

Calculating Reserves on Cost-to-Go (CTG) Based on Historical Data

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Outline

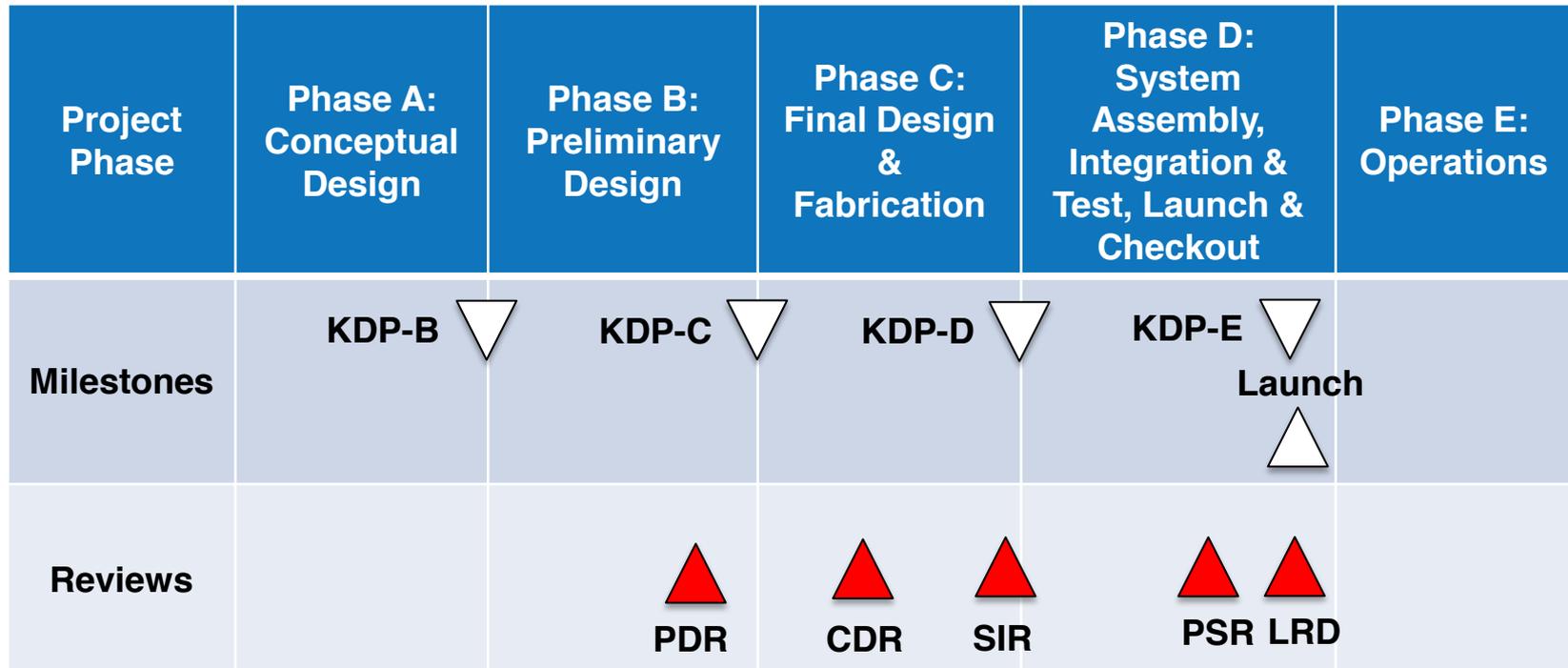


- Background
- Industry Guidance
- Historical Data Overview
- Methodology
- Results from Phase B, PDR, CDR and SIR
- Cost-to-Go Requirement from SIR to Ship
- Summary

Introduction

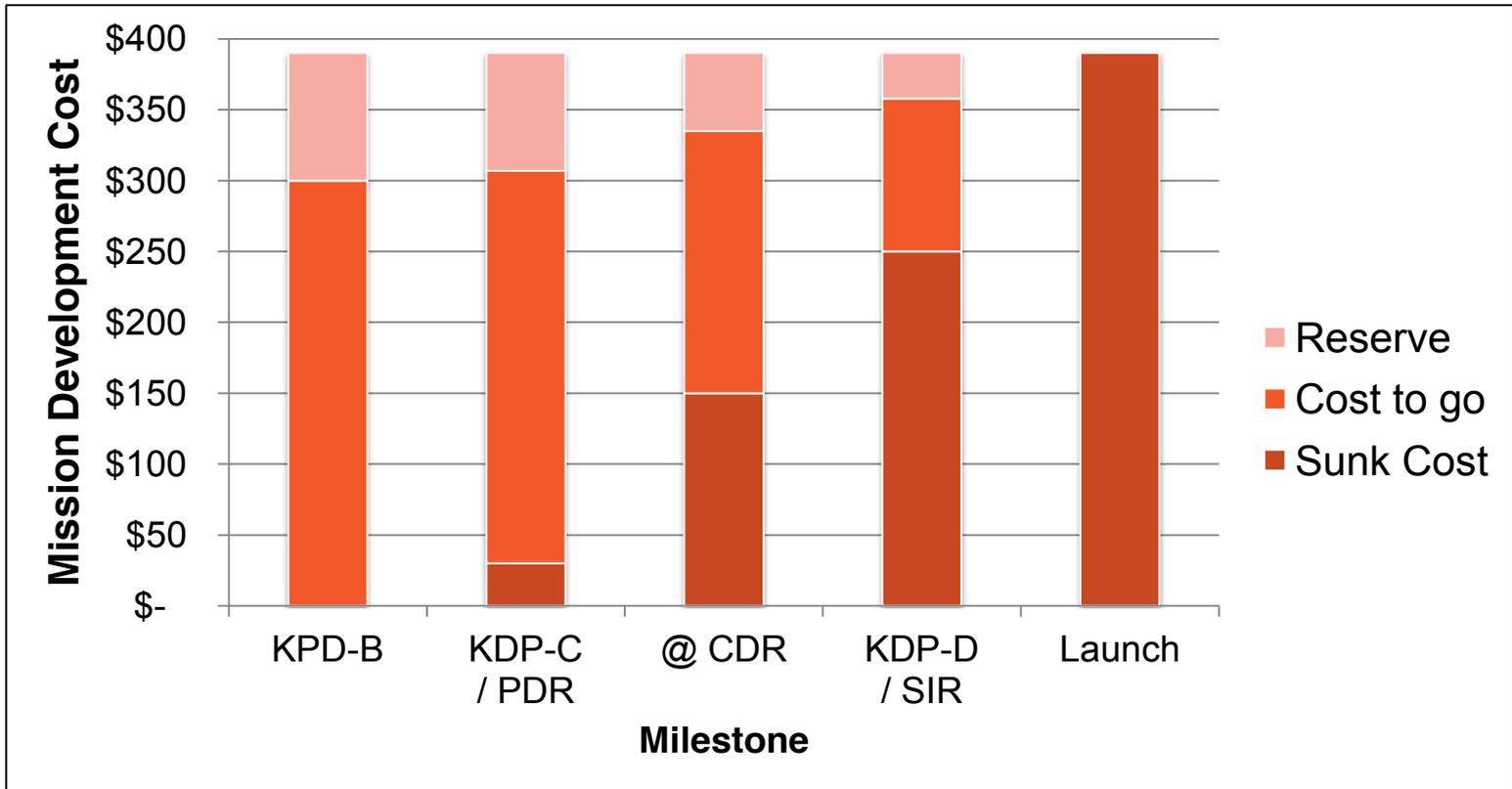
- NASA Center guidance typically requires that a mission hold decreasing percentage cost reserves on cost-to-go (CTG) as the project matures
- This approach is seemingly contradictory to historic cost growth which often occurs in the later stages of system integration and test where the actual CTG base is lower
 - *Given how late in a mission's development that cost growth typically occurs, it would seem more appropriate to have a higher percentage reserve on CTG as the project matures as opposed to decreasing percentages*
- This study looks at the reserve percentage on CTG for a variety of NASA missions at the start of Phase B, at the Preliminary Design Review (PDR), at the Critical Design Review (CDR) and Systems Integration Review (SIR) based on the sunk cost and historical cost growth from each of these milestones
 - *In addition, the study will also look at some of the external factors that have caused cost growth and remove them from the calculation so as to provide a reserve on CTG with and without external factors*
- The data can then be used to potentially adjust Center guidance and/or establish NASA HQ SMD model for reserve on CTG to set more robust guidance for future missions

NASA Project Lifecycle



- Definitions:
 - KDP = Key Decision Point = Transition from one Phase to the next
 - PDR = Preliminary Design Review
 - CDR = Critical Design Review
 - SIR = Systems Integration Review
 - PSR = Pre-Ship Review
 - LRD = Launch Readiness Date

Explanation of Percent Reserves on Cost-to-Go (CTG)



- Percent Reserves on CTG = $\$ \text{ Reserve} / \$ \text{ CTG} * 100\%$
- Example above shows constant 30% Reserves on CTG at each milestone
- As can be seen, CTG decreases over time as sunk cost increases

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Reserve Discussion Reference

- JPL “Design, Verification/Validation and Operations Principles for Flight Systems” (D-17868), originally published February 2000

Milestone	Start of Phase B (KDP-B)	At PDR (KDP-C)	At CDR	At SIR (KDP-D)	Ship to Launch Site
JPL Budget Reserve Guideline	30%	25%	20%	20%	10%

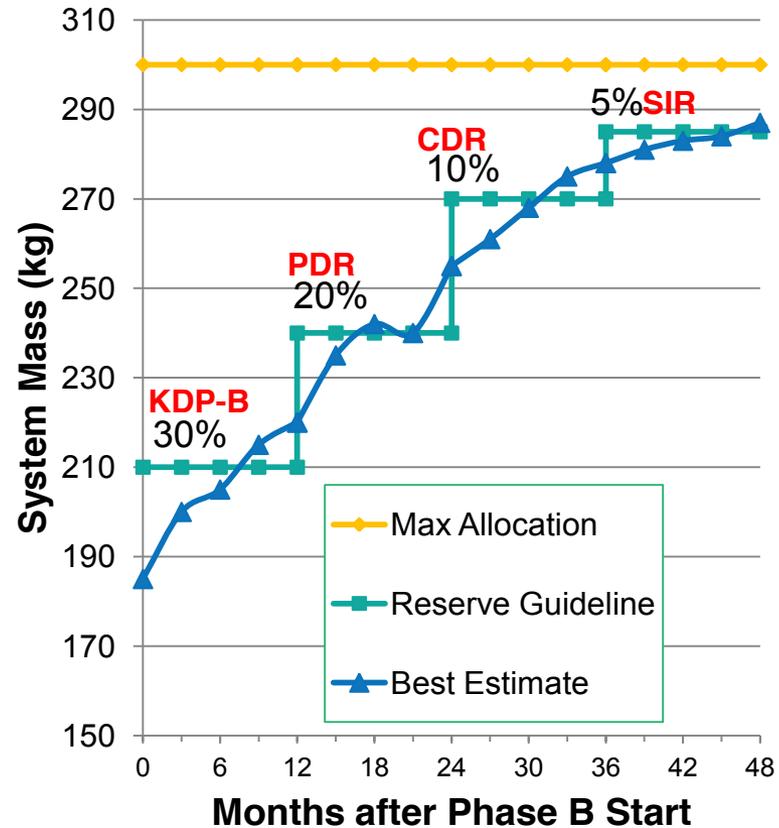
- GSFC Goddard Procedural Requirement (GPR) 7120.7 “Schedule Margins and Budget Reserves to be Used In Planning Flight Projects and In Tracking Their Performance”, May 2008

- *At the time of Initial Confirmation (Key Decision Point-B [KDP-B]), flight projects should have a budget reserves level of 30% or higher through Phase D*
- *At the time of Confirmation (KDP-C), flight projects should have a budget reserves level of 25% or higher through Phase D*
- *At the time of delivery to the launch site, flight projects should have a budget reserves level of 10%*

Milestone	Start of Phase B (KDP-B)	At PDR (KDP-C)	At CDR	At SIR (KDP-D)	Ship to Launch Site
GSFC Budget Reserve Guideline	30%	25%	25%	25%	10%

Cost Reserve Approach is Based on Mass Reserve

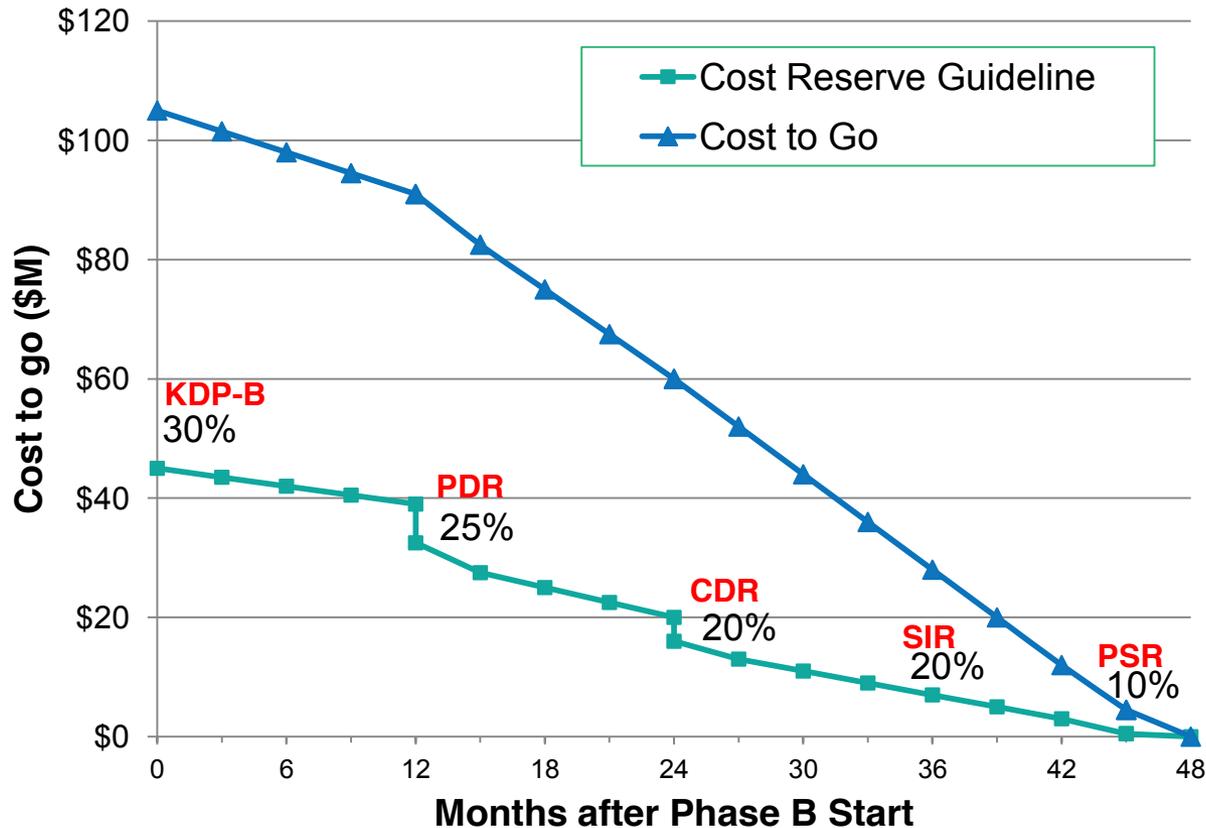
- Cost reserve guidelines are modeled after mass reserve guidelines where mass reserve guidelines decrease as a function of time
- Mass margin guidelines are based upon total mass to date, however, not on mass-to-go
- If cost guidelines were based on sunk cost, then decreasing percentage would be more appropriate as sunk cost gets larger over time similar to mass
- Cost reserve guidelines, however, are based upon CTG which gets smaller as a function of time



* Note: Mass margins shown are based upon JPL "Design, Verification/Validation and Operations Principles for Flight Systems" (D-17868)

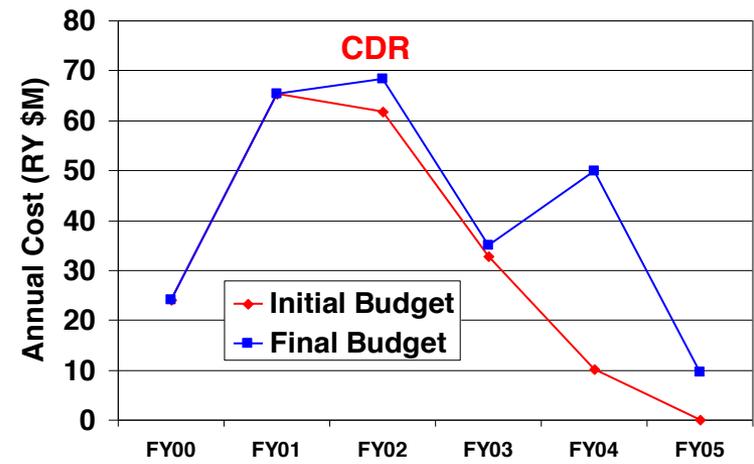
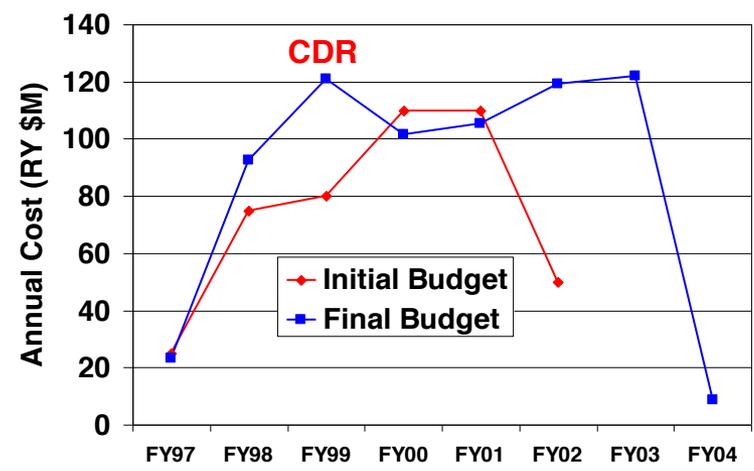
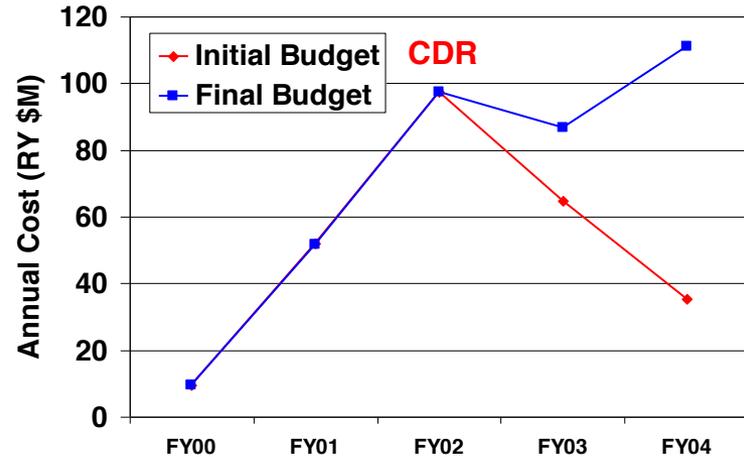
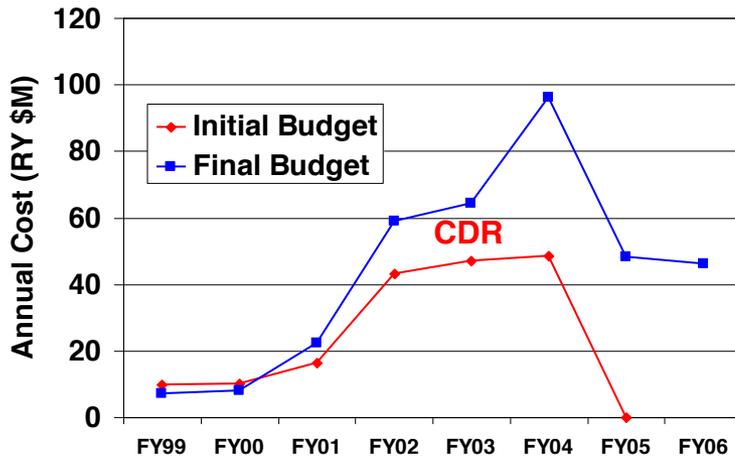
Comparison of Mass vs. Cost Reserve Guidelines

- Decreasing percent reserve on CTG implies that less cost growth is expected as the project matures, which is inconsistent with history as cost typically grows as a project matures



* Note: Cost reserve guidelines are based upon JPL "Design, Verification/Validation and Operations Principles for Flight Systems" (D-17868)

Constant or Increasing Percentage Reserve on CTG is More Important Given Timing of Historical Cost Growth



Examples above of real projects show that Cost-to-go typically will increase past CDR as cost and schedule growth occurs

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Large Diversity of Missions Included in Analysis

- List includes 30 science missions providing a representative mix

Mission	Launch Date	Theme	Mission Type	Lead Org.
AIM	Apr-07	Helio	CAT 3	Other
Cassini	Oct-97	Planetary	CAT 1	JPL
Cloudsat	Apr-06	Earth	CAT 2	JPL
DAWN	Sep-07	Planetary	CAT 2	JPL
Deep Impact	Jan-05	Planetary	CAT 2	JPL
EO-1	Nov-00	Earth	CAT 2	GSFC
Fermi (GLAST)	Jun-08	Astro	CAT 2	GSFC
GALEX	Apr-03	Astro	CAT 3	JPL
GENESIS	Aug-01	Planetary	CAT 2	JPL
GRAIL	Sep-11	Planetary	CAT 2	JPL
IBEX	Oct-08	Helio	CAT 3	Other
ICESAT	Jan-03	Earth	CAT 2	GSFC
Kepler	Mar-09	Astro	CAT 2	JPL
LRO	Jun-09	Planetary	CAT 2	GSFC
MER	Jul-03	Planetary	CAT 1	JPL

Mission	Launch Date	Theme	Mission Type	Lead Org.
MESSENGER	Aug-04	Planetary	CAT 2	APL
MRO	Aug-05	Planetary	CAT 1	JPL
New Horizons	Jan-06	Planetary	CAT 1	APL
OCO	Feb-09	Earth	CAT 2	JPL
PHOENIX	Aug-07	Planetary	CAT 2	JPL
RHESSI	Feb-02	Helio	CAT 3	Other
SDO	Feb-10	Helio	CAT 1	GSFC
Spitzer	Aug-03	Astro	CAT 1	JPL
Stardust	Feb-99	Planetary	CAT 2	JPL
STEREO	Oct-06	Helio	CAT 2	GSFC
Swift	Apr-04	Astro	CAT 2	GSFC
Terra	Dec-99	Earth	CAT 1	GSFC
TRMM	Nov-97	Earth	CAT 2	GSFC
WISE	Jun-09	Astro	CAT 2	JPL
WMAP	Jun-01	Astro	CAT 2	GSFC

- Includes mix of Science Themes
 - 12 Planetary, 7 Astrophysics, 6 Earth Science and 5 Heliophysics
- Includes mix of different sized missions based on NASA 7120.5E Mission Category
 - 7 Category 1 (CAT 1) missions with Life Cycle Cost (LCC) > \$1B FY12\$
 - 19 Category 2 (CAT 2) missions with LCC >\$250M but < \$1B FY12\$
 - 4 Category 3 (CAT 3) missions with LCC < \$250M FY12\$

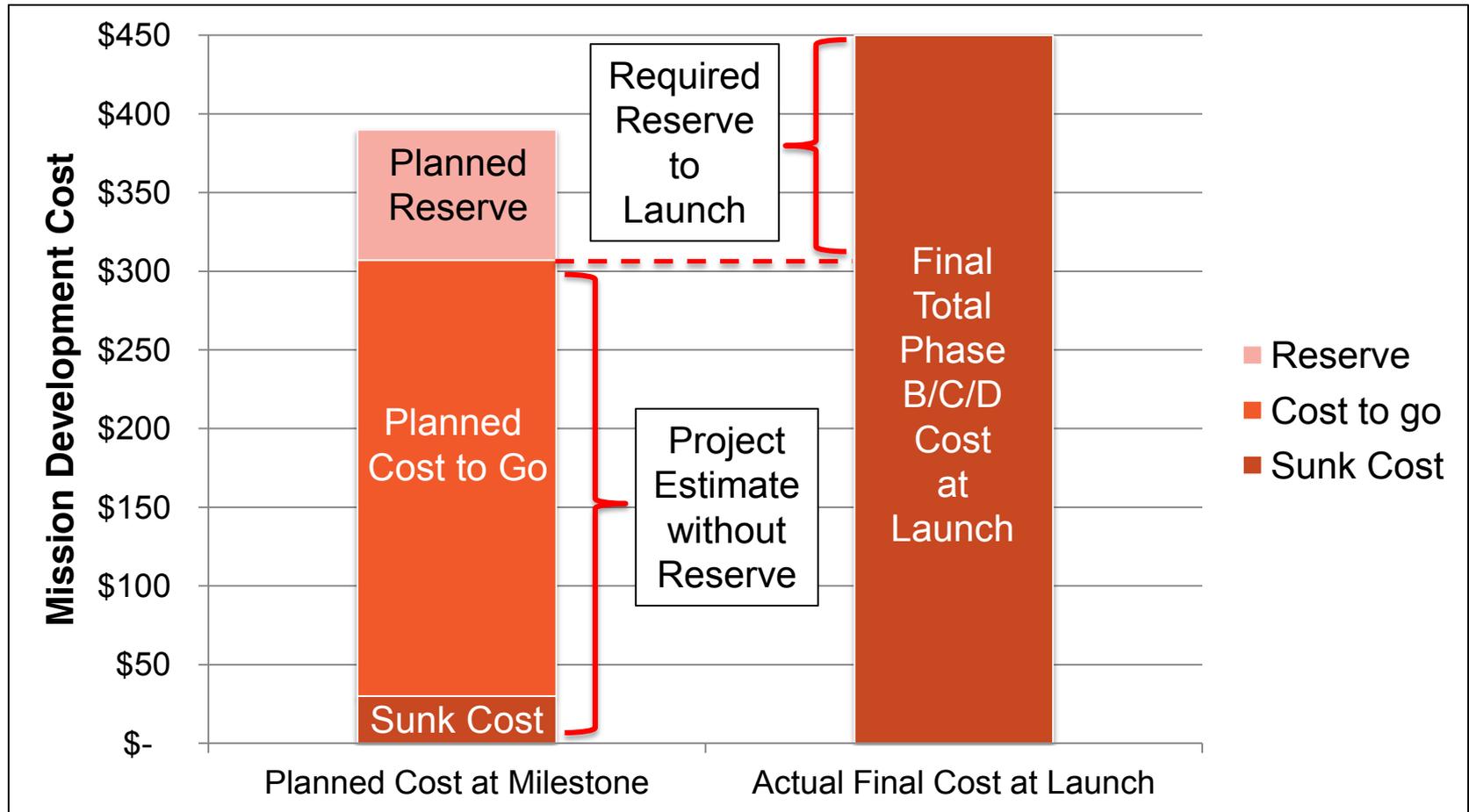
Data Collection Approach

- Collected data at primary historical milestones
 - *KDP-B or Start of Phase B, PDR, CDR, Final Actual Cost at Launch*
- Gathered cost data from any available and reliable source for time frame
 - *Milestone Review presentations, Monthly Reports, other official financial reports*
- Collected System Integration Review (SIR) milestone CTG data as available based on project history
 - *Problematic since SIR was not always a required milestone*
 - *SIR also occurs at different times for any given project*
 - *Approach*
 - Used cost data from actual SIR time frame if applicable
 - Used KDP-D data if available
 - Use ATLO Readiness Review (ARR) for older JPL missions if available
 - Use first instrument delivery date if no other date was specified

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Calculation of Required Percent Reserve on CTG



- Required Reserve Percentage on CTG

- $(\text{Final Cost} - \text{Project Estimate w/o reserve}) / \text{Planned CTG} * 100\%$ where:

- Final Cost = Total Phase B/C/D cost at Launch
 - Project Estimate w/o reserve = Sunk Cost + Planned CTG

Consideration for Removing External Events

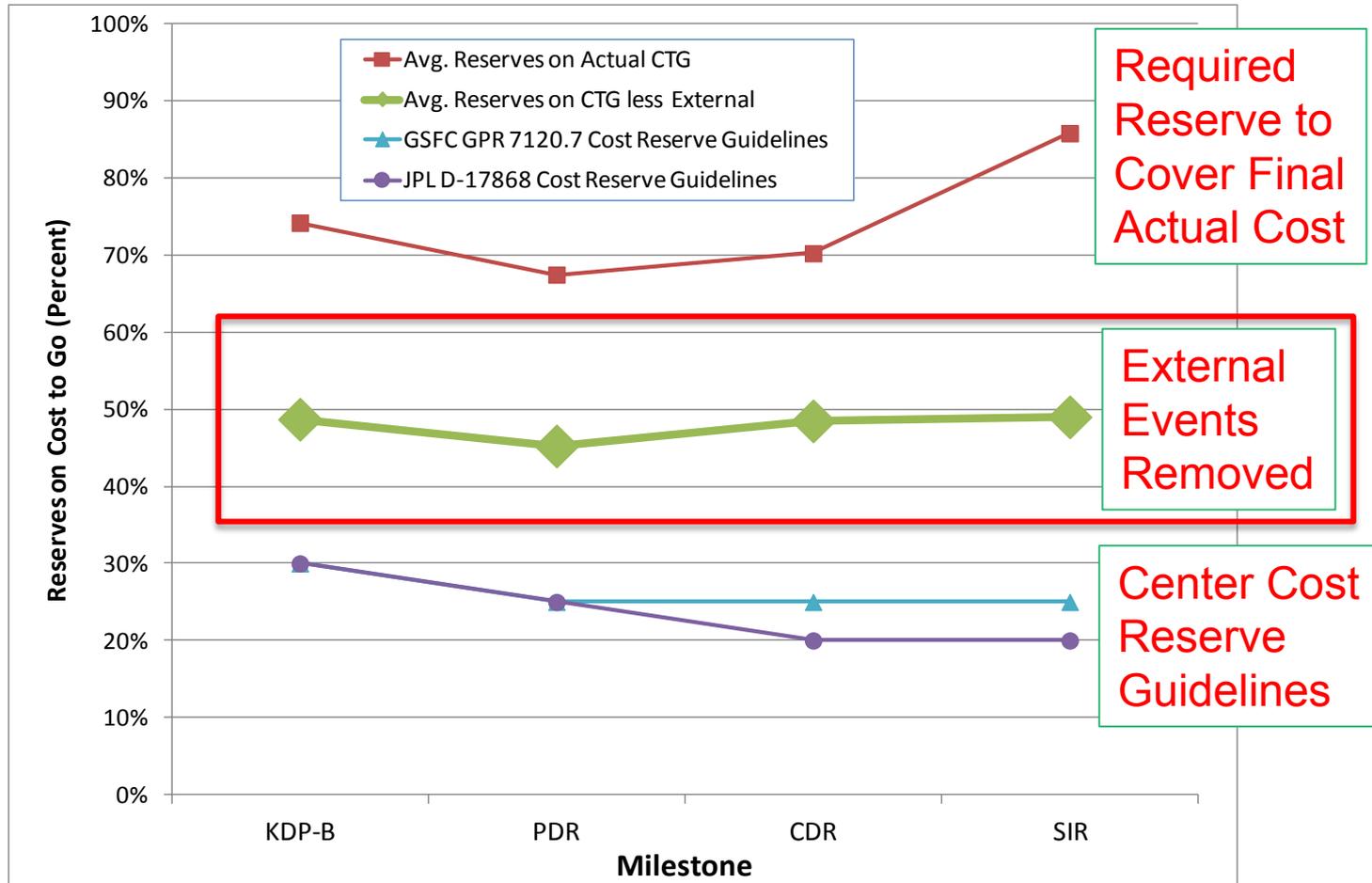
- Calculated reserves required on CTG at various milestones
 - *Percent required reserves for final actual CTG to launch is very high*
- Center reserve guidelines are focused at events happening with the project
 - *Events external to the project should be covered by NASA Headquarters' managed Unallocated Future Events (UFE) as stated in NPR 7120.5E*
- Adjusted the cost at each milestone to remove external factors that were beyond the project's control
 - *Took External Factor costs from Explanation of Change (EoC) study**
 - Common External factors
 - *Launch delays*
 - *Additional Oversight required by NASA HQ or NASA Center Specific*
 - *Full Cost Accounting policy changes*
 - *Identified dates associated with all External costs*
 - Consult EoC Key Event Timeline or mapping vs. EoC events
 - Consult project documents for date of event
 - *Removed external costs from milestone budgets to use in calculation*

* Please see "Explanation of Change (EoC) Study: Approach & Findings", 2013 IEEE Aerospace Conference, March 2013

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Required Percent Reserve on Results for Actual CTG and CTG Minus External Cost



Average Required Percent Reserves on CTG with External Events Removed is ~48% Constant Across all Milestones

Further Observation of Required Reserves

- Data shows that, with or without external events considered, reserve guidelines as a percent of cost-to-go should be **constant or increase** for each milestone
 - External events such as launch delays cause an increase in reserves on CTG near SIR*
- Overall required reserves, excluding external events, are on the order of 50% on average

	KDP-B	PDR	CDR	SIR
Avg. Project Reserves	21%	23%	23%	18%
Avg. Reserves on Actual CTG	74%	67%	70%	86%
Avg. Reserves on CTG less External	49%	45%	48%	49%
JPL D-17868 R2	30%	25%	20%	20%
GSFC GPR 7120.7	30%	25%	25%	25%

- However, requiring projects to carry 50% reserve is not a reasonable expectation
 - Average is based on missions in the data set, some of which had substantial cost growth as they were initiated with an initial budget which was inconsistent with their scope*
 - These missions, given current NASA policy*, are less likely to be initiated
 - Segmenting the data for “well planned” missions, that were more within the scope of their initial requirements, provides additional insight*

* Please see NASA Procedural Requirements (NPR) 7120.5E, August 2012, NASA Space Flight Program and Project Management Requirements

Required Reserves for “Well Planned” Missions

- Cost growth is a function of the initial planned budget and the final actual cost
 - *Well planned missions, by definition, should experience less cost growth as the initial planned budget should encompass the expected cost of fully developing the systems*
- For the purposes of this analysis, a well planned mission is defined as those that experienced a cost increase of less than 50% from the start of Phase B to the final actual cost
 - *This should provide a better picture of the required reserve posture for well planned missions*

Category	# Missions	KDP-B	PDR	CDR	SIR
Missions with > 50% cost increase from KDP-B	11	79%	65%	66%	66%
Missions with < 50% cost increase from KDP-B	19	30%	31%	37%	33%

- Based on these results, a more appropriate guideline for well planned missions would be a constant reserve of 30% to 35% on cost-to-go for each major milestone

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Additional Reserves Analysis

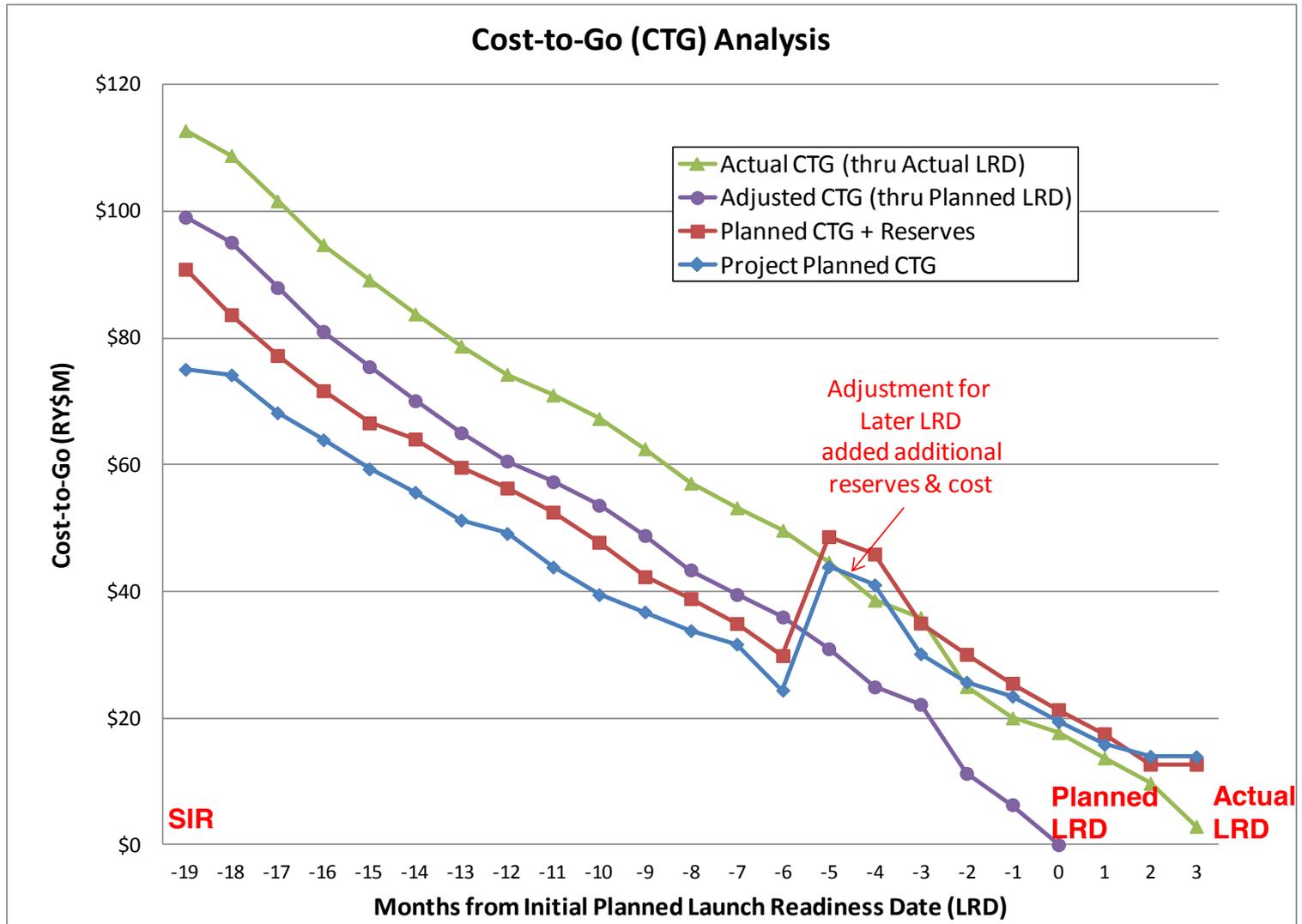
Reserves on Development CTG From SIR to Ship

- Center guidance for reserves on Cost-to-go for both JPL and Goddard Space Flight Center reduce the requirement to 10% at time of ship - i.e. Pre-Ship Review (PSR)
- Some debate exists, however, if the reserves as a percentage of CTG should decrease linearly from SIR to PSR or stay constant from SIR to PSR
- Monthly reserves on cost-to-go to launch were calculated for cost growth of historical analogies from SIR to Launch for three example missions
- Analogies are adjusted to exclude cost impact of respective launch delays
 - *All analogies experienced delays due to launch vehicle and pad availability*
 - *Required reserves were calculated to initial planned launch readiness date (LRD)*
- Results indicated that average percent reserve required is, on average, a 31% over the first 10 months after SIR
 - *Budget adjustments for delays/replans for 2 of the 3 missions investigated occurred after 10 months so trend could not be examined for a longer period*

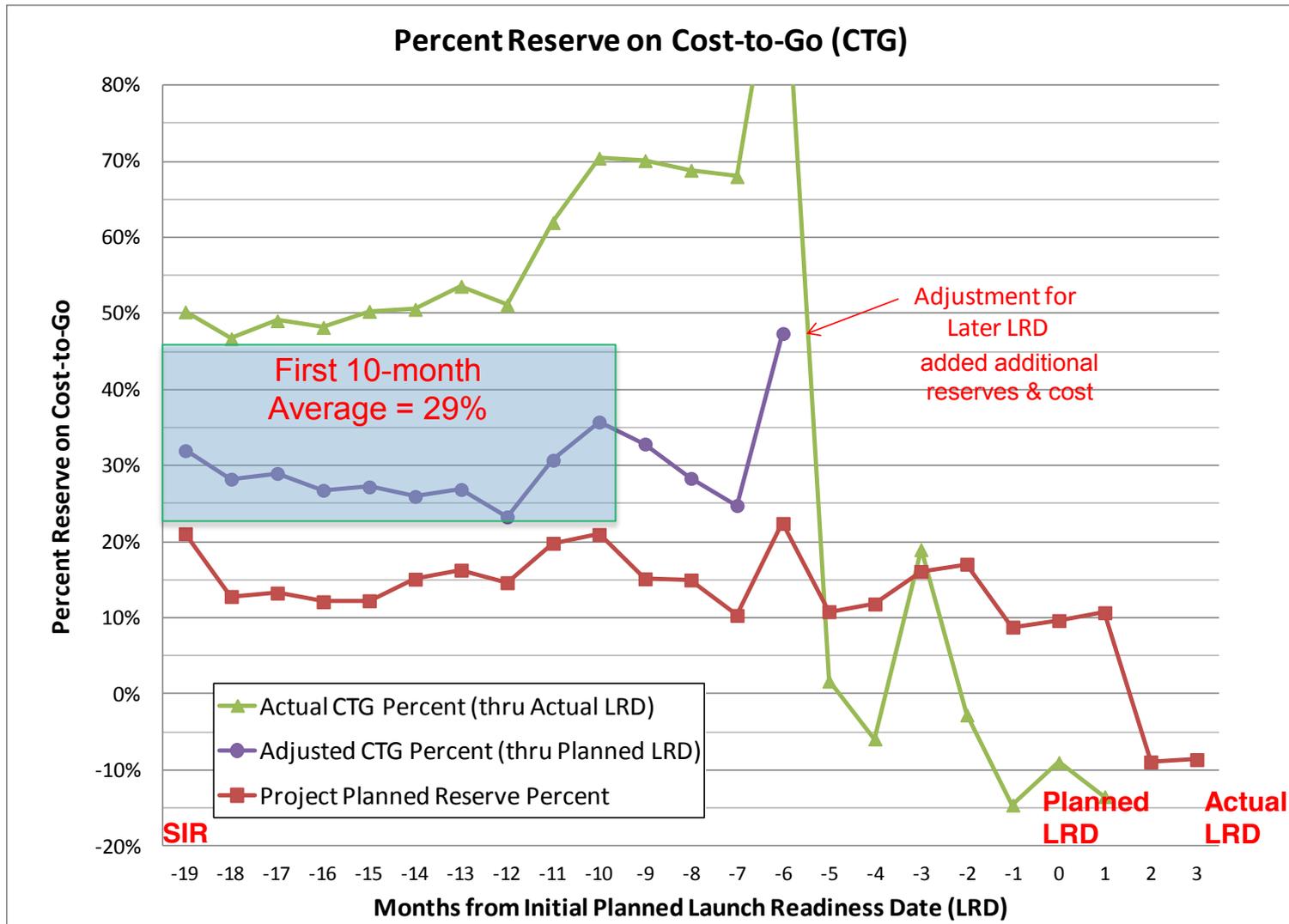
SIR to Ship Reserves Analysis Assessment Approach

- Three historical projects looked at on a monthly basis to understand reserve requirement from SIR to Launch given project stated CTG
 - *Monthly activity reports used to assess CTG and to provide historical actual cost to complete*
- Four values used in calculation
 - *PCTG = Project Planned Cost-to-go*
 - *RCTG = Reserves on Cost-to-go (unencumbered and unliened)*
 - *ActCTG = Actual Cost-to-Go (through to actual launch date)*
 - *AdjCTG = Adjusted Cost-to-Go (reflects CTG through initial planned launch date)*
- Three values calculated
 - *Project % Reserves on Planned Cost-to-go = $RCTG / PCTG$*
 - *Required % Reserves on Actual Cost-to-go = $(ActCTG - PCTG) / PCTG$*
 - *Required % Reserves on Adjusted Cost-to-go = $(AdjCTG - PCTG) / PCTG$*

Example Mission #1 Reserves Analysis – Cost-to-go

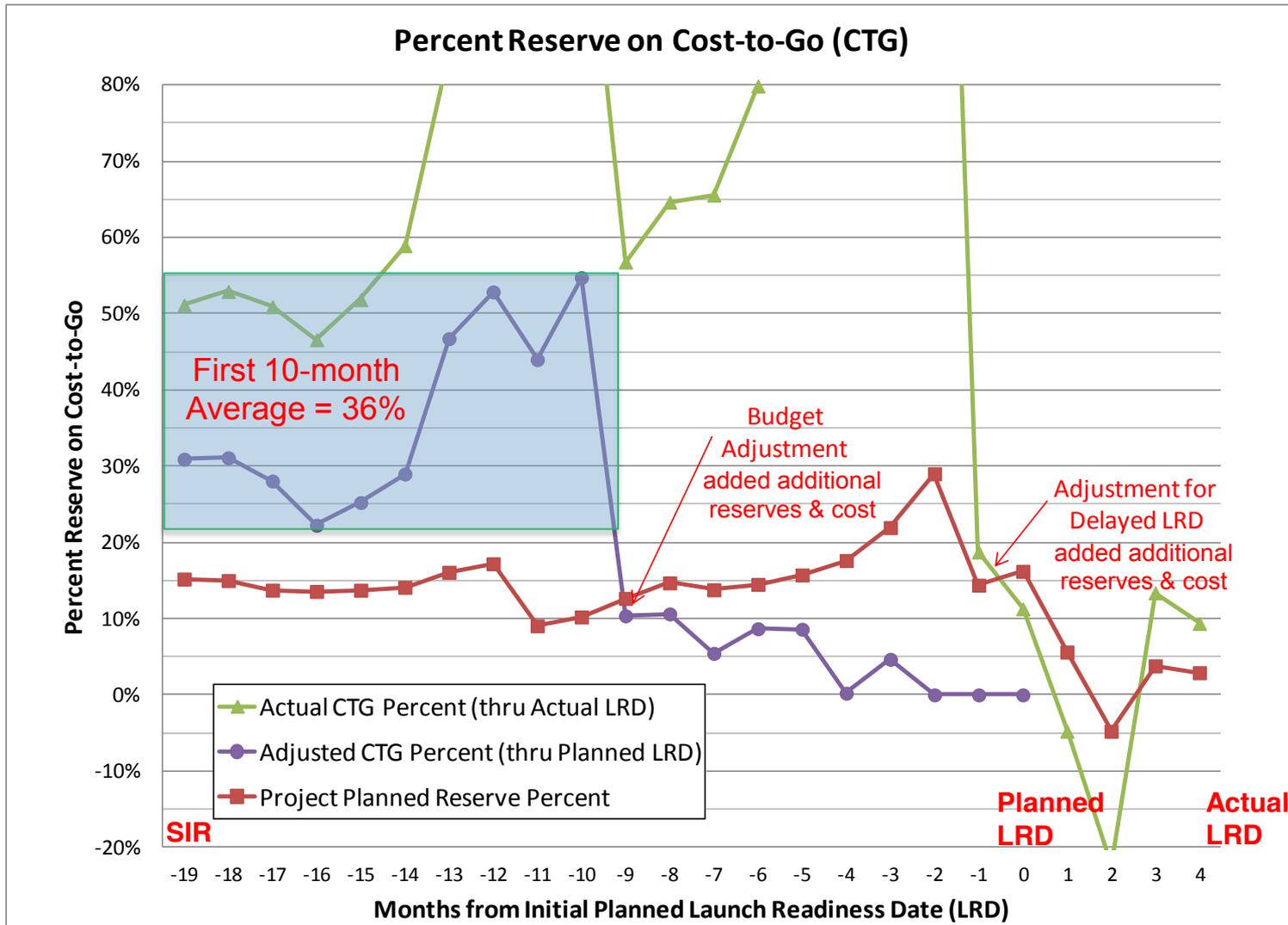


Example Mission #1 Analysis – Reserves on Cost-to-go



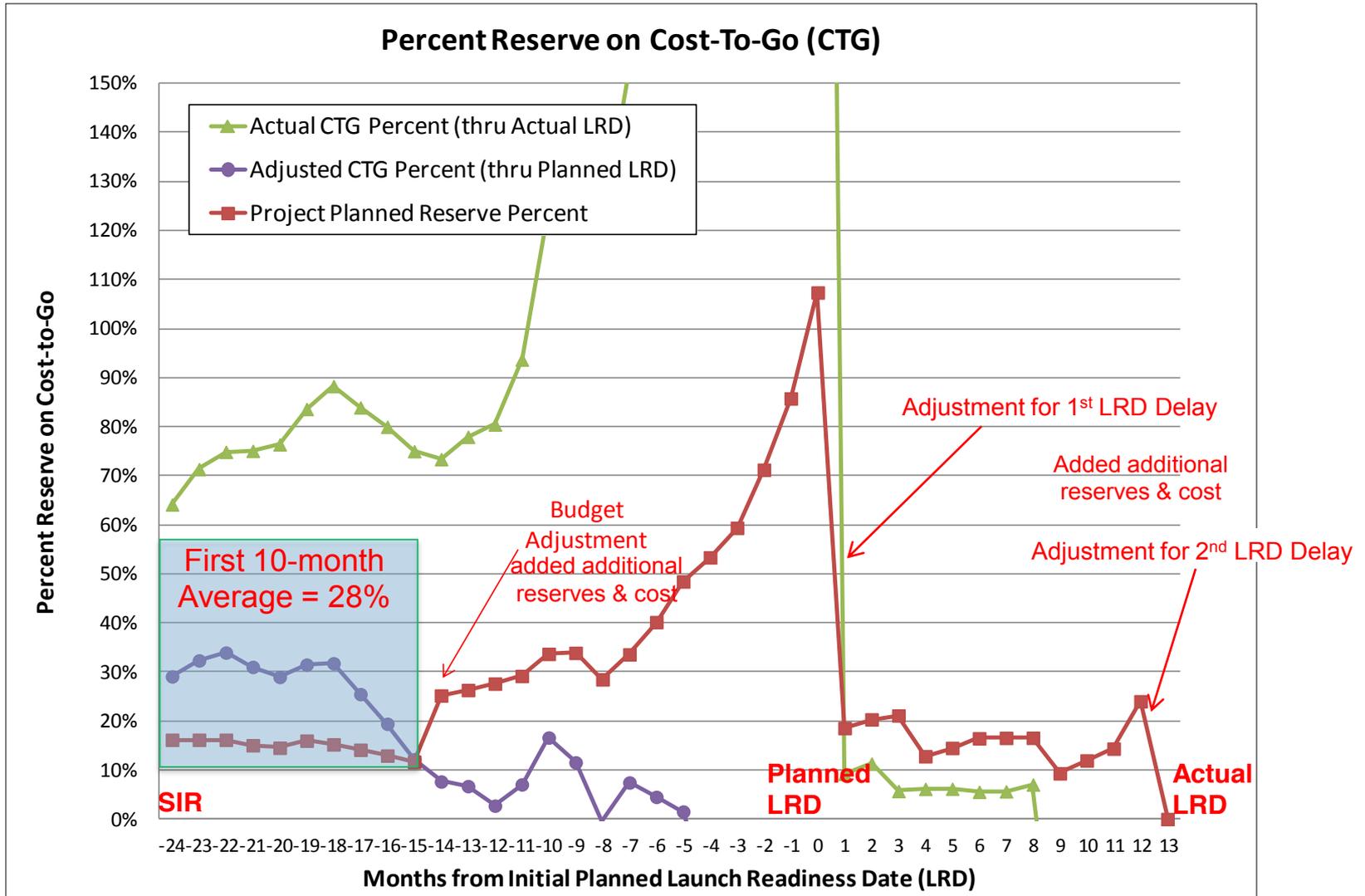
Ten month average after SIR but prior to adjustment = 29% reserve required on planned CTG to initial LRD

Example Mission #2 Analysis – Reserves on Cost-to-go



Ten month average after SIR but prior to adjustment = 36% reserve required on planned CTG to initial LRD

Example Mission #3 Analysis – Reserves on Cost-to-go



Ten month average after SIR but prior to adjustment = 28% reserve required on planned CTG to initial LRD

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Summary

- Study was determined to assess if reserves on cost-to-go were consistent with Center guidelines of decreasing percent reserves on CTG
- Results show that, even with external events removed, project internal guidelines for reserves, as a percent of cost-to-go, are somewhat low and should be a constant percentage over the duration of the project
- Results, with external events removed, indicate the following guidelines are more appropriate for well planned missions for percent reserves on cost-to-go
 - @ KDP-B = 30%
 - @ PDR = 31%
 - @ CDR = 37%
 - @ SIR = 33%
 - From SIR to PSR = 31%
- Based on the analysis, consideration should be given to revising guidelines to provide at least a 30% reserve on cost-to-go at each milestone