

National Aeronautics and
Space Administration

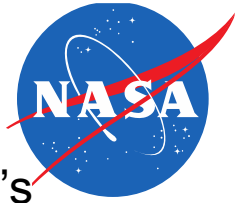


TIMING IS EVERYTHING

Susan Harkins Bertsch
NASA Cost & Schedule Symposium
April 25, 2024

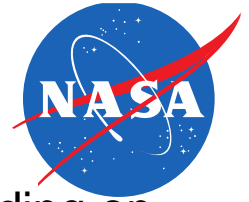


Timing Is Everything

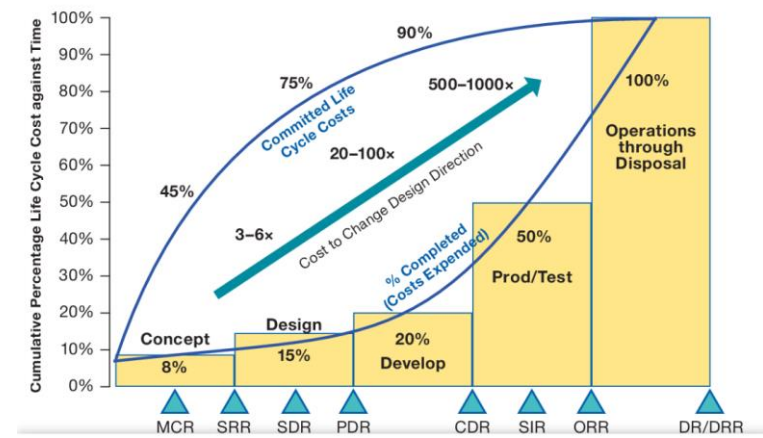


- Specifically, the timing of how to allocate a cost estimate over a project's development
- I learned a set of metrics and cost phasing relationships early on my NASA cost estimation career, passed the lore on to interns and new hires, reiterated with each new acquisition
- As a senior cost estimator at JSC, I have worked almost all the IGEs for our new human spaceflight developments and regularly reach into my trusty toolbox of tried-and-true metrics to guide the exercise of turning an estimate into a cost flow and preliminary budget
- But the times they are a-changin', and that has led to a project to re-examine these metrics and investigate the relationship of newer acquisitions to the historical data set

Standard Time

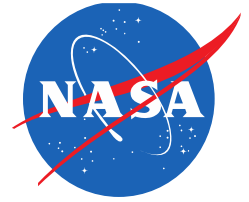


- Long, long time ago, I can still remember that I was told that cost spending on NASA projects followed a general spending ogive anchored by metrics at associated with key phases
 - 15% of total development costs spent through PDR
 - 40% - 60% of total development costs spent through CDR
- Available data generally validated these relationships, although the mission data set was extremely thin and very old
 - But I got it from Joe Hamaker so it had to be good
- Mission data set and metrics aligned with relationships outlined in other NASA sources
 - NASA Systems Engineering Handbook
 - Program Management Profession (PMP) training

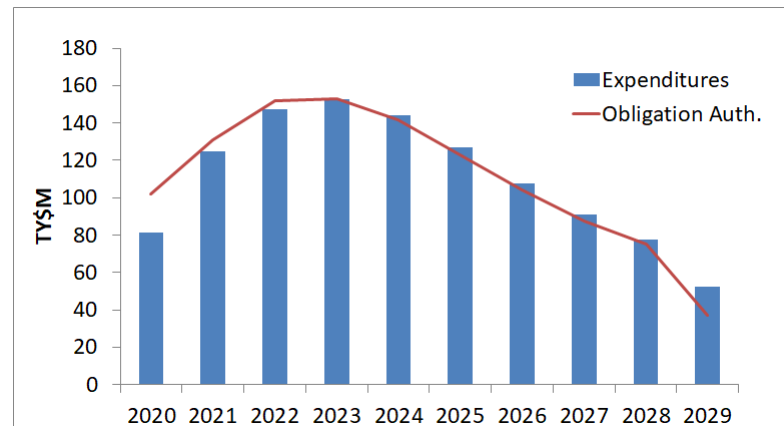
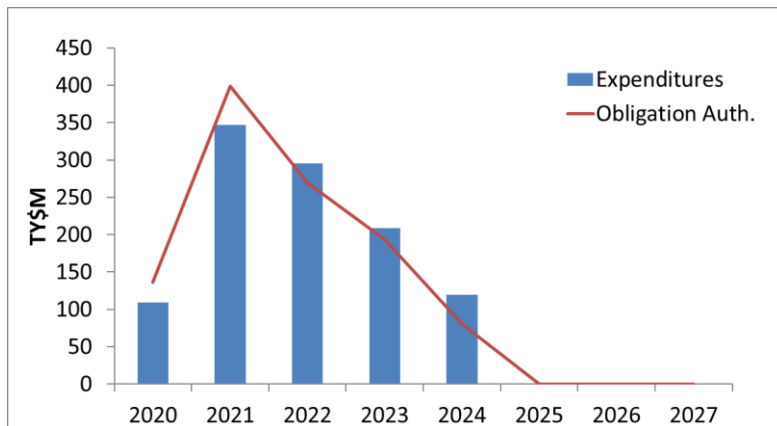


Courtesy NASA Systems Engineering Handbook, 1995

Phasing Estimation Relationship Modeling

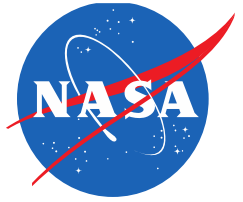


- NASA did fund research into phase estimating relationships (PERs) in 2013, resulting in a data-driven model for estimation of annual funding given cost and schedule estimates
- However, PER is a tool and not data and it is a tool driven by schedule inputs. Optimism bias on schedule dates in various developments yielded an aggressive spending plan inconsistent with available monies and/or a schedule inconsistent with available funding



- This drove me back to the question of sanity checks against spending through key milestones and the need for validation of what spending should look like

Strange Times

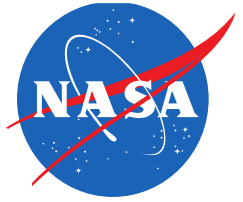


- At the same time as I am wrestling with trying to fit competing cost and schedule ambitions into the traditional box, I see a steady stream of projects wanting to break the rules and phase their cost estimates in strange ways

This paper is meant to answer two key questions

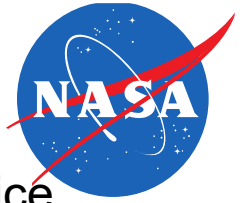
- What, indeed, are the “rules”?
- Are things really changing or just a set of one-off observations?

Methodology



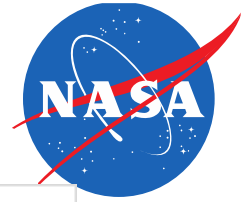
- Sourced all data from ONCE (CADRe)
 - Constant dollar cost by phase, Phases A-D, drawn from User Reports interface
 - Converted dollars to percentage of total development cost for each phase
- Used data from LRD instances for completed missions to get end state and validate metrics
 - EOM only used if sole source for mission data
- Used data from CDR and SIR for missions in work, missions with CADRes not yet complete
 - Study of temporal data for completed missions show that phase cost and percentage of total can be very fluid over a project life cycle
 - Used end-stage milestone data to choose milestones closer to a development end state and get reasonably close to an LRD end state
- Dataset was cleaned up for clear anomalies, but outliers not removed so that trend data could be observed
- Data sorted and presented by launch year
 - For presentation purposes and to show trend (if any) over time

Observations From Mission Data Through PDR

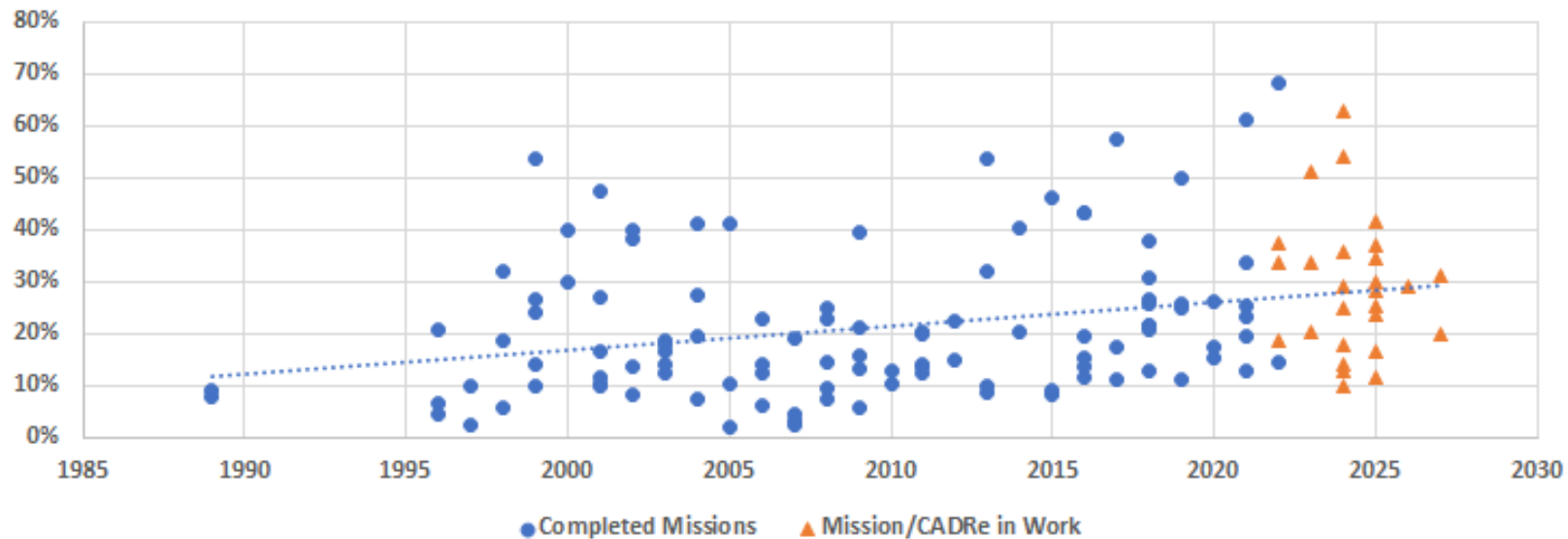


- “Kitchen Sink” approach to include every mission was a deliberate choice
 - Forward work to into dataset to formulate rationale to determine how to deal with outlier data
- Various “what-if” exercises were run excluding various missions (e.g., large joint satellite developments, parsing data by mission class), found that median data remained in a range of 15% to 20%
 - In other words, Joe Hamaker was right
- The data set is very noisy, with as many projects below the median as above
- The accepted historical metric remains reliable for continued use as an average for setting early budget phasing
- Deviations from the average need to be queried for consistency with overall project spending plan, particularly with regard to realism and risk associated with assumptions

Mission Data Through PDR



Cost Through PDR, Pct of Total Development



Percentages Through PDR Based on Sum of Phase A-B Costs as a Percent of Total Development Cost

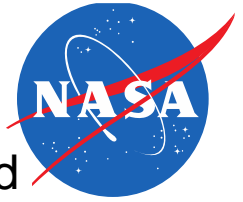
Median Value for Completed Missions

17% through PDR (Std Dev 14%)

Median Value with Addition of Missions
In Work and/or Pending Completion of
LRD CADRes

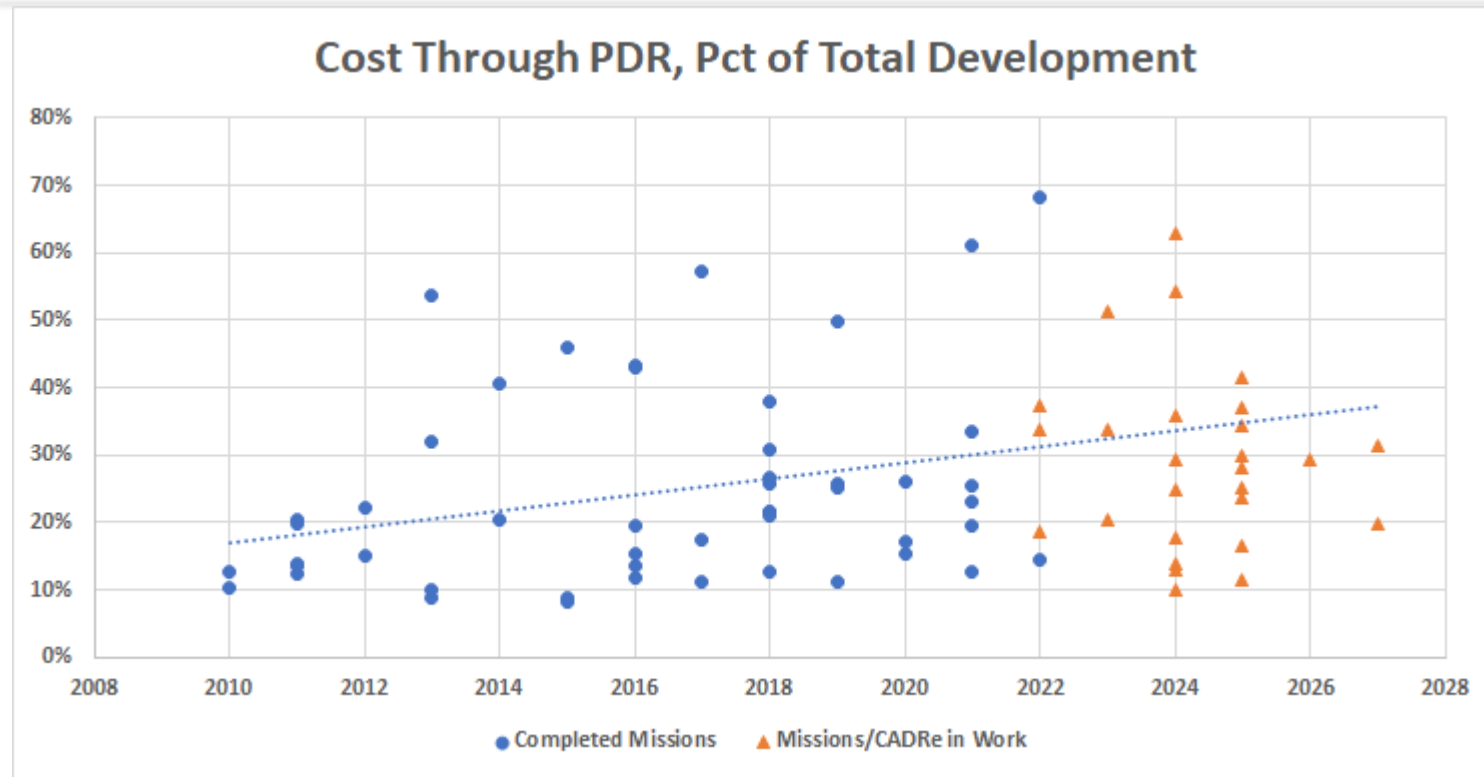
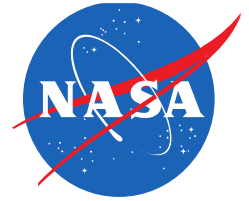
19% through PDR (Std Dev 14%)

Is Spending Through PDR Increasing?



- There is an observable trend, even through the noise, toward increased spending through PDR
 - Rationale offered by projects
 - Need to increase spending in early phases to secure long-lead items to keep schedule
 - Obligations to secure firm-fixed contract work. Monies have an optic as “spent” but are in fact simply moved elsewhere
 - Requirements churn and/or budget replanning force an inefficiency reflected in early stages of project
 - Inefficiencies due to Covid shutdowns, supply chain disruptions
 - Partly a contributor to the “in work” CADRe data, although some missions were well past Phases A-B by the start of the pandemic
 - Forward work needed to see if trend persists
 - Decided to take a more focused look at the data from missions in the modern era to assess trends
 - Drew chalk line from mission launch date of 2010, year in which NASA began investments in commercial space programs
 - Clear increase in Phase A-B spending (cost through PDR) observed
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Mission Data Through PDR, 2010-Present



Percentages Through PDR Based on Sum of Phase A-B Costs as a Percent of Total Development Cost

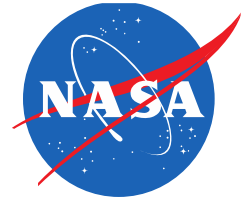
Median Value for Completed Missions

20% through PDR (Std Dev 15%)

Median Value with Addition of Missions
In Work and/or Pending Completion of
LRD CADRes

22% through PDR (Std Dev 14%)

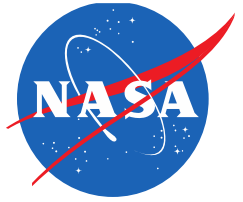
Time for a Warning



- The static dataset of LRD outcomes can mask the temporal evolution of early phase spending
- As noted earlier, there are varying rationale for increased frontloading of development costs. These must be carefully weighed for realism because the historical dataset does show examples where early frontloading of work is associated with overall cost growth
- One example from the dataset is highlighted
 - Less a deliberate frontloading of costs than an arithmetic effect of underestimating cost growth due to heritage assumptions
- Forward work to perform complete assessment on missions where a complete milestone set of data is available

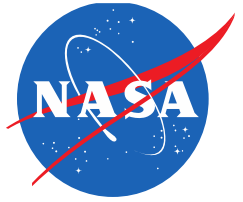
	Planned Spending	
Milestone	Through PDR	Cost Growth
SRR	21.4%	
PDR	26.4%	10.9%
CDR	20.8%	35.5%
SIR	20.0%	41.2%
LRD	17.2%	64.3%

Time for More Warning



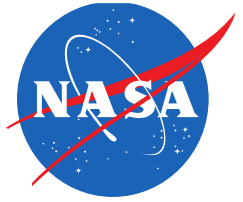
- Desire to award multiple contracts through PDR has gained a lot of traction in the Agency
- This work largely solidifies the long-assumed metric of 15% through PDR, and it also shows that none of the missions in the dataset spent less than 10% through that milestone
 - If funding is less than these levels, risk is that expected PDR maturity is at risk unless commercial partners make up the difference
- Need to ensure that incumbents are either capable of funding the difference on their own and/or have the ability to wait for milestone payments
- Firm-fixed price contracting is the assumed safeguard against cost growth, but there are potential schedule and non-performance risks

Observations From Mission Data Through CDR

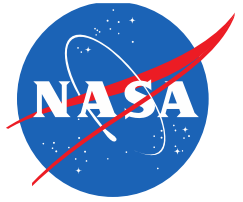


- Overall spending through CDR at the high end of the rule of thumb
 - 60% to 65% through this milestone
 - Higher than expected
- No obvious rationale for higher-than-expected results
 - Same “what if” exercises for outliers for PDR data did not move median, standard deviation values much
- Clear forward work needed to parse the data further
 - Query CADRe data directly to look at temporal breakdown
 - Possible use of different metric, e.g., time elapsed instead of Agency milestones
- Data charts in backup

Recap

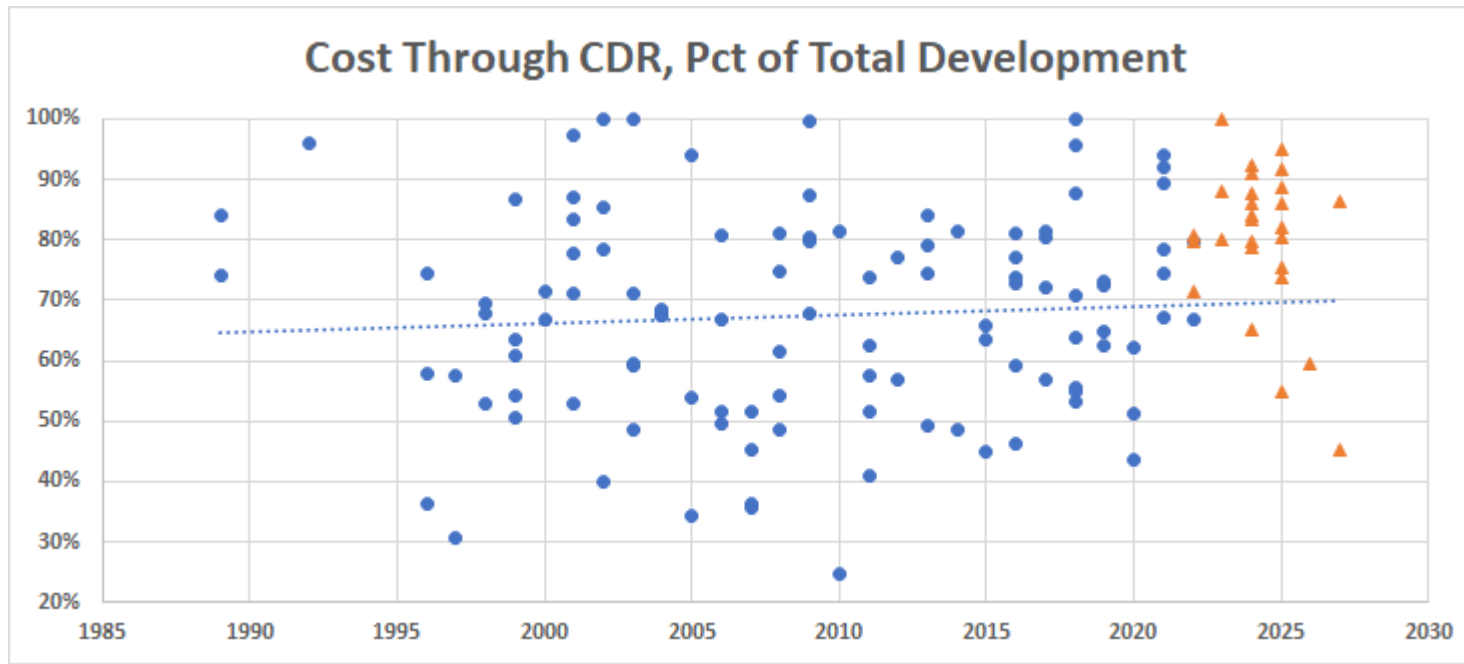
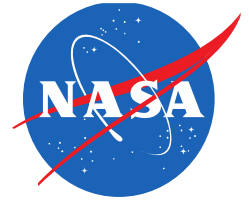


- Traditional cost through PDR on completed missions does hold close to the assumed metric of 15%
- There is enough of a drift toward increased spending in early phases to expand the traditional metric to a range of 15% to 20%
- More work needed to understand cost spending through CDR
- Recognize that the end state often does not mirror the initial cost state. Question the reality of the entire phasing plan and perform risk planning accordingly



BACKUP

Mission Data Through CDR



Percentages Through PDR Based on Sum of Phase A-B Costs as a Percent of Total Development Cost

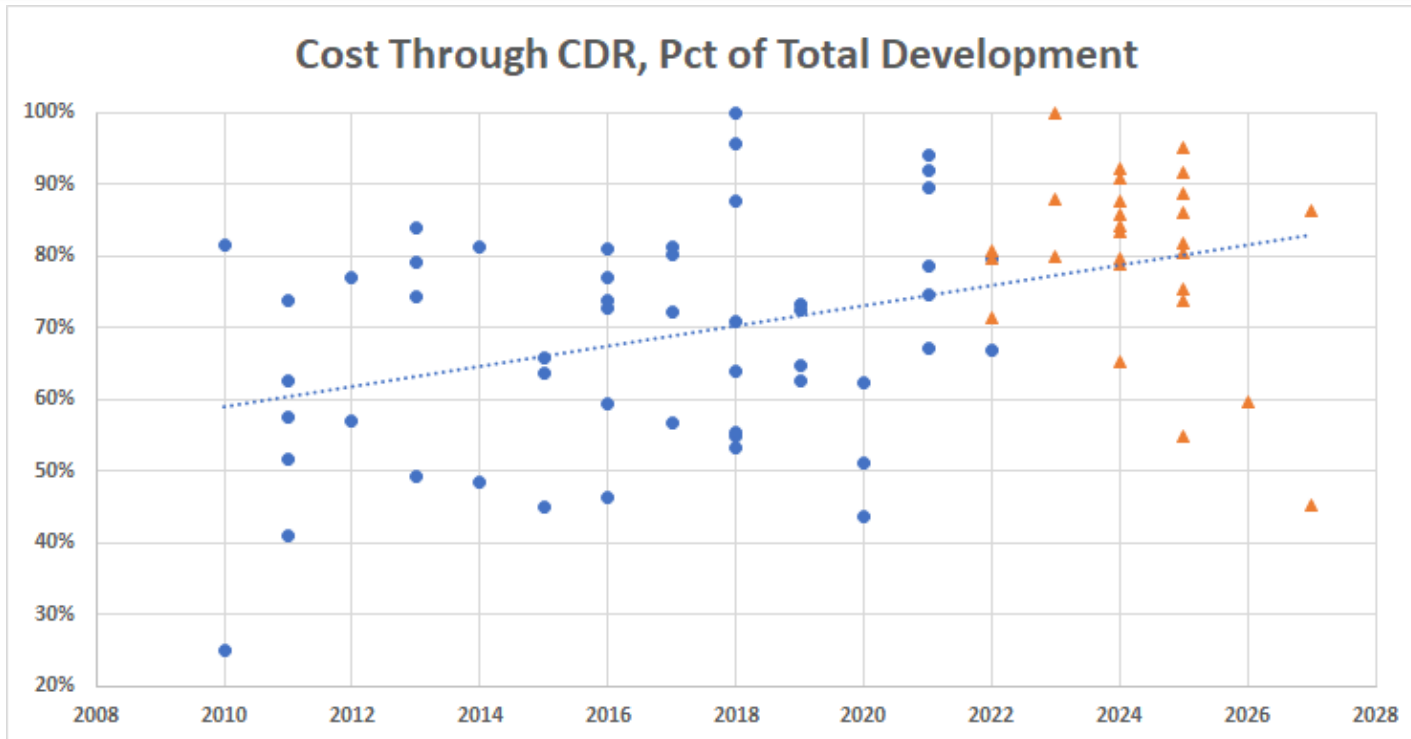
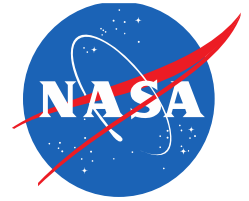
Median Value for Completed Missions

61% through PDR (Std Dev 32%)

Median Value with Addition of Missions
In Work and/or Pending Completion of
LRD CADRes

63% through PDR (Std Dev 32%)

Mission Data Through CDR



Percentages Through PDR Based on Sum of Phase A-B Costs as a Percent of Total Development Cost

Median Value for Completed Missions

65% through PDR (Std Dev 32%)

Median Value with Addition of Missions
In Work and/or Pending Completion of
LRD CADRes

67% through PDR (Std Dev 32%)