Cost Estimating Requirements to Support New Congressional Reporting Requirements

February 2007

Agenda

- Summary of NASA's cost and schedule performance
- Claimed causes for cost and schedule growth
- Current initiatives to mitigate cost and schedule growth
- Future activities

Background

Study	Cost/Budget Growth		
	Average	Median	% overruns
NASA in the 90s	36%	26%	78%
NASA in the 70s	43%	26%	75%
NASA in the 80s			
Gruhl study	61%	50%	95%
GAO study	83%	60%	89%
DoD	45%	27%	76%

Source: Schaffer 2004 Study

Note: Cost growth data are drawn from budget data and are based on growth from ATP to launch

- The average cost growth rate over the past ten years is about 30 percent (Schaffer and Hamaker)
- Current projects have exceed their estimated launch dates by an average of about 35 percent (including those associated with LV services) (2007 PA&E Study)
- Cost and schedule growth
  - Adversely effects other projects in the portfolio
  - Damages our reputation and credibility with our Congressional stakeholders and therefore hampers our ability to obtain requested funds

Summary of Cost & Schedule Growth Reasons from Past Studies

Cost Growth Reasons	1970s	1980s	1990s	2000s
Inadequate definitions prior to agency budget decision and to external commitments	X	X	X	X
Optimistic Cost Estimates/Estimating Errors	X	X	X	X
Inability to execute initial schedule baseline	X	X	X	X
Inadequate risk assessments	X	X	X	X
Higher technical complexity of projects than anticipated	X	X	X	X
Changes in Scope (Design/Content)	X	X	X	X
Inadequate assessment of impacts of schedule changes on cost		X	X	X
Annual Funding instability			X	X
Eroding in-house technical expertise			X	X
Poor tracking of contractor requirements against plans			X	X
Launch Vehicle			X	
Reserve Position adequacy		X		X
Lack of Probabilistic estimating		X		X
"Go as you can afford" Approach				X
Lack of formal document for recording key technical, schedule and programmatic assumptions (CARD)**				X

** CADRe has since been implemented as a requirement of NPR 7120.5

Sources:
GAO Report: Need for improved reporting & Cost Estimating on Major Unmanned satellite projects (NASA)
GAO Report: Financial Status of Major Federal Acquisitions
GAO Report to Congress March 1973 Cost Growth in Major Weapons Systems
Rand Report: Acquisition Policy Effectiveness October 1979
An Analysis of DOD/NASA Cost Growth Profiles for the Congressional Committee of Gov't operations January 1980
NASA Project Management Study January 1981
Office of Comptroller: New Project Estimates Study August 1985
Office of Comptroller: Lessons Learned on Cost/Schedule June 1990
NASA Program/Project Planning Study November 1992
NASA Cost Growth: A look at recent performance January 2004
GAO Work on DOD Space Acquisitions Dec 2006
GAO Report: NASA: Long Term Commitment to and Investment in Space Exploration July 2006
GAO Report: NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management May 2004

Summary of Claimed Root Causes from Recent Studies

Claimed Root Causes	Data Driven		Experience & Feedback		
	Two Recent Studies	Study of current portfolio	PM	Centers Cost Community	AO*
Proposals are optimistic in order to win. Emphasis on science			X	X	X
Over optimism early in formulation leads to over optimistic estimates and cost growth during implementation	X			X	
Lack of sufficient time and $ (only .4% of LCCE) in Phase A/B to do systems engineering and better understand risks	X		X	X	X
Insufficient reserves				X	X
Untenable schedules				X	
Weak independent validation of cost and schedule				X	
Frequenty approve projects that have lower TRLs than were claimed				X	X
Instruments designs lack detail and often fail to identify technology challenges	X		X	X	X
Heritage HQ, SW, and COTS assumptions did not materialize			X	X	X
Roles of PI and project manager are often poorly understood					X
Tendency to over-engineer				X	X
Unanticipated adverse impact of de-scopes	X			X	
Contributions from foreign partners are often late	X	X	X	X	
Unanticipated Launch Vehicles delays or price increases	X			X	
Unstable/Inadequate budget profiles	X	X	X	X	X
Adverse financial impacts of other project in NASA's portfolio	X			X	X
NASA-imposed changes to requirements	X	X	X	X	X

* PA&E Capture form JPL sponsored forum

Current Initiatives to Mitigate Cost and Schedule Growth

- Developing Cost Analysis Data Requirement (CADRe) documents on all Flight and Ground System projects for the project managers
- Making CADRe data available to all NASA stakeholders -- will improve future estimates
- Established policy and wrote Strategic Planning Guidance that requires
  - All projects to submit budget requests that reflect a 70 percent probability of completing within the requested resources as determined by a reconciled Independent Probabilistic Cost Estimate
  - New projects about to enter Phase A must undergo a Basis of Estimate review
- Conducting Cost Risk workshops at development centers: JPL, GSFC, GRC, MSFC, JSC, and KSC
- Re-evaluating root causes for cost and schedule growth at NASA and recommending and coordinating mitigating actions
- Sponsoring cost estimating research to address weakness in estimating methodologies and tools

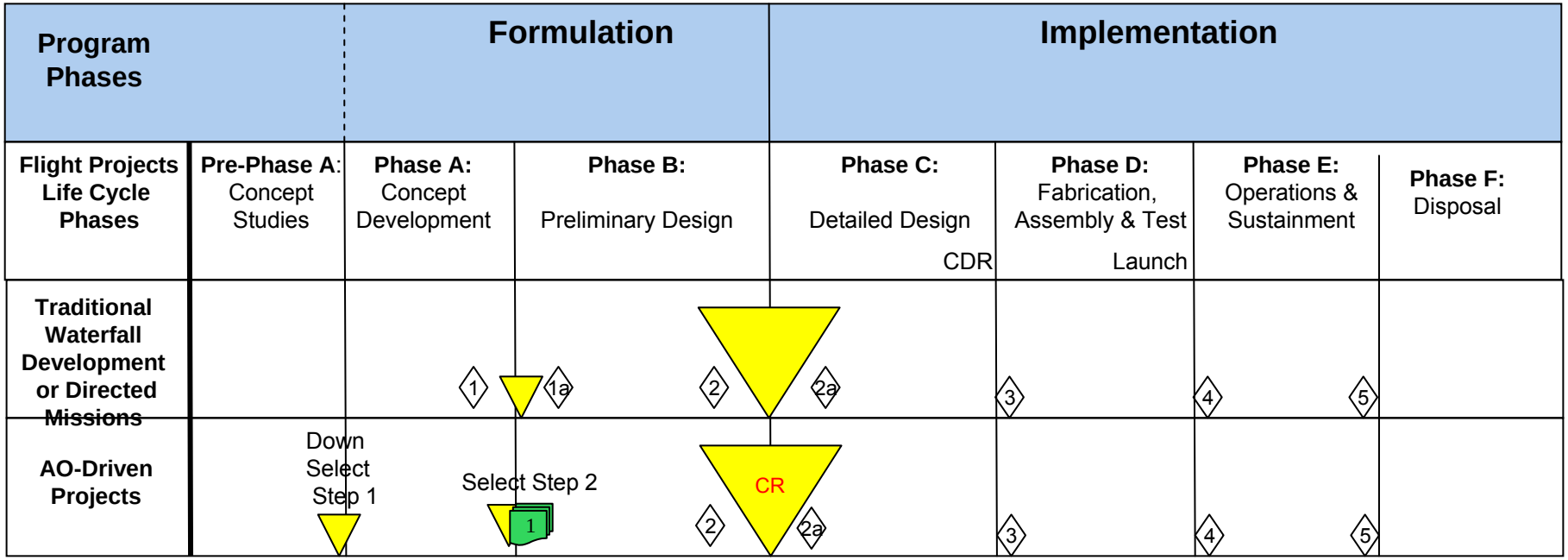
What is the CADRe?

- A three-part document that:
  - Describes a NASA project, at a given point in time, to allow an independent entity to estimate the project's life cycle cost (Parts A & B)
  - Describes changes to the project since the previous CADRe submission (Part A)
  - Captures the NASA project's projected and actual life cycle costs within the project's and a NASA Cost Estimating Work Breakdown Structures (WBS) (Part C)
- The CADRe is not a project monitoring tool for external organizations

Why Are CADRes needed?

- Provides approved basis for independent estimates
  - Describes project mission and approach that facilitates understanding
  - Explicitly addresses risk areas
  - Contains objective technical data that tend to drive costs
- Documents reasons for cost and schedule growth so that agency can better explain to stakeholders
- Provides historical record of cost, schedule, and technical project attributes so that estimators can better estimate future similar projects
- Required by NPR 7120.5

When are CADRes Required?



Legend

- GPMC Mission Decision Review/ICR
- 1 — All parts of CADRe due 30 days after site review
- 1a — CADRe update, if necessary
- 1 — CADRe delivered; based on Concept Study Report (CSR) and winning proposal
- 2 — All parts of CADRe due 30 days after site review
- 2a — CADRe update, if necessary
- 3 — Update as necessary 30 days after CDR
- 4 — CADRe, All Parts 90 days after launch, as built or as deployed configuration
- 5 — CADRe, Part C only during last year of planned project life

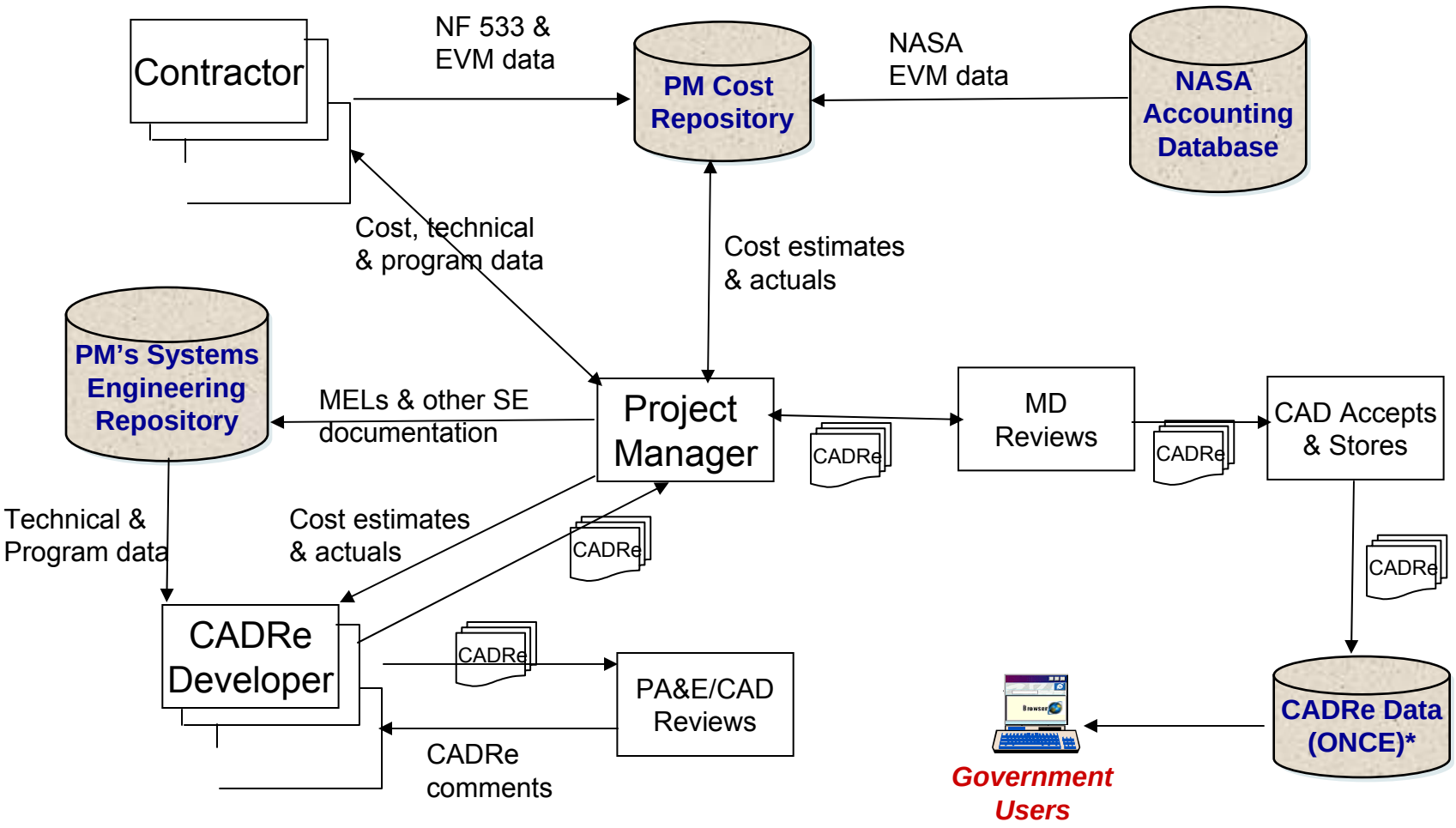
How Will the Data Be Used?

- Prepare more realistic cost and schedule estimates from analogous data contained in the CADRes;
- Ensures that project and independent estimators estimate the same technical and programmatic content;
- Assess proposed project schedule in light of performance of similar past projects; recommend adjusted schedule and costs to PMC;
- Assess extent to which heritage percentages are achieved; adjust estimates accordingly;
- Assess software development productivity of historical data; adjust estimates accordingly;
- Assess software reuse; adjust estimates accordingly;
- Assess software code growth; adjust estimates accordingly; and
- Analyze reasons for cost growth
  - Provide better answers to OMB and Congress
  - Develop policy strategies to rectify

How Will the CADRes be Developed?

- NASA PMs are responsible for CADRes per NPR 7120.5
- PA&E/Cost Analysis Division conducts kick off meeting with Program Exec, Project Manager & staff, Mission Directorate Cost Focal Point, & IPAO cost analyst
  - Explains nature of requirement and expectations
  - Agree how CADRe will be developed
  - If performed by support contractor, determine how data will be provided
    - Access provided on web site or provided directly
  - Agree on RFP language or DRD (“active projects only”)
- PA&E is paying for development and PM approves; support contractor develops CADRe from supplied data
- Developing CADRes only for projects launched after 1995

CADRe Data Collection Process



* One NASA Cost Engineering Database (ONCE)

What Does a 70 Percent Confidence Level Mean and Why are We Doing This?

- A cost estimate for any project is not a single number. It has a range of possible values because the drivers are nebulous due to
  - Immature Technology – TRL was tool low or assessed too high
  - Requirements Volatility
  - Percent new design required
  - Extent to which existing hardware or software can be reused as-is
  - Activities take longer because they are more complicated than estimated
  - Component, Subsystem, Assembly Weights (or mass)
  - Number of Software Lines of Code
  - Launch vehicle uncertainty
  - Multi-Contractor Teams and Organizational Interfaces
  - Conflicting Schedules and Workload
  - System Testing and Retesting
  - Geographic Distribution of Production Sites
  - Security Arrangements
  - Funding stability
  - Trained Personnel
  - Supplier Viability

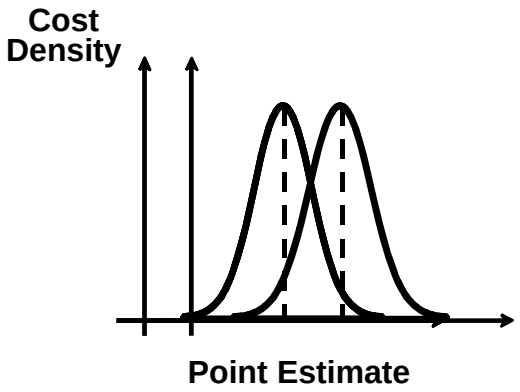
Why We Do Probabilistic Cost Estimating

- It is impossible to estimate precisely how much something will cost or how long it will take
- Decision-makers and cost analysts should always think of a cost estimate as a probability distribution, NOT as a deterministic number.
- The best we can provide is the probability distribution
- It is up to the decision-maker to decide where he/she wants to set the budget
- The probability distribution provides a quantitative basis for making this determination.
  - Low budget = high probability of cost overrun
  - High budget = low probability of cost overrun

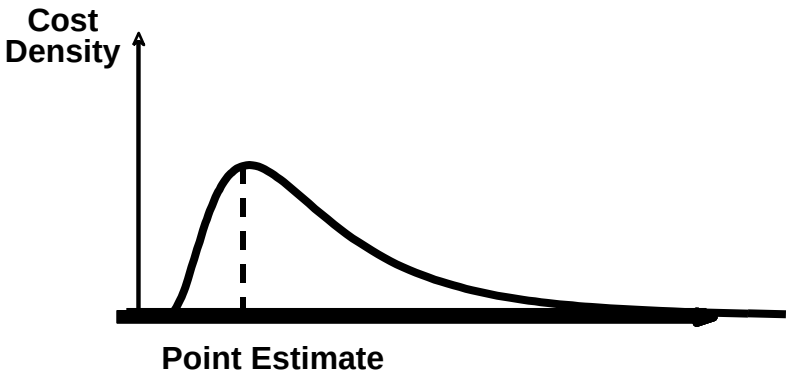
Determining the Range of Possible Cost Levels

- Information is needed to estimate project cost
  - Technical Description of Project (e.g., CADRe)
  - Risk list and Management Plan
- Risks, Technical and Otherwise, Drive the Range of Possible Estimates for Each WBS Elements

Cost Probability Distribution for Low-Risk Cost Element



Cost Probability Distribution for High-Risk Cost Element



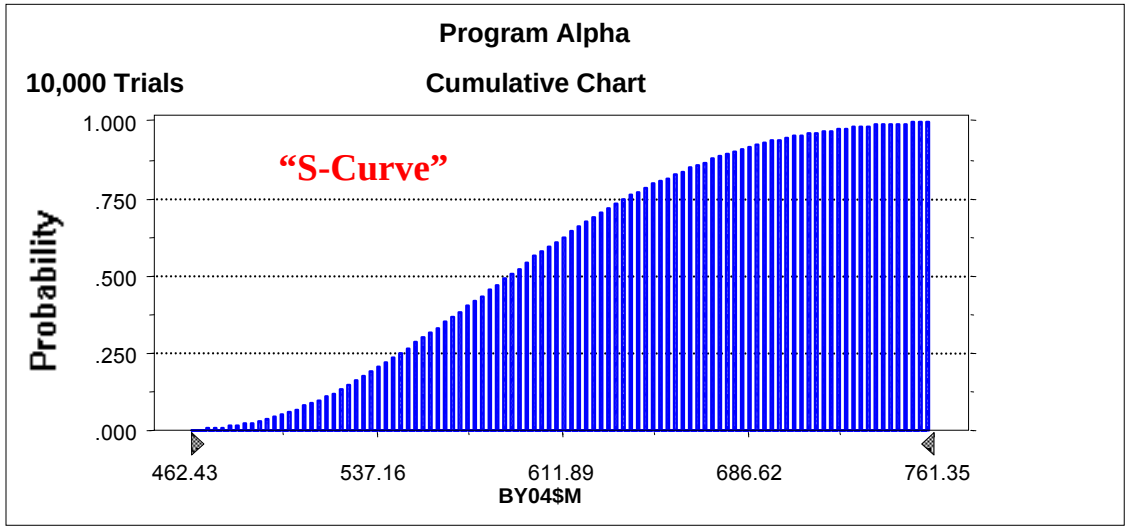
Probabilistic Estimating Is Not Limited to Cost Estimating

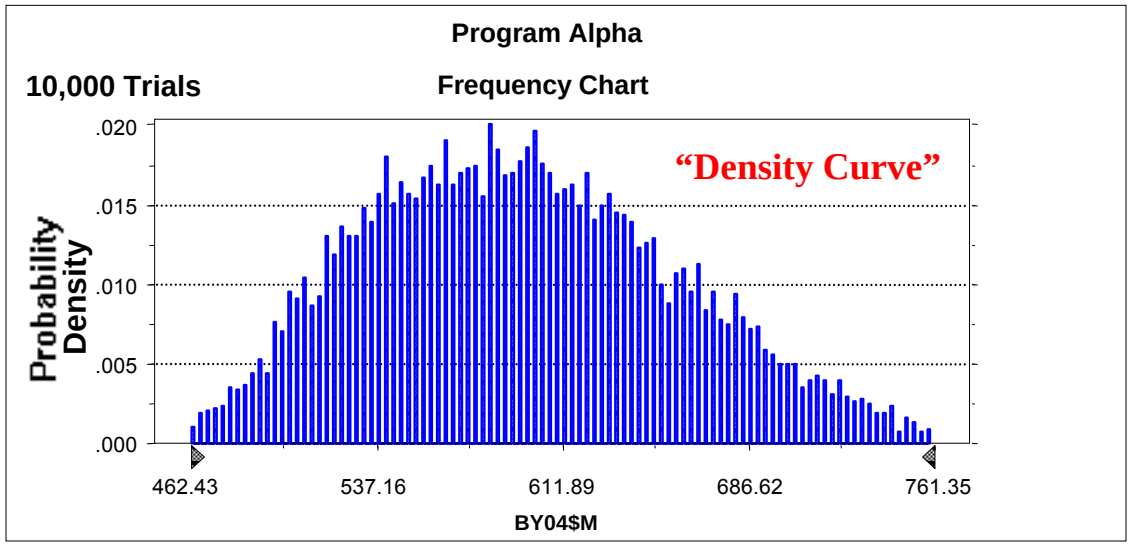
- In Engineering, *Computer Simulation of Mission Operations* is Standard Practice, with Key Characteristics Modeled by Monte Carlo Analysis of Random Variables, e.g.,
  - Pointing Accuracy
  - Data Throughput
  - Retro Rocket Thrust
  - Decision Timing
- Cost-Risk Analysis Enables the Cost Analyst to Conduct a *Computer Simulation of Cost*
  - WBS-Element Costs Are Modeled As Random Variables
  - Total Cost Distribution is Establish by Monte Carlo Simulation of the Sum of the WBS-Element Cost Probability Distributions

What a Cost Estimate Looks Like

Percentile	Value
10%	516.81
20%	538.98
30%	557.85
40%	575.48
50%	592.72
60%	609.70
70%	629.19
80%	650.97
90%	683.01

Statistics	Value
Trials	10,000
Mean	596.40
Median	592.72
Mode	---
Standard Deviation	63.18
Range Minimum	450.19
Range Maximum	796.68





70 Percent Confidence Level Estimating Policy (Background)

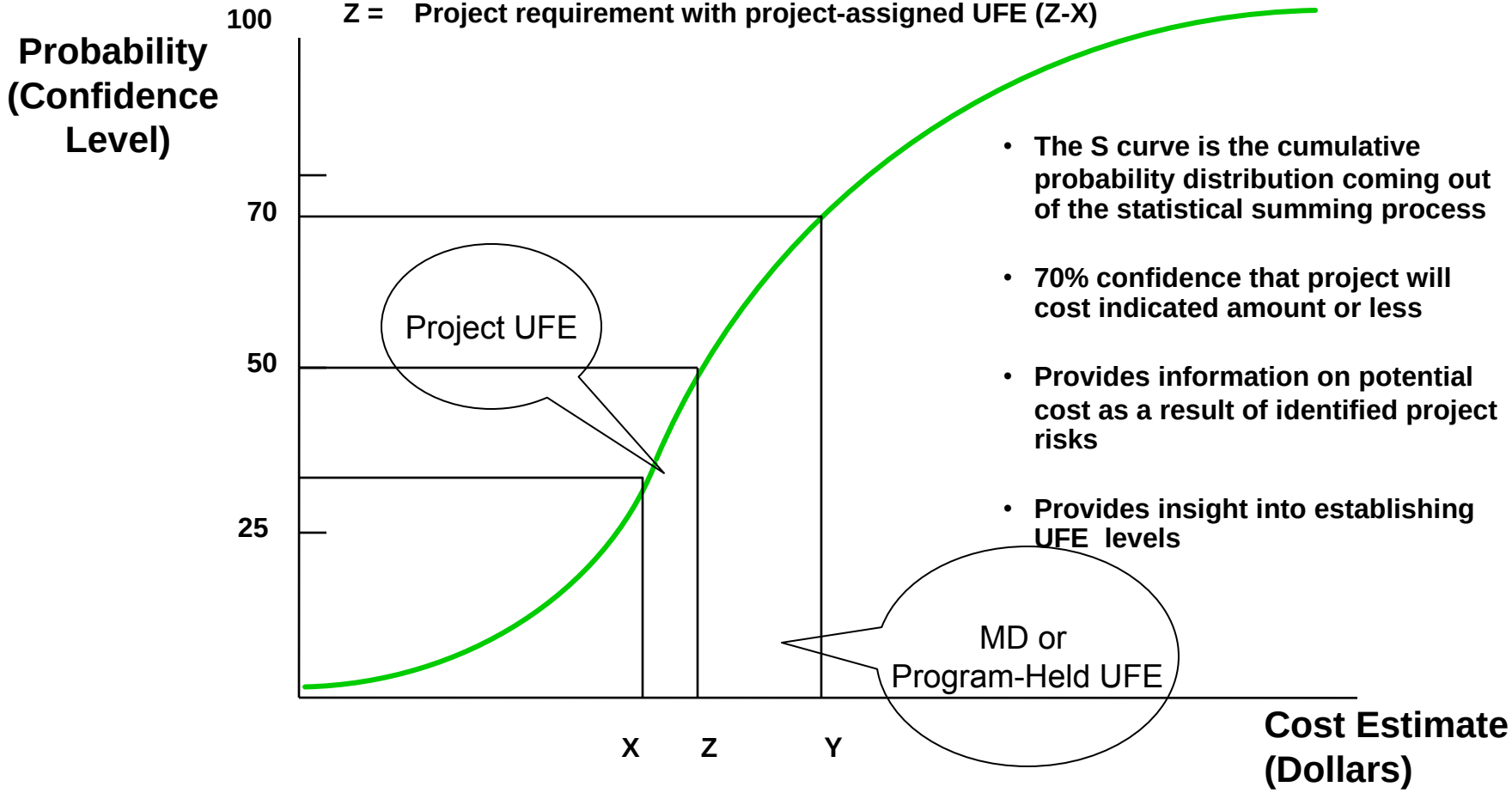
- SMC 3/27/06 meeting minutes:
  - "Griffin determined that NASA's standard practices will be to budget projects at a 70% confidence level based on the independent cost estimate. Any proposed deviations from this standard must be brought forward for consideration to the appropriate management council."
  - "… initiate a pattern of honest dealing between Program and Project Managers, HQ, the Congress, and the WH, and to avoid the pattern of finger-pointing for cost overruns and schedule slips that have plagued the industry in the past".
- March and April 2007 SMC meetings clarified policy about budgeting to a 70% confidence level:
  - NASA flight system projects must submit budgets at a 70 percent confidence level starting at phase A
  - Budgets will be based on a reconciliation between the project manager's estimate and an Independent Probabilistic Cost Estimate (IPCE)
  - IPAO does Independent Probabilistic Cost Estimate (IPCE) at P-NAR and NAR for the category 1 and 2 projects; otherwise Mission Directorates are responsible for obtaining an IPCE
  - 70 percent Confidence Level budgets are not required for projects in operation where budgets are funded at level of effort

Implementing the Policy Through the Strategic Planning Guidance

- All NASA projects must submit budgets at a 70 percent confidence level starting at phase A
  - Programs or projects that are currently in phase E (operations phase) where the majority of resources are considered to be "level of effort" are not subject to this requirement
- Mission Directorates or programs must fund each project to at least the 50 percent confidence level (July 2007 PMC decision)
- Budgets will be based on the most recent reconciliation between the project manager's estimate and an Independent Probabilistic Cost Estimate (IPCE)
- The IPAO will develop the IPCE at the starts of Phase B and C for Category 1 and 2 missions
- Mission Directorates must ensure that an IPCE is developed for projects entered into Phase A
- PA&E will conduct Basis of Estimate reviews for all new starts being proposed in the forthcoming budget (pre phase A initiatives)
- Mission Directorates are encouraged to supply supporting documentation to justify executability of requested resources

Definition of Cost Confidence Level (CCL)

X = Project most likely point estimate
Y = Cost estimate where there is a 70% chance that final actual cost will be less than cost estimate
Y-X= Total Unallocated Future Expenses (UFE) REQUIRED to meet 70 % CL
Z = Project requirement with project-assigned UFE (Z-X)



- The S curve is the cumulative probability distribution coming out of the statistical summing process
- 70% confidence that project will cost indicated amount or less
- Provides information on potential cost as a result of identified project risks
- Provides insight into establishing UFE levels

Implementing the Policy Through the Strategic Planning Guidance (Concluded)

	Priors	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	BTC	TOTAL
Approved 70% CL Estimate at Last KDP																		
Full Cost Budget	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Approved Direct Cost LCCE at Last KDP MS																		
Direct Cost Budget with MD-held UFE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pre Formulation *																		0.0
Formulation (A, B)																		0.0
Development (C, D)																		0.0
Project Management																		0.0
Systems Engineering																		0.0
Safety and Mission Assurance																		0.0
Science/Technology																		0.0
Payloads																		0.0
Spacecraft																		0.0
Launch Vehicle/Services																		0.0
Ground Systems																		0.0
Systems Integration & Test																		0.0
Education and Public Outreach																		0.0
Mission Operations - Prime (E)																		0.0
Mission Operations - Extended (E)																		0.0
Disposal (F)																		0.0
Project UFE (non-add)																		
The indirect cost (orange) cells will be updated by PA&E based on OCFO rates																		
Indirect costs assigend to project		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Center M&O																		0.0
Corporate G&A																		0.0
Other indirect costs																		0.0
MD or Program-held UFE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Direct																		0.0
Indirect																		0.0

Other Cost Estimating Initiatives

- Conduct Cost Risk Workshops at key centers
  - Explain why project budgets must reflect a 70 percent probability of being completed within the given resources and time
  - Explain the requirement for cost estimating, who is responsible for developing which types of estimates and when they should be completed
  - Explain the fundamentals of probabilistic cost estimating
  - Explore various ways to develop probabilistic cost estimates
  - Explain desire to see probabilistic cost estimate documented in CADRe
  - Provide a notional cost estimating time-line leading up to a KDP decision
  - Explain cost reconciliation process with IPAO at KDPs
  - Provide expectations for submission to Strategic Planning Guidance (documentation and timing)
  - Listen and record issues, concerns, and recommendations for improvements
- Completed GRC, GSFC, JPL , KSC
- Remaining: MSFC and JSC

Other Cost Estimating Initiatives (Continued)

- Re-evaluating root causes for cost and schedule growth
  - Reviewed and synthesized results of historical studies
  - Sought advice from retired NASA personnel
  - Surveyed experience of current NASA project managers
  - Surveyed experience of NASA cost estimating community
  - Reviewed top level root caused of cause and schedule growth of projects within NASA's current portfolio
  - Conducted workshop on root causes on Announcement for Opportunity types of mission
  - Summarized results and briefed Associate Administrator
  - Need to complete more thorough analysis of about ten projects and finalize recommendations

Other Cost Estimating Initiatives (Concluded)

- Estimating and assessing the costs and schedule-to-go on an annual basis
- Sponsoring cost and schedule estimating research methods and tools. Examples include:
  - Parametric estimating tools and data need to be updated to provide joint probabilistic cost and schedule estimates
  - Need better assessment tools to determine probability of completing within remaining budget and stated schedule
  - Developed an electronic CADRe/EVM CPR facilitation environment for improved cost management