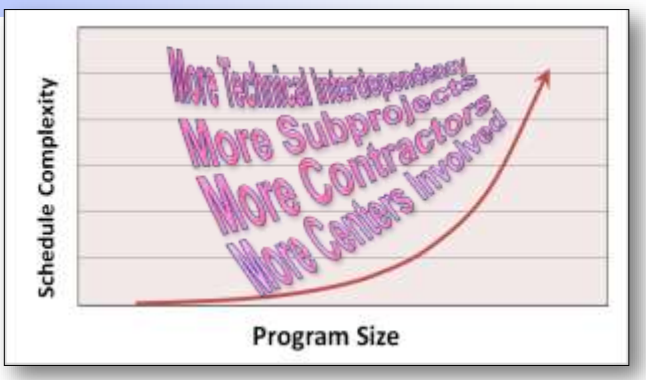
*LCC through first lunar mission

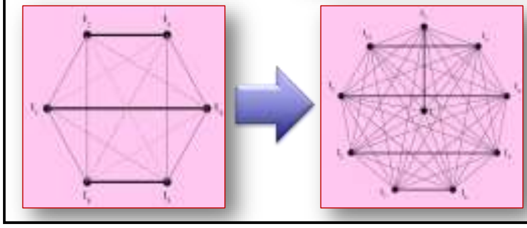
Constellation JCL

Schedule Complexity

Why are human space flight schedules almost always broken? ~ Answer: Complexity and size

- **Program size exponentially increases the number of interconnections among moving parts** (e.g. subprojects, disciplines, contractors, centers, center directorates)

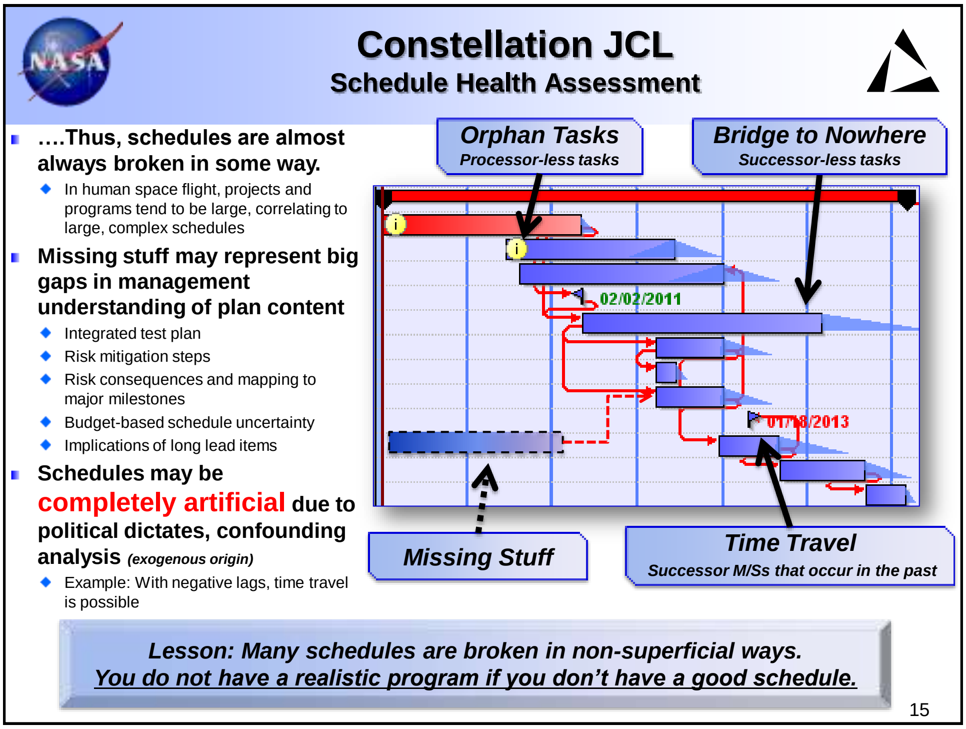




Lesson: Schedule complexity increases non-linearly as a function of project size;

Lots of complexity = more potential for schedule errors, missed connections, and omission

-Constellation suffered from this fact.



Constellation JCL

Schedule Health Assessment

- ….Thus, schedules are almost always broken in some way.
  - In human space flight, projects and programs tend to be large, correlating to large, complex schedules
- Missing stuff may represent big gaps in management understanding of plan content
  - Integrated test plan
  - Risk mitigation steps
  - Risk consequences and mapping to major milestones
  - Budget-based schedule uncertainty
  - Implications of long lead items
- Schedules may be **completely artificial** due to political dictates, confounding analysis *(exogenous origin)*
  - Example: With negative lags, time travel is possible

Orphan Tasks
Processor-less tasks

Bridge to Nowhere
Successor-less tasks

Missing Stuff

Time Travel
Successor M/Ss that occur in the past

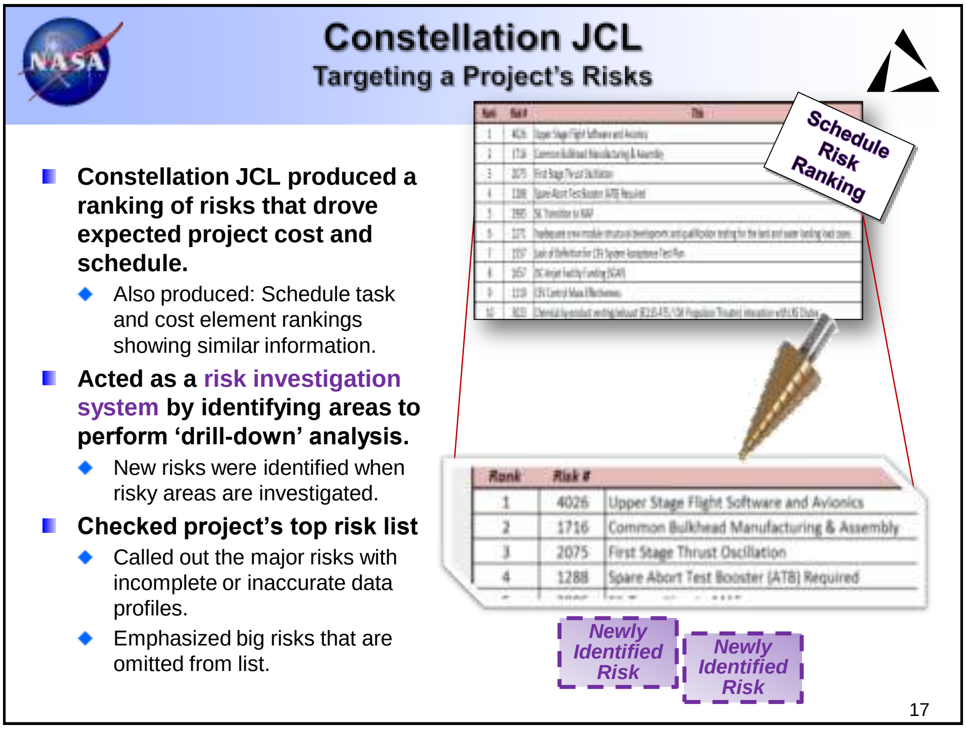
Lesson: Many schedules are broken in non-superficial ways.
You do not have a realistic program if you don't have a good schedule.

Constellation JCL

Schedule Uncertainty Issues

- **Problems with History**
  - *"What? Schedule data sets do not exist."*
    - Yes they do; NASA has an ongoing program data collection effort ('CADRe').
  - *"The analogous levels I'm looking for may not be available in past schedules."*
    - Higher levels are available; Apply them to your schedule assessments.
    - Allocate that level to lower levels if you're doing a JCL. (Note: There are easy ways to do this, and really convoluted ones…)
  - *"Historical data sets don't really show schedule growth due to discrete risks."*
    - Assess composite uncertainty (uncertainty + discrete risk consequences); compare to history.
- **Problems with Past Performance**
  - *"Schedule baselines have fluctuated."*
    - That's the point. Track the changes at the most relevant level.
  - *"No… they **really** fluctuated. The schedule structures are different. The task I was tracking went away."*
    - They aren't fluctuating **that** much; track at higher levels, but try to ascertain where the work associated with missing tasks went.
    - Try to track at omnipresent **bottleneck events**, like tasks on the critical path leading to PDRs, CDRs, major tests, etc.

Lesson: Schedule uncertainty from real data sources is highly useful for establishing context for your program assessment and JCLs.
Data will behave if you get your hands dirty.



Constellation JCL

Targeting a Project's Risks

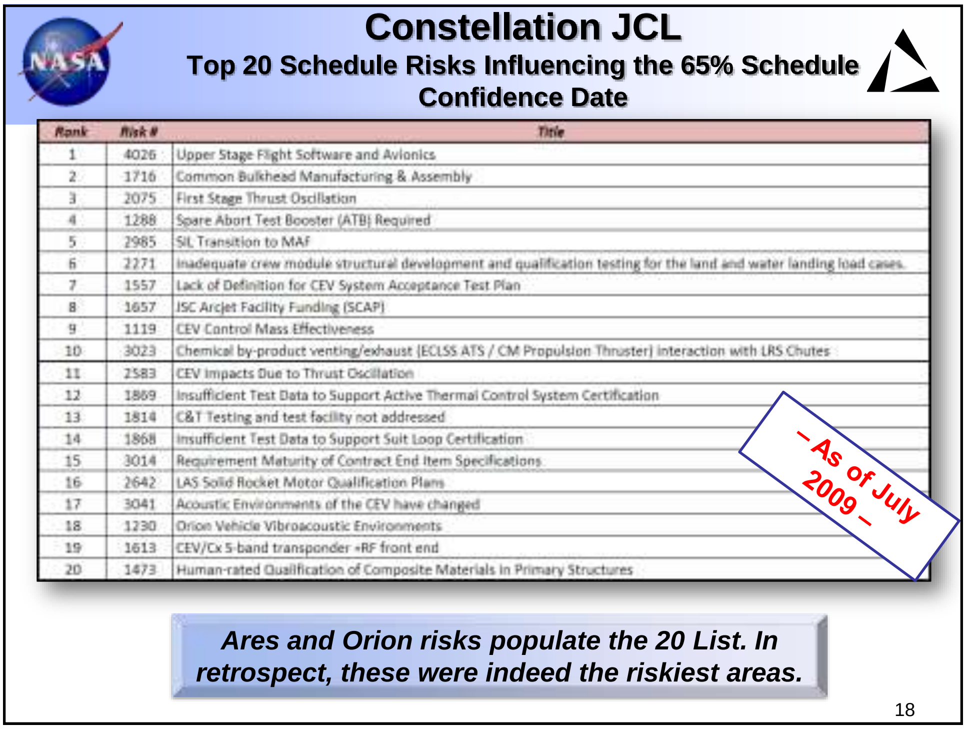
- **Constellation JCL produced a ranking of risks that drove expected project cost and schedule.**
  - Also produced: Schedule task and cost element rankings showing similar information.
- **Acted as a risk investigation system by identifying areas to perform 'drill-down' analysis.**
  - New risks were identified when risky areas are investigated.
- **Checked project's top risk list**
  - Called out the major risks with incomplete or inaccurate data profiles.
  - Emphasized big risks that are omitted from list.

Schedule Risk Ranking

Rank	Risk #	
1	4026	Upper Stage Flight Software and Avionics
2	1716	Common Bulkhead Manufacturing & Assembly
3	2075	First Stage Thrust Oscillation
4	1288	Spare Abort Test Booster (ATB) Required

Newly Identified Risk

Newly Identified Risk



Constellation JCL

Top 20 Schedule Risks Influencing the 65% Schedule Confidence Date

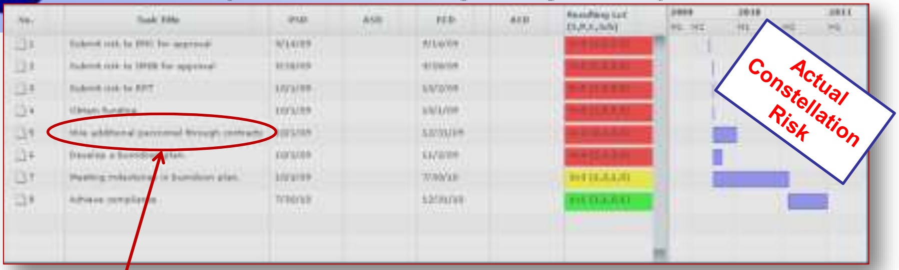
Rank	Risk #	Title
1	4026	Upper Stage Flight Software and Avionics
2	1716	Common Bulkhead Manufacturing & Assembly
3	2075	First Stage Thrust Oscillation
4	1288	Spare Abort Test Booster (ATB) Required
5	2985	SIL Transition to MAF
6	2271	Inadequate crew module structural development and qualification testing for the land and water landing load cases.
7	1557	Lack of Definition for CEV System Acceptance Test Plan
8	1657	JSC Arcjet Facility Funding (SCAP)
9	1119	CEV Control Mass Effectiveness
10	3023	Chemical by-product venting/exhaust (ECLSS ATS / CM Propulsion Thruster) interaction with LRS Chutes
11	2583	CEV Impacts Due to Thrust Oscillation
12	1869	Insufficient Test Data to Support Active Thermal Control System Certification
13	1814	C&T Testing and test facility not addressed
14	1868	Insufficient Test Data to Support Suit Loop Certification
15	3014	Requirement Maturity of Contract End Item Specifications
16	2642	LAS Solid Rocket Motor Qualification Plans
17	3041	Acoustic Environments of the CEV have changed
18	1230	Orion Vehicle Vibroacoustic Environments
19	1613	CEV/Cx S-band transponder +RF front end
20	1473	Human-rated Qualification of Composite Materials in Primary Structures

– As of July 2009 –

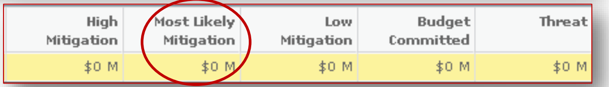
Ares and Orion risks populate the 20 List. In retrospect, these were indeed the riskiest areas.

Constellation JCL

Risk Completeness and Subjectivity: Incomplete Risks



- **$0 mitigation cost, but step #5 suggests 'hiring of additional personnel..'**



High Mitigation	Most Likely Mitigation	Low Mitigation	Budget Committed	Threat
$0 M	$0 M	$0 M	$0 M	$0 M

- ***Half of Risk X's fields, including cost uncertainty and detailed description of the issues were blank***
- ***Many risks like it were similarly incomplete***

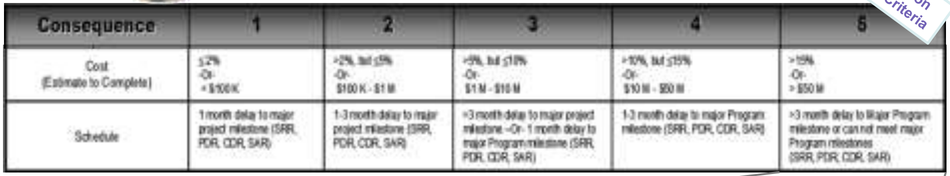
Lesson: Risks are often incomplete, subjectively assessed, or simply unjustifiable.
Take very great care quantitatively incorporating risks into an assessment and JCL.

Constellation JCL

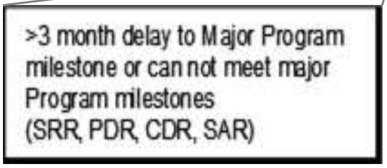
Risk Scoring: 'Local' Issue Inflation

"The component I designed is kindof a really big deal, so OF COURSE its risk is a 5 schedule consequence and 5 cost consequence."

Constellation Scoring Criteria



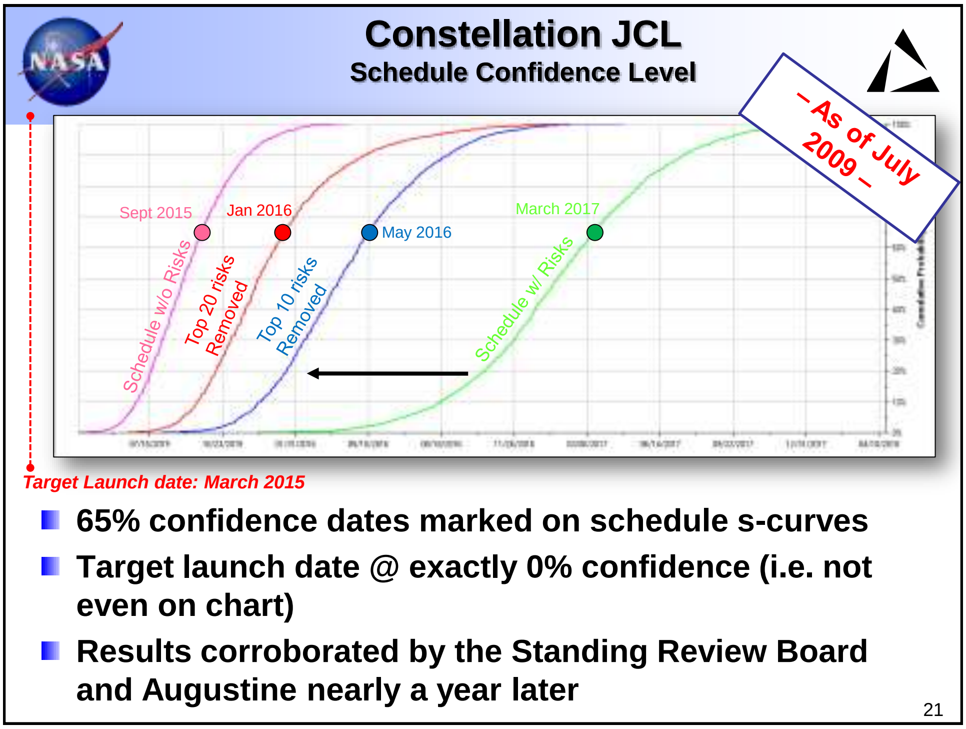
Consequence	1	2	3	4	5
Cost (Estimate to Complete)	≤2% -Or- < $100K	>2%, but ≤5% -Or- $100K - $1M	>5%, but ≤10% -Or- $1M - $10M	>10%, but ≤15% -Or- $10M - $50M	>15% -Or- > $50M
Schedule	1 month delay to major project milestone (SRR, PDR, CDR, SAR)	1-3 month delay to major project milestone (SRR, PDR, CDR, SAR)	>3 month delay to major project milestone -Or- 1 month delay to major Program milestone (SRR, PDR, CDR, SAR)	1-3 month delay to major Program milestone (SRR, PDR, CDR, SAR)	>3 month delay to Major Program milestone or can not meet major Program milestones (SRR, PDR, CDR, SAR)



>3 month delay to Major Program milestone or can not meet major Program milestones (SRR, PDR, CDR, SAR)

- **Without an integrated picture of schedule, how can Billy Bob risk owner ascertain his risk's schedule effects on milestones that his work, along with an infinity of other tasks, may or may not touch directly?**
- **Shouldn't the true risk consequence scores come from the JCL/integrated program assessment and not serve as an input into it?**

Lesson: In Constellation, risks were often scored with inflated importance of local issues.
If you have time… talk to the risk owners and obtain the true "local" consequence of the risk.

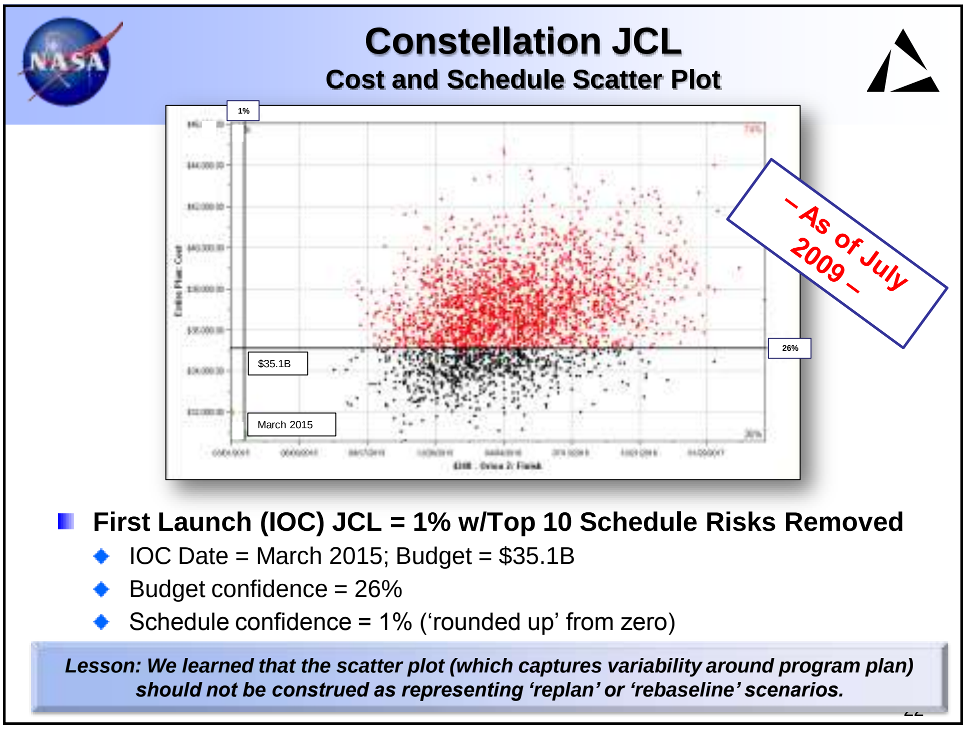


Constellation JCL

Schedule Confidence Level

Target Launch date: March 2015

- 65% confidence dates marked on schedule s-curves
- Target launch date @ exactly 0% confidence (i.e. not even on chart)
- Results corroborated by the Standing Review Board and Augustine nearly a year later



Constellation JCL

Cost and Schedule Scatter Plot

- **First Launch (IOC) JCL = 1% w/Top 10 Schedule Risks Removed**
  - IOC Date = March 2015; Budget = $35.1B
  - Budget confidence = 26%
  - Schedule confidence = 1% (‘rounded up’ from zero)

Lesson: We learned that the scatter plot (which captures variability around program plan) should not be construed as representing ‘replan’ or ‘rebaseline’ scenarios.

Orion JCL

Overview

- **Constellation was survived by its capsule, repurposed as a multi-mission vehicle.**
- **The Orion Multi-Purpose Crew Vehicle (MPCV) is a NASA program developing a manned spacecraft for missions beyond Low Earth Orbit.**
  - First manned mission planned for 2021, with unmanned test flights in 2014 and 2017
  - Built by Lockheed Martin/Airbus (via ESA)
- **First official JCL from Johnson Space Center at KDP-C being constructed**
- **Subject to new JCL language in updated NASA policy**
- **Since Constellation, GAO has formally endorsed our JCL approach.**
- **Congress has begun talking in terms of JCL, asking for it by name.**

Orion JCL

JCL is now built into the fabric of NASA budgeting policy.

- **NASA Procedural Requirement (NPR) 7120.5 E (effective Aug 2012) ~ JCL Summary:** http://nodis3.gsfc.nasa.gov/npg_img/N_PR_7120_005E_/N_PR_7120_005E_.pdf
  - @KDP B: Tightly coupled and single-project programs > $250M shall provide a range of cost and a range for schedule established by probabilistic analysis. JCL not required at this time.
  - @KDP C: ….shall develop a resource-loaded schedule and perform a risk-informed probabilistic analysis that produces a JCL.
  - Any JCL approved by the Decision Authority at less than 70 percent shall be justified and documented.
  - Many of these requirements echoed in NPD 1000.5A http://nodis3.gsfc.nasa.gov/npg_img/N_PD_1000_005A_/N_PD_1000_005A__main.pdf
- **NASA Technical Memo: 70% JCL could require between 30% to 50% schedule reserves and UFE for a tightly coupled program**
  - Kuo, Wilson: Joint Confidence Level Requirement: Policy and Issues (NASA TM-2011-216154)
- **Exceptions are granted for 'tailored' program plans that meet the intent of the NPR.**
  - CCP has agreed to produce an analysis that 'meets the intent' of the JCL requirement.

Orion JCL

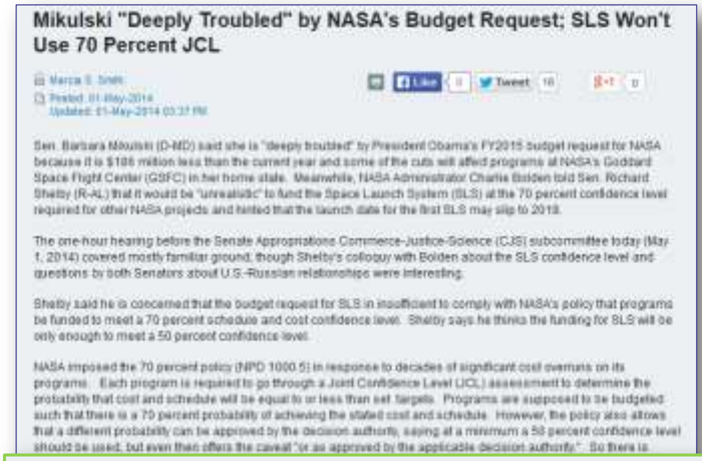
GAO loves it

- ***"Over the past several years, NASA has made positive changes that have helped contribute to the improved performance of its projects."***
- ***"For example, NASA instituted the joint cost and schedule confidence level (JCL) process, which is expected to quantify potential risks and calculates cost, schedule, and reserve estimates based on all available data."***
- ***"NASA also addressed one of our 2011 recommendations by beginning to provide more transparency into project costs in the early phases of development, such as life cycle cost estimate ranges for projects in formulation and information on prior year costs."***
- ***"This information should allow the Congress sufficient information to conduct oversight and ensure earlier accountability and should bring more attention to and focus on conducting early, reliable estimates of project costs."***

GAO-13-276SP Assessments of Selected Large-Scale Projects, April 2013, p. 22

Orion JCL

Congress understands it



Mikulski "Deeply Troubled" by NASA's Budget Request; SLS Won't Use 70 Percent JCL

Marcia S. Smith
Posted: 01-May-2014
Updated: 01-May-2014 03:37 PM

Sen. Barbara Mikulski (D-MD) said she is "deeply troubled" by President Obama's FY2015 budget request for NASA because it is $186 million less than the current year and some of the cuts will affect programs at NASA's Goddard Space Flight Center (GSFC) in her home state. Meanwhile, NASA Administrator Charlie Bolden told Sen. Richard Shelby (R-AL) that it would be "unrealistic" to fund the Space Launch System (SLS) at the 70 percent confidence level required for other NASA projects and hinted that the launch date for the first SLS may slip to 2018.

The one-hour hearing before the Senate Appropriations Commerce-Justice-Science (CJS) subcommittee today (May 1, 2014) covered mostly familiar ground, though Shelby's colloquy with Bolden about the SLS confidence level and questions by both Senators about U.S.-Russian relationships were interesting.

Shelby said he is concerned that the budget request for SLS in insufficient to comply with NASA's policy that programs be funded to meet a 70 percent schedule and cost confidence level. Shelby says he thinks the funding for SLS will be only enough to meet a 50 percent confidence level.

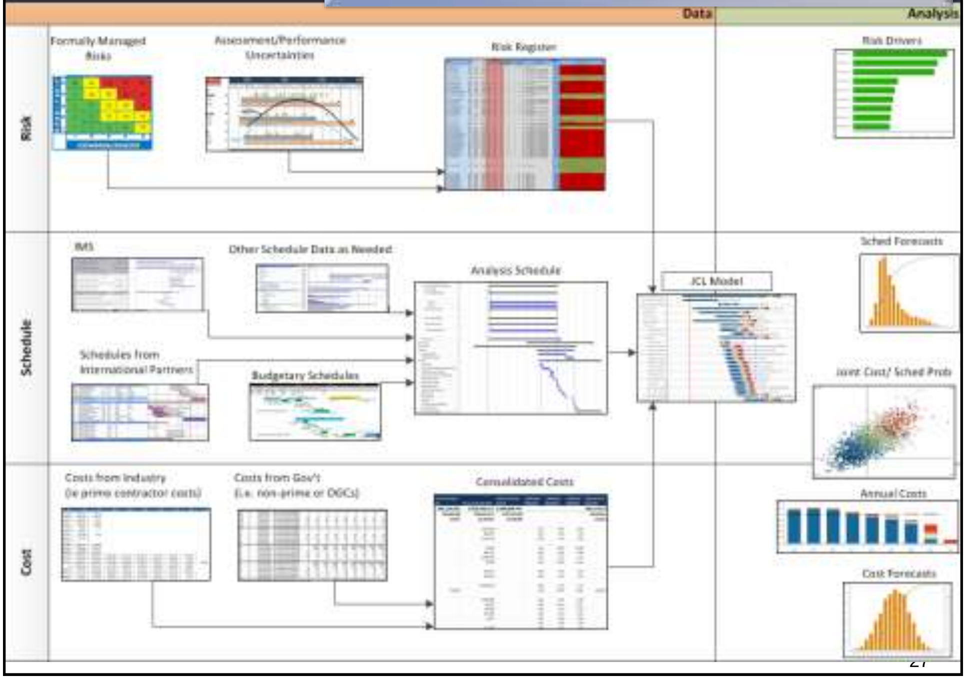
NASA imposed the 70 percent policy (NPD 1000.5) in response to decades of significant cost overruns on its programs. Each program is required to go through a Joint Confidence Level (JCL) assessment to determine the probability that cost and schedule will be equal to or less than set targets. Programs are supposed to be budgeted such that there is a 70 percent probability of achieving the stated cost and schedule. However, the policy also allows that a different probability can be approved by the decision authority, saying at a minimum a 50 percent confidence level should be used, but even then offers the caveat "or as approved by the applicable decision authority." So there is

Lesson: JCL's intuitive, elegant nature has made it a natural communication tool between NASA and congress.

Shelby said he is concerned that the budget request for SLS in insufficient to comply with NASA's policy that programs be funded to meet a 70 percent schedule and cost confidence level. Shelby says he thinks the funding for SLS will be only enough to meet a 50 percent confidence level.

Orion Joint Confidence Level Model Overview

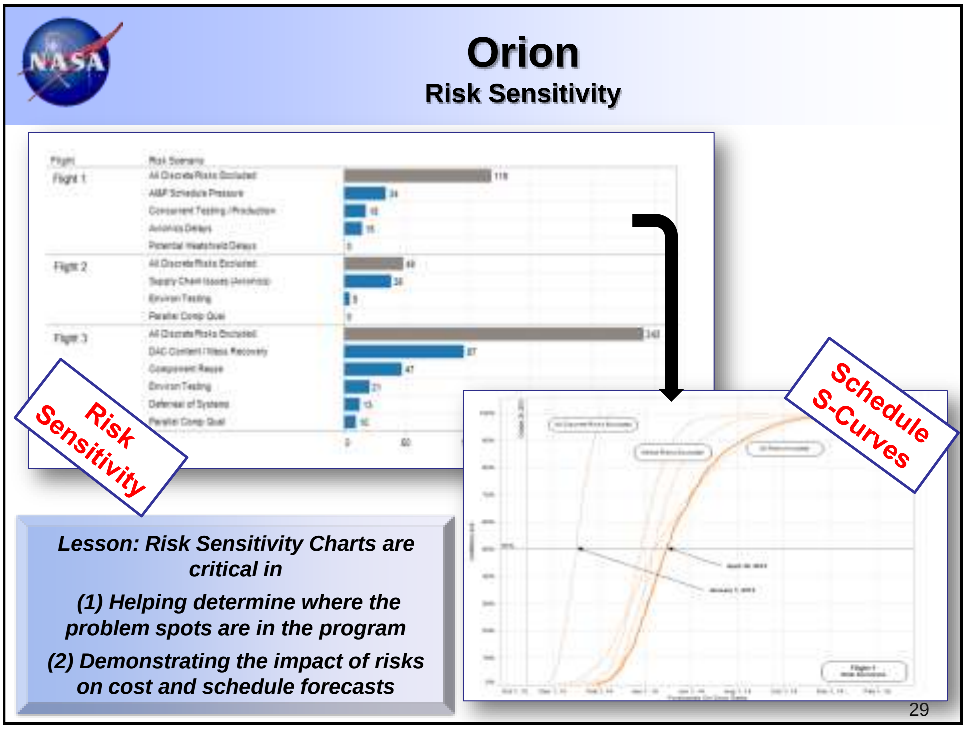
Lesson: JCL modeling can have a high data requirement.


Data
Analysis
Risk
Schedule
Cost
Formally Managed Risks
Assessment/Performance Uncertainties
Risk Register
Risk Drivers
IMS
Other Schedule Data as Needed
Analysis Schedule
JCL Model
Sched Forecasts
Schedules from International Partners
Budgetary Schedules
Joint Cost/ Sched Prob
Costs from Industry (ie prime contractor costs)
Costs from Gov't (i.e. non-prime or DGCs)
Consolidated Costs
Annual Costs
Cost Forecasts

Orion
Use of JCL Products

- **Many JCL products are actionable and lend themselves well to program management. These products include:**
  - Impacts of discrete program risks
  - 'What-if' scenarios
  - Recommended annual funding reserve
- **Management has found these other products more useful than the traditional cost and schedule CDFs ('ranges')**
- **The Orion Program Control team is constantly evolving with JCL models to find new analyses for program insight**

Lesson: JCL is acting as a forcing function to truly integrate cost, schedule, and risk systems into useful reporting products.



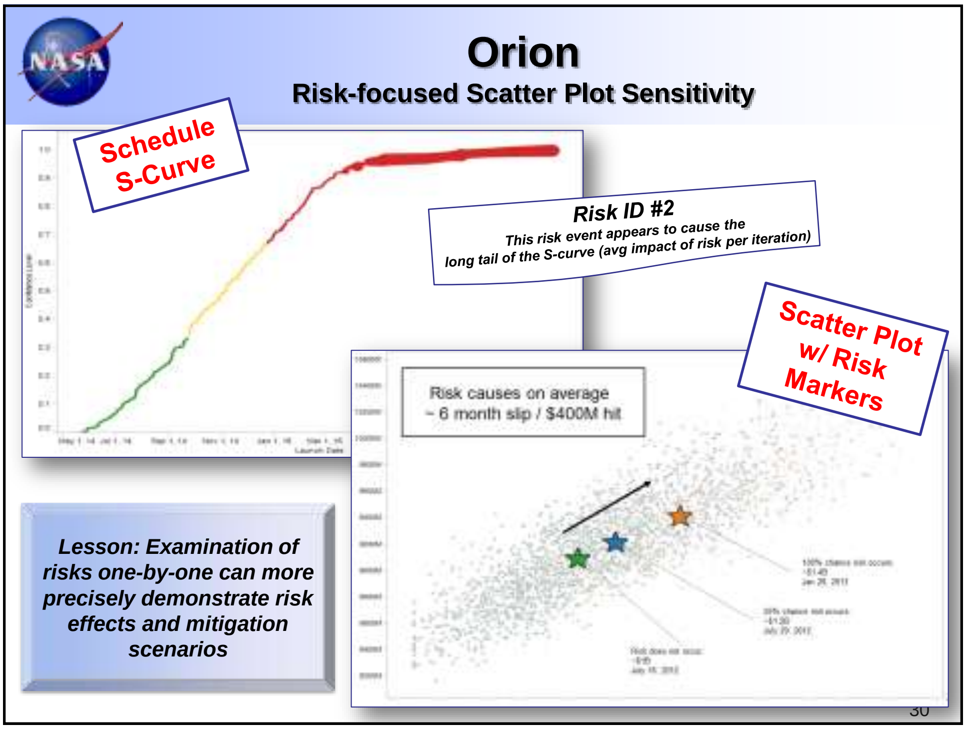
Orion

Risk Sensitivity

Lesson: Risk Sensitivity Charts are critical in

(1) Helping determine where the problem spots are in the program

(2) Demonstrating the impact of risks on cost and schedule forecasts



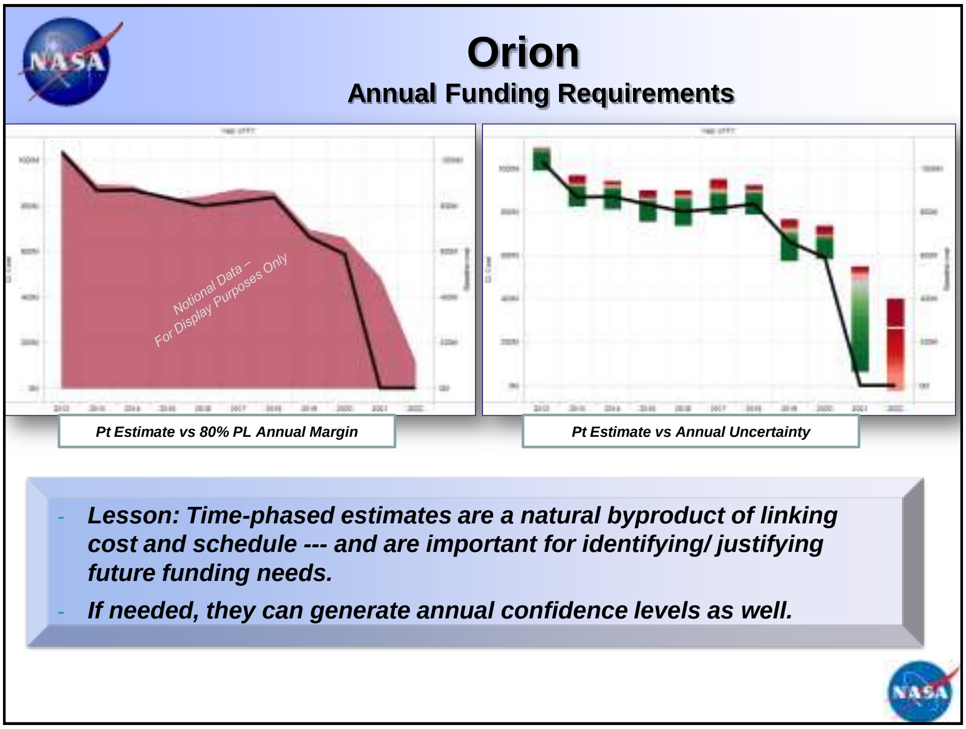
Orion

Risk-focused Scatter Plot Sensitivity

Risk ID #2

This risk event appears to cause the long tail of the S-curve (avg impact of risk per iteration)

Lesson: Examination of risks one-by-one can more precisely demonstrate risk effects and mitigation scenarios



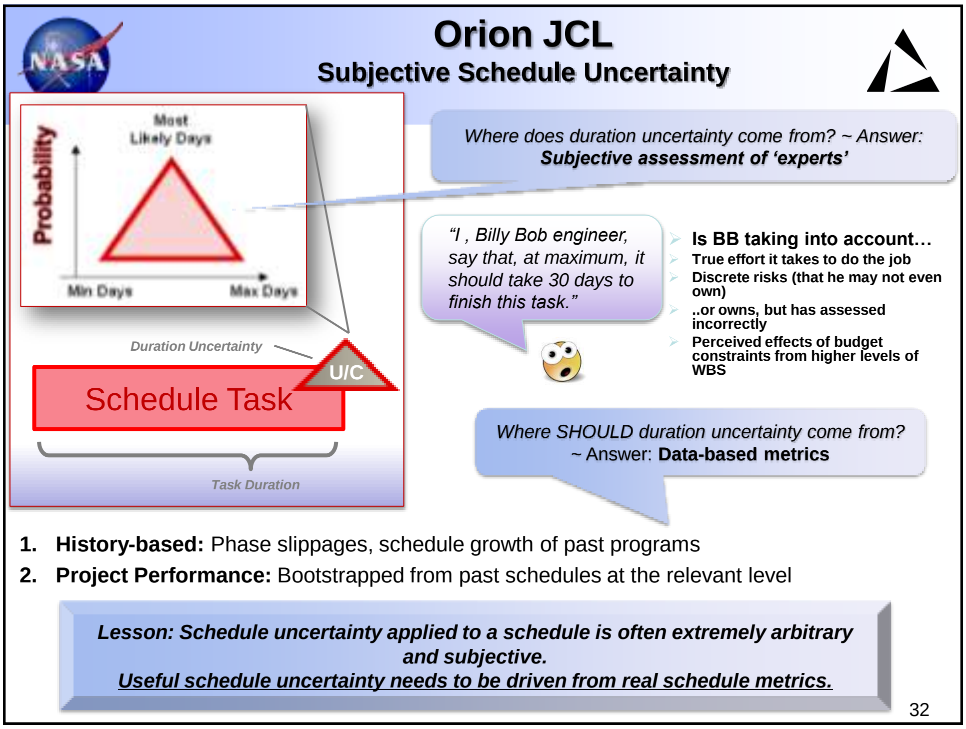
Orion

Annual Funding Requirements

Pt Estimate vs 80% PL Annual Margin

Pt Estimate vs Annual Uncertainty

- *Lesson: Time-phased estimates are a natural byproduct of linking cost and schedule --- and are important for identifying/ justifying future funding needs.*
- *If needed, they can generate annual confidence levels as well.*



Orion JCL

Subjective Schedule Uncertainty

Where does duration uncertainty come from? ~ Answer: ***Subjective assessment of 'experts'***

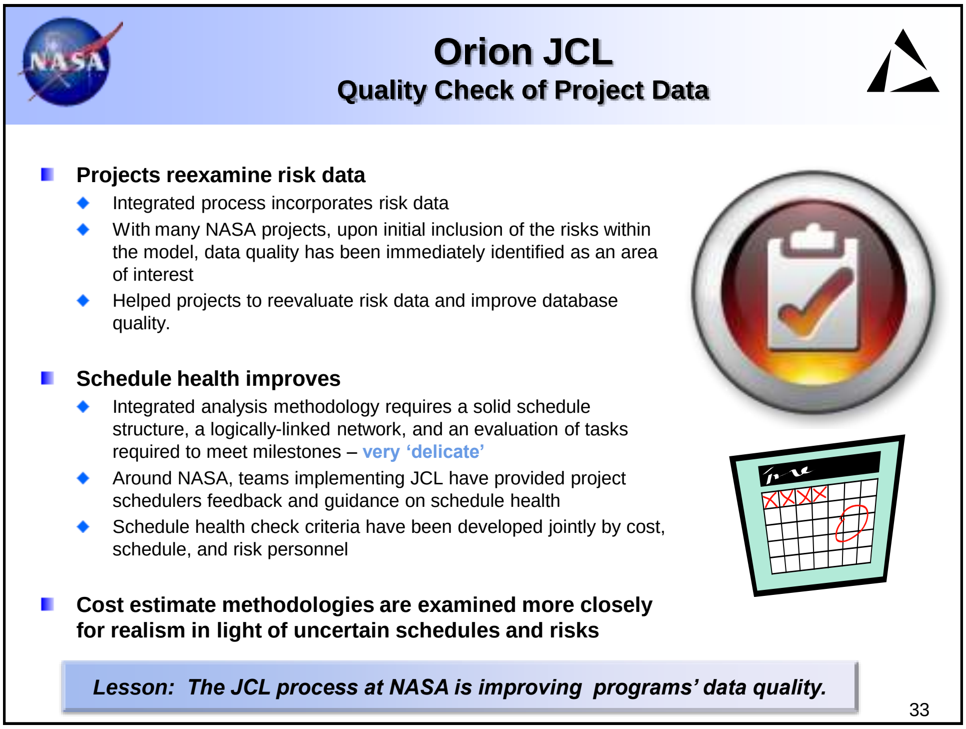
"I , Billy Bob engineer, say that, at maximum, it should take 30 days to finish this task."

- **Is BB taking into account…**
- **True effort it takes to do the job**
- **Discrete risks (that he may not even own)**
- **..or owns, but has assessed incorrectly**
- **Perceived effects of budget constraints from higher levels of WBS**

Where SHOULD duration uncertainty come from? ~ Answer: **Data-based metrics**

1. **History-based:** Phase slippages, schedule growth of past programs
2. **Project Performance:** Bootstrapped from past schedules at the relevant level

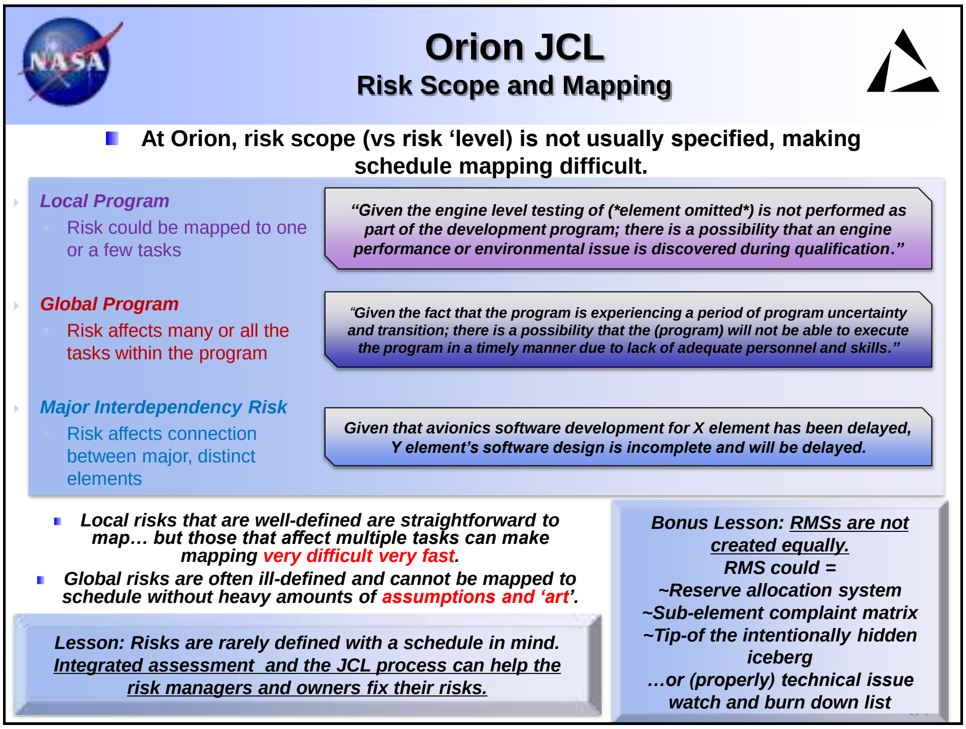
Lesson: Schedule uncertainty applied to a schedule is often extremely arbitrary and subjective.
Useful schedule uncertainty needs to be driven from real schedule metrics.



Orion JCL
Quality Check of Project Data

- **Projects reexamine risk data**
  - Integrated process incorporates risk data
  - With many NASA projects, upon initial inclusion of the risks within the model, data quality has been immediately identified as an area of interest
  - Helped projects to reevaluate risk data and improve database quality.
- **Schedule health improves**
  - Integrated analysis methodology requires a solid schedule structure, a logically-linked network, and an evaluation of tasks required to meet milestones – **very 'delicate'**
  - Around NASA, teams implementing JCL have provided project schedulers feedback and guidance on schedule health
  - Schedule health check criteria have been developed jointly by cost, schedule, and risk personnel
- **Cost estimate methodologies are examined more closely for realism in light of uncertain schedules and risks**

Lesson: The JCL process at NASA is improving programs' data quality.



Orion JCL
Risk Scope and Mapping

- **At Orion, risk scope (vs risk 'level) is not usually specified, making schedule mapping difficult.**

Local Program
- Risk could be mapped to one or a few tasks

"Given the engine level testing of (*element omitted*) is not performed as part of the development program; there is a possibility that an engine performance or environmental issue is discovered during qualification."

Global Program
- Risk affects many or all the tasks within the program

"Given the fact that the program is experiencing a period of program uncertainty and transition; there is a possibility that the (program) will not be able to execute the program in a timely manner due to lack of adequate personnel and skills."

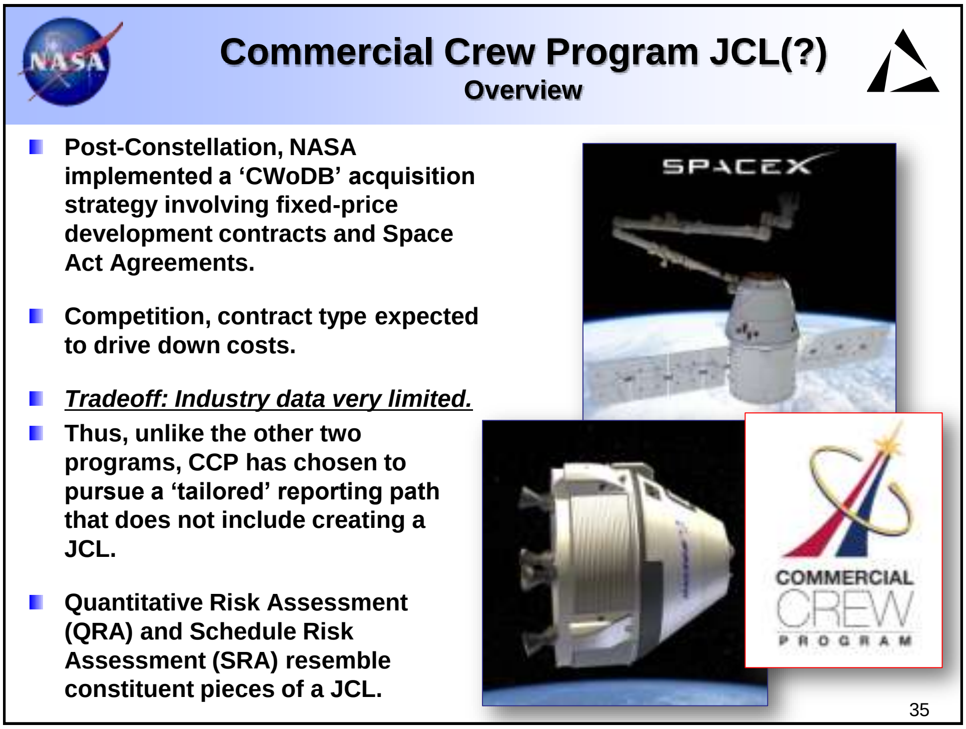
Major Interdependency Risk
- Risk affects connection between major, distinct elements

Given that avionics software development for X element has been delayed, Y element's software design is incomplete and will be delayed.

- ***Local risks that are well-defined are straightforward to map… but those that affect multiple tasks can make mapping very difficult very fast.***
- ***Global risks are often ill-defined and cannot be mapped to schedule without heavy amounts of assumptions and 'art'.***

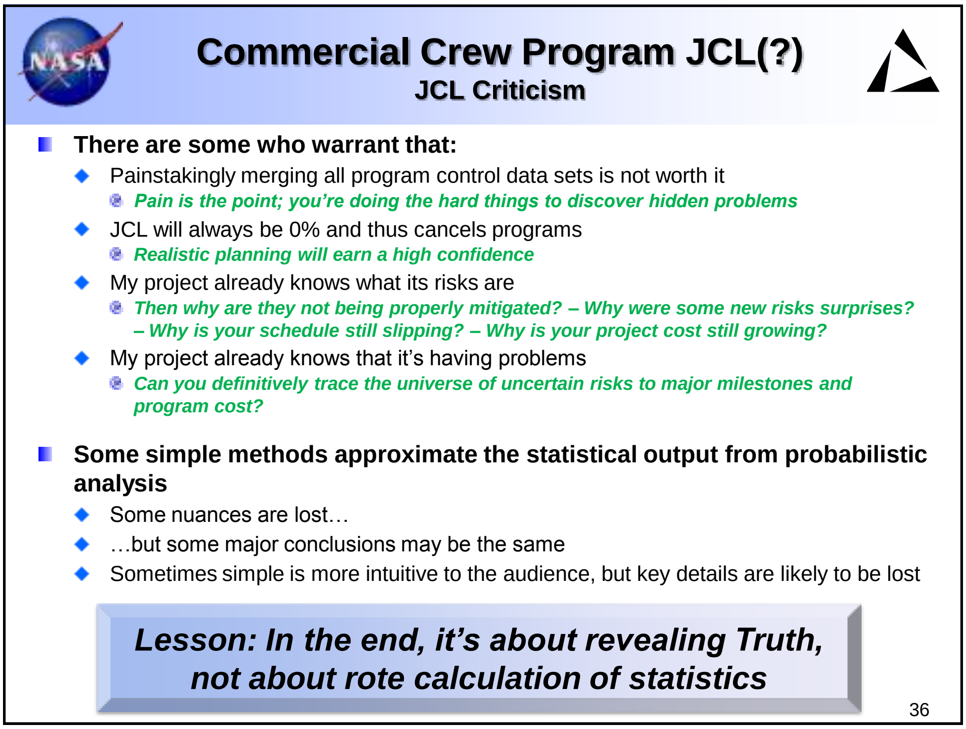
Lesson: Risks are rarely defined with a schedule in mind. Integrated assessment and the JCL process can help the risk managers and owners fix their risks.

Bonus Lesson: RMSs are not created equally.
RMS could =
~Reserve allocation system
~Sub-element complaint matrix
~Tip-of the intentionally hidden iceberg
…or (properly) technical issue watch and burn down list


SPACEX
COMMERCIAL
CREW
PROGRAM

Commercial Crew Program JCL(?)
Overview

- **Post-Constellation, NASA implemented a 'CWoDB' acquisition strategy involving fixed-price development contracts and Space Act Agreements.**
- **Competition, contract type expected to drive down costs.**
- ***Tradeoff: Industry data very limited.***
- **Thus, unlike the other two programs, CCP has chosen to pursue a 'tailored' reporting path that does not include creating a JCL.**
- **Quantitative Risk Assessment (QRA) and Schedule Risk Assessment (SRA) resemble constituent pieces of a JCL.**



Commercial Crew Program JCL(?)
JCL Criticism

- **There are some who warrant that:**
  - Painstakingly merging all program control data sets is not worth it
    - ***Pain is the point; you're doing the hard things to discover hidden problems***
  - JCL will always be 0% and thus cancels programs
    - ***Realistic planning will earn a high confidence***
  - My project already knows what its risks are
    - ***Then why are they not being properly mitigated? – Why were some new risks surprises? – Why is your schedule still slipping? – Why is your project cost still growing?***
  - My project already knows that it's having problems
    - ***Can you definitively trace the universe of uncertain risks to major milestones and program cost?***
- **Some simple methods approximate the statistical output from probabilistic analysis**
  - Some nuances are lost…
  - …but some major conclusions may be the same
  - Sometimes simple is more intuitive to the audience, but key details are likely to be lost

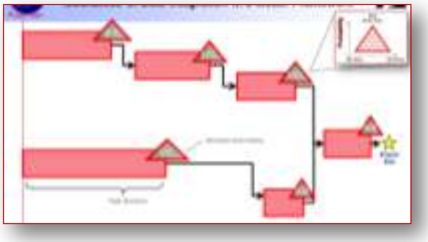
Lesson: In the end, it's about revealing Truth, not about rote calculation of statistics

Commercial Crew Program QRA/SRA

Alternative to JCL

Risk Title	Uncertainty			Likelihood		Uncertainty			Consequence	
	Low	ML	High	%	Yes?	Low	ML	High		Impact
Risk A	33%	50%	66%	50%	1	80%	104%	127%		$ 5,191,666.67

- **QRA**
  - Statistical summation of risks' cost impacts weighted by likelihood of occurrence
  - Point estimate value used to determine program reserve adequacy
  - Distributions applied to cost impact and likelihood
  - Monte Carlo simulation
- **SRA**
  - Risk-adjusted schedule analysis
  - JCL analysis sans the cost-loading



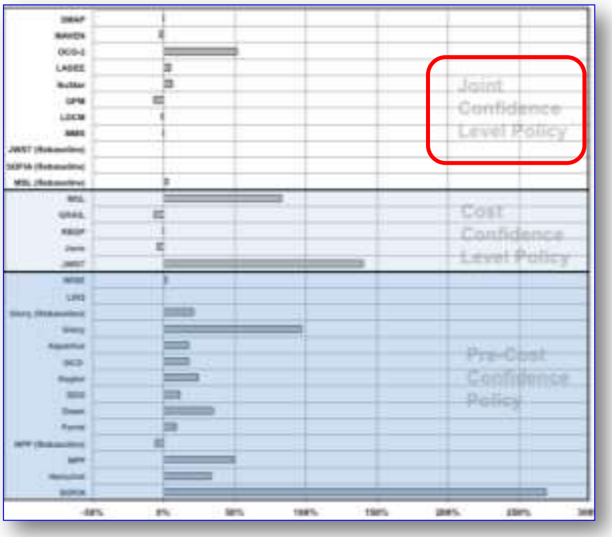
Lesson: There are several viable alternatives to JCL for program health reporting.

Epilogue

NASA Cost Performance by Policy

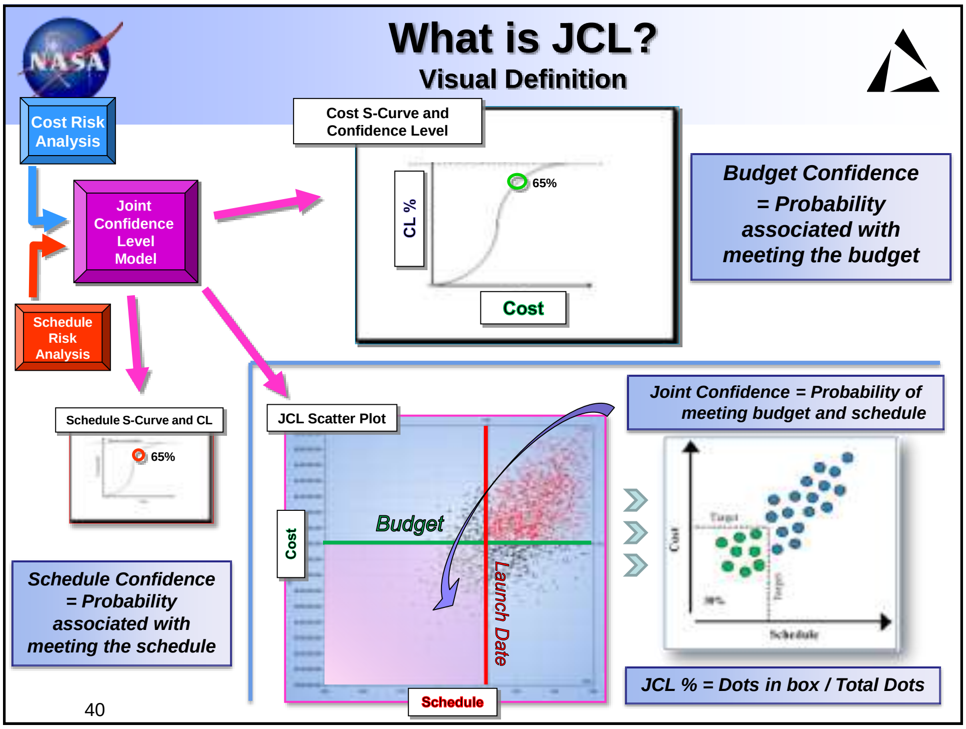
- **Historical cost performance comparison from FY 14 budget and performance documentation**
- **Shows cost growth by project across cost policy evolution**

***Lesson:** NASA cost performance is showing steady improvement over time w/JCL.*



http://www.nasa.gov/pdf/754125main_12-NASA_FY14_M%26P508-pt3.pdf

Backup and Resources



What is JCL?

Visual Definition

Cost Risk Analysis

Schedule Risk Analysis

Joint Confidence Level Model

Cost S-Curve and Confidence Level

Budget Confidence = Probability associated with meeting the budget

Schedule S-Curve and CL

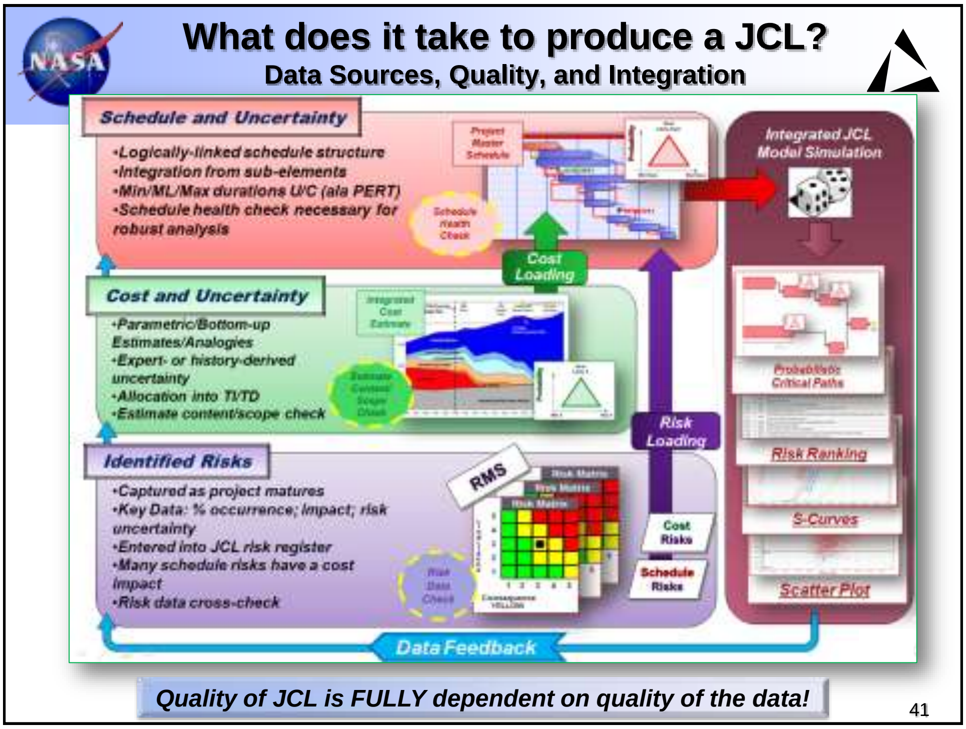
Schedule Confidence = Probability associated with meeting the schedule

JCL Scatter Plot

Joint Confidence = Probability of meeting budget and schedule

JCL % = Dots in box / Total Dots

CL %
65%
Cost
65%
Cost
Budget
Launch Date
Schedule
Cost
Target
Target
30%
Schedule



What does it take to produce a JCL?
Data Sources, Quality, and Integration

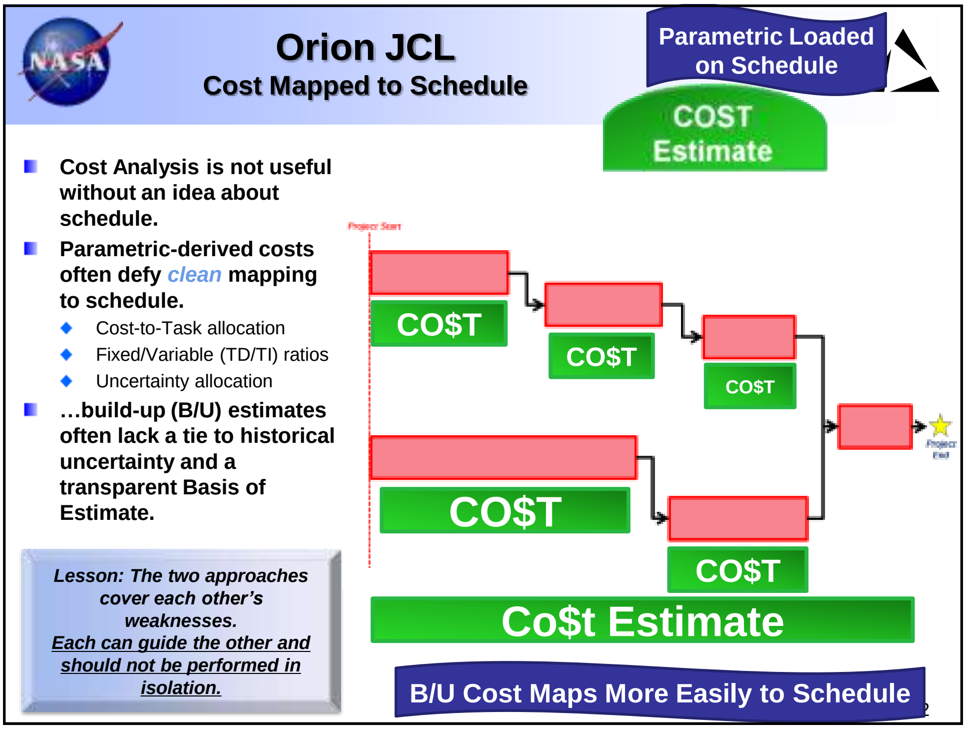
Schedule and Uncertainty
- Logically-linked schedule structure
- Integration from sub-elements
- Min/ML/Max durations U/C (ala PERT)
- Schedule health check necessary for robust analysis

Cost and Uncertainty
- Parametric/Bottom-up Estimates/Analogies
- Expert- or history-derived uncertainty
- Allocation into TI/TD
- Estimate content/scope check

Identified Risks
- Captured as project matures
- Key Data: % occurrence; impact; risk uncertainty
- Entered into JCL risk register
- Many schedule risks have a cost impact
- Risk data cross-check

Project Master Schedule
Schedule Health Check
Cost Loading
Integrated Cost Estimate
Estimate Content Scope Check
RMS
Risk Matrix
Risk Data Check
Risk Loading
Cost Risks
Schedule Risks
Integrated JCL Model Simulation
Probabilistic Critical Paths
Risk Ranking
S-Curves
Scatter Plot
Data Feedback

Quality of JCL is FULLY dependent on quality of the data!



Orion JCL
Cost Mapped to Schedule

Parametric Loaded on Schedule

- Cost Analysis is not useful without an idea about schedule.
- Parametric-derived costs often defy *clean* mapping to schedule.
  - Cost-to-Task allocation
  - Fixed/Variable (TD/TI) ratios
  - Uncertainty allocation
- …build-up (B/U) estimates often lack a tie to historical uncertainty and a transparent Basis of Estimate.

Lesson: The two approaches cover each other's weaknesses.
Each can guide the other and should not be performed in isolation.

COST Estimate
Project Start
CO$T
CO$T
CO$T
CO$T
CO$T
Project End
Co$t Estimate

B/U Cost Maps More Easily to Schedule

HQ JCL Brochure

What Is JCL?

Joint Confidence Level (JCL) is an integrated uncertainty analysis of cost and schedule. The result of a JCL indicates the probability that a project's cost will be equal to or less than the targeted cost AND that the schedule will be equal to or less than the targeted finish.

Why Do a JCL?

JCL analysis provides a cohesive and holistic picture of the project's ability to achieve cost and schedule goals by systematically integrating technical, cost, schedule, and risk data.

As an integrating framework, a JCL can show the impacts of risk to a project as well as highlight the relationship between cost and schedule. This relationship can be extremely important in situations with constrained budgets.

A complete JCL analysis can also facilitate transparency with stakeholders on expectations and probabilities of meeting those expectations.

When Is a JCL Required?

NASA requires that a JCL analysis be completed and submitted at Key Decision Point (KDP) C for all projects above $250 million. However, projects should start planning for their JCL at KDP-B when producing their probabilistic range estimates.

Facts and Myths About JCL

- MYTH: JCL analysis requires expensive software tools.

  FACT: NASA has JCL tools available at no cost to the projects.
- MYTH: A JCL requires a detailed resource-loaded schedule.

  FACT: Completing a JCL requires only costs, not labor categories and rates.
- MYTH: A JCL must be based on a detailed integrated master schedule (IMS).

  FACT: Projects do not need an IMS for a JCL. Summary and analysis schedules are preferred!

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National Aeronautics and
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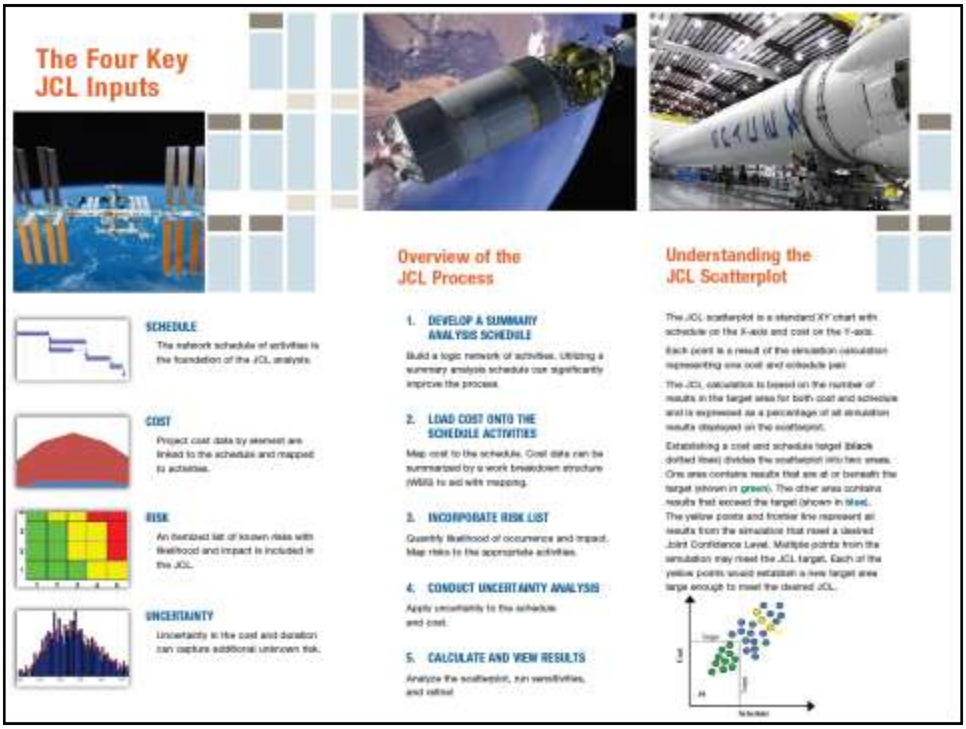
UNDERSTANDING JOINT CONFIDENCE LEVEL (JCL) AT NASA

Office of Evaluation

Cost Analysis Division
JCL Analysis Primer



The Four Key JCL Inputs

SCHEDULE

The network schedule of activities is the foundation of the JCL analysis.

COST

Project cost data by element are linked to the schedule and mapped to activities.

RISK

An itemized list of known risks with likelihood and impact is included in the JCL.

UNCERTAINTY

Uncertainty in the cost and duration can capture additional unknown risk.

Overview of the JCL Process

1. **DEVELOP A SUMMARY ANALYSIS SCHEDULE**

   Build a logic network of activities. Utilizing a summary analysis schedule can significantly improve the process.

2. **LOAD COST ONTO THE SCHEDULE ACTIVITIES**

   Map cost to the schedule. Cost data can be summarized by a work breakdown structure (WBS) to aid with mapping.

3. **INCORPORATE RISK LIST**

   Quantify likelihood of occurrence and impact. Map risks to the appropriate activities.

4. **CONDUCT UNCERTAINTY ANALYSIS**

   Apply uncertainty to the schedule and cost.

5. **CALCULATE AND VIEW RESULTS**

   Analyze the scatterplot, run sensitivities, and refine!

Understanding the JCL Scatterplot

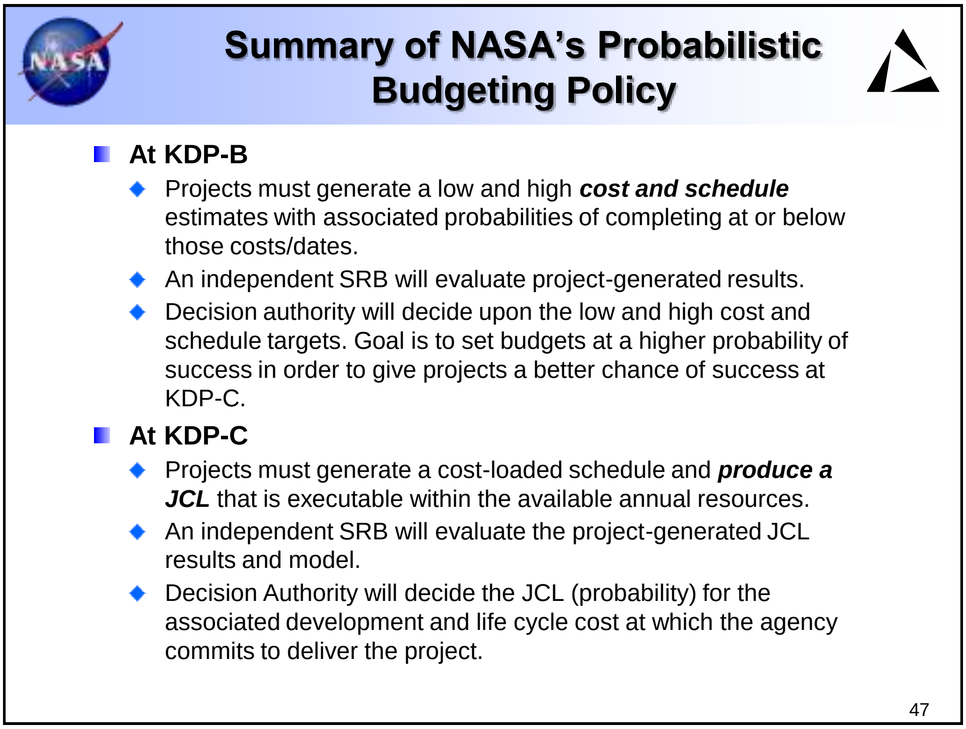
The JCL scatterplot is a standard XY chart with schedule on the X-axis and cost on the Y-axis.

Each point is a result of the simulation calculation representing one cost and schedule pair.

The JCL calculation is based on the number of results in the target area for both cost and schedule and is expressed as a percentage of all simulation results displayed on the scatterplot.

Establishing a cost and schedule target (black dotted lines) divides the scatterplot into two areas. One area contains results that are at or beneath the target (shown in green). The other area contains results that exceed the target (shown in blue). The yellow points and frontier line represent all results from the simulation that meet a desired Joint Confidence Level. Multiple points from the simulation may meet the JCL target. Each of the yellow points would establish a new target area large enough to meet the desired JCL.

NASA JCL Policy



Summary of NASA’s Probabilistic Budgeting Policy

- **At KDP-B**
    - Projects must generate a low and high ***cost and schedule*** estimates with associated probabilities of completing at or below those costs/dates.
    - An independent SRB will evaluate project-generated results.
    - Decision authority will decide upon the low and high cost and schedule targets. Goal is to set budgets at a higher probability of success in order to give projects a better chance of success at KDP-C.
- **At KDP-C**
    - Projects must generate a cost-loaded schedule and ***produce a JCL*** that is executable within the available annual resources.
    - An independent SRB will evaluate the project-generated JCL results and model.
    - Decision Authority will decide the JCL (probability) for the associated development and life cycle cost at which the agency commits to deliver the project.