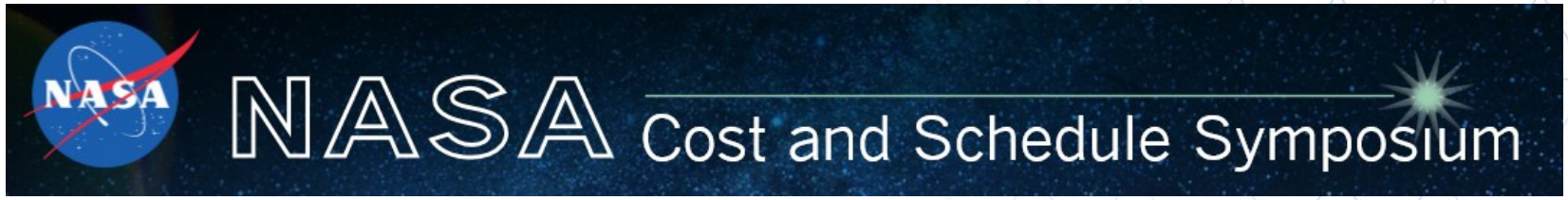
JOHNS HOPKINS APPLIED PHYSICS LABORATORY

TECOLOTE RESEARCH



In and Out of Context: Revisiting NASA and Industry Spacecraft Cost Comparisons

2026 NASA Cost & Schedule Symposium
NASA Glenn Research Center (GRC)

Dr. Rachel Sholder (Business Operations Lead for Space Formulation, JHU/APL)
Dr. Kathy Kha (Technical Expert – Space Integration Group, Tecolote Research)

Agenda

- Introduction
- Prior Work
- Motivation
- Methodology
- Spacecraft Level Analysis
- Mission Level Analysis
- Conclusions & Key Takeaways
- Path Forward
- Acknowledgements



Introduction

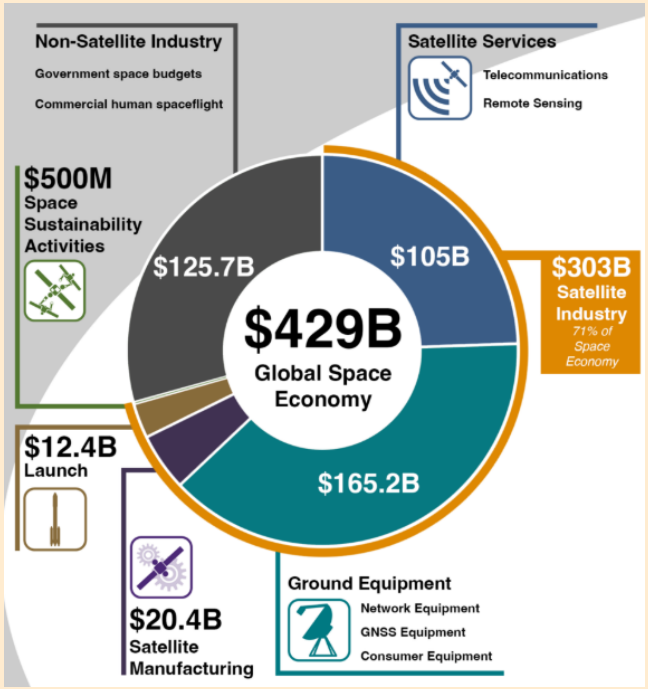


Image credit: Satellite Industry Association

- The global space economy is going through a huge period of growth currently

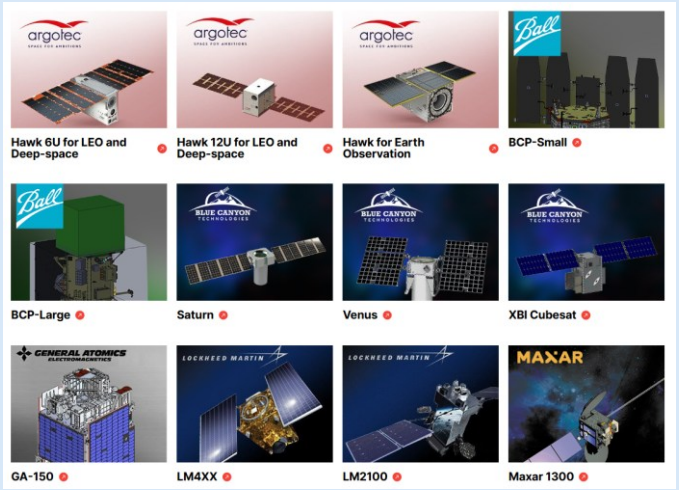


Image credit: NASA RSDO

- Competition in an era of shrinking budgets
- USG space agencies are looking to save on cost (or schedule)
  - NASA RSDO
  - EO 14271

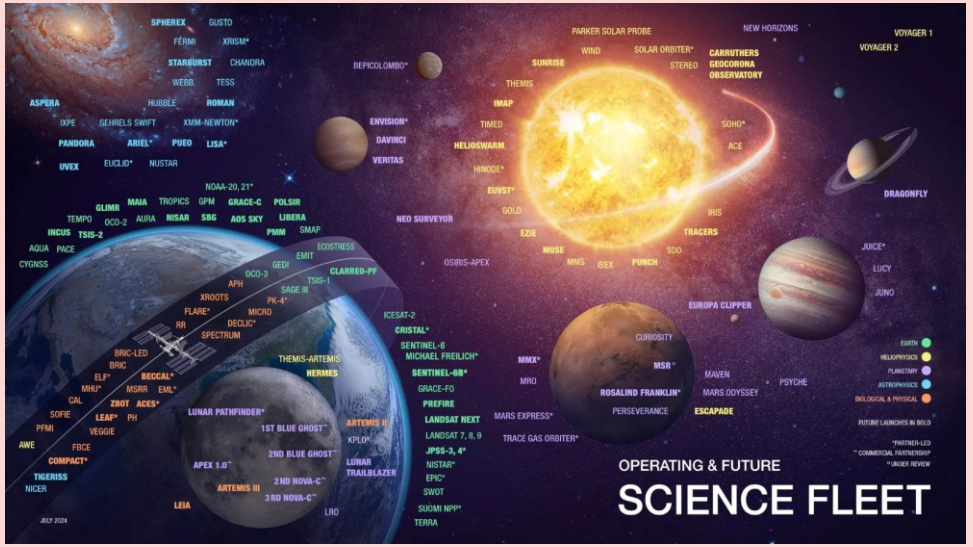


Image credit: NASA GSFC

- Huge variation in the types of missions NASA pursues
- Important to understand the nuances of the programmatic and technical benefits and risks prior to mission concept formulation

Prior Work – Kim and Hyde (2025)

- Kim and Hyde's paper compares costs of NASA- and industry-built spacecraft
- Three Summarized Findings:
  1. Industry-built spacecraft are associated with lower costs, especially for lower-risk classification C and D projects
  2. For higher-risk class A and B projects, spacecraft developer has no significant effect
  3. Additionally, spacecraft developer does not significantly affect total project cost, regardless of the risk classification

JOURNAL OF SPACECRAFT AND ROCKETS

In and Out: Comparative Analysis of NASA and Industry Spacecraft Costs

Moon J. Kim*
National Aeronautics and Space Administration Headquarters, Washington, D.C. 20546
and
Tupper Hyde†
National Aeronautics and Space Administration Goddard Space Flight Center, Greenbelt, MD 20771

https://doi.org/10.2514/1.A36406

Spacecraft development is costly and complex, requiring diverse management and acquisition strategies. As the private sector's role grows, cost models must account for varying private sector participation. Science missions without commercial value rely on traditional procurement, where a public agency manages the overall project. Within this approach, agencies must decide whether to develop spacecraft in-house or contract with industry. This study examines whether spacecraft developer type—NASA or industry—affects spacecraft cost under traditional procurement. A regression model reveals that industry-built spacecraft are associated with lower cost, especially for lower-risk classification C and D projects. However, for higher-risk class A and B projects, developer type has no significant effect. Additionally, spacecraft developer type does not significantly affect total project cost, regardless of the risk classification. Since spacecraft cost accounts for 40% of the total project cost on average, the impact of developer type on the overall project cost is diminished. Consistent with existing models, spacecraft mass remains the primary cost driver, with mission risk classification and deep-space operation also influencing costs. These findings offer insights into spacecraft cost dynamics, particularly in complex missions, and contribute to a more nuanced understanding of how to better leverage industry's cost advantages in public programs.

Prior Work – Kim and Hyde (2025)

Unclear methodology & data normalization:

- Unclear what is included in total project costs
- "The study excluded 10 projects involving multiple spacecraft builds because the available data did not allow for the separation of the initial unit development costs from the subsequent unit production costs."
- "This test resulted in no statistically significant difference, suggesting the need for a more robust statistical test."

Used "NASA"/"in-house" and "industry"/"out-of-house" interchangeably:

- Defined in-house as NASA-built
- Defined out-of-house as outsourced to private contractor
- No designation for when the NASA/JPL/APL implementing organization ≠ NASA/JPL/APL spacecraft manufacturer

No food for thought regarding implications to space policy and the state of the industry

Unclear descriptive statistics results (with findings reported in absolute dollars):

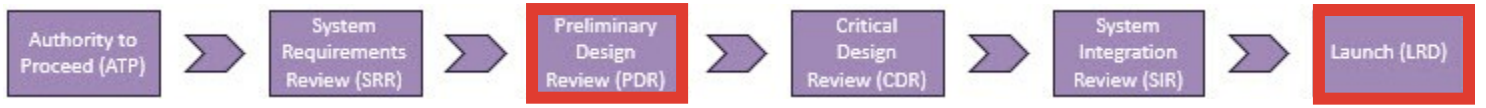
- "The sample mean cost for industry-built projects is $411 million, with a standard deviation of $1,049 million (~$1 billion)."

Motivation

- **Traditional Assumption:** Industry/commercial spacecraft are lower cost
- **Policy Spotlight**: Ongoing debate highlighted by the 2025 Executive Order 14271
- **Prior Work**: Lots of interest and debate over Kim and Hyde's findings
- **The Missing Piece of the Puzzle**:
  - Do cost growth patterns tell the same or different story as cost advantages in terms of absolute dollars?

*This presentation provides a data-driven examination of **cost growth** for NASA- and industry-built spacecraft both at the spacecraft- and mission-level.*

Methodology



Data

- Cost data collected via PDR and Launch CADRes (Part C)
- Programmatic data collected via CADRes (Parts A, B)
- 41 unmanned missions:
  - Launch dates from 2003 to 2025
  - Total development costs up to $1B
- Costs were normalized:
  - Phases A-D
  - Exclude LV costs
  - Includes project & management reserves
  - First unit normalization for multiple spacecraft builds

Calculations

- Cost growth is evaluated at two levels:
  - Mission level (WBS 1-7, 9-10)
  - Spacecraft (SC) plus I&T level (WBS 6, 10)
- **Cost growth** was calculated from PDR to Launch as:

$$cost\ growth = \frac{(Cost\ @\ Launch - Cost\ @\ PDR)}{Cost\ @\ PDR}\ x\ 100\%$$

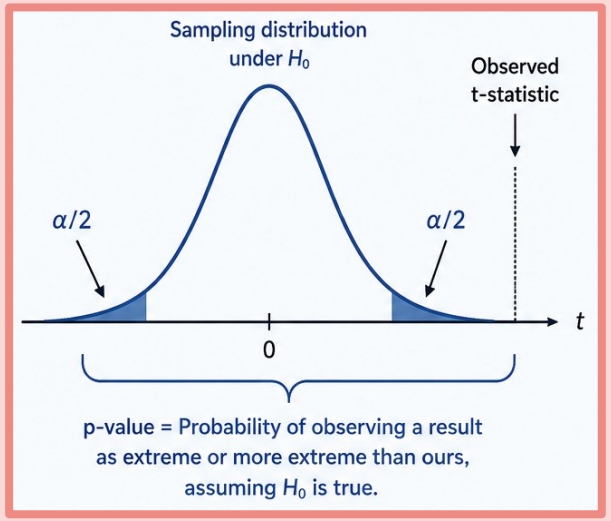
Classification

- Classified according to spacecraft developer:
  - NASA-built *(N = 13)*
  - Industry-built *(N = 28)*
- Classified according to NASA mission risk classifications
  - Classes: A, B, C, D

	Class A	Class B	Class C	Class D
Agency Priority	High	High	Medium	Low
National significance	Very high	High	Medium	Low to medium
Mission Lifetime	Long > 5 yrs	Medium 2-5 yrs	Short < 2 yrs	Short < 2 yrs
Cost	High	High to medium	Medium to low	Low
Alternative Opportunities for Science Collection/ Reflight	None	Few	Some	Many

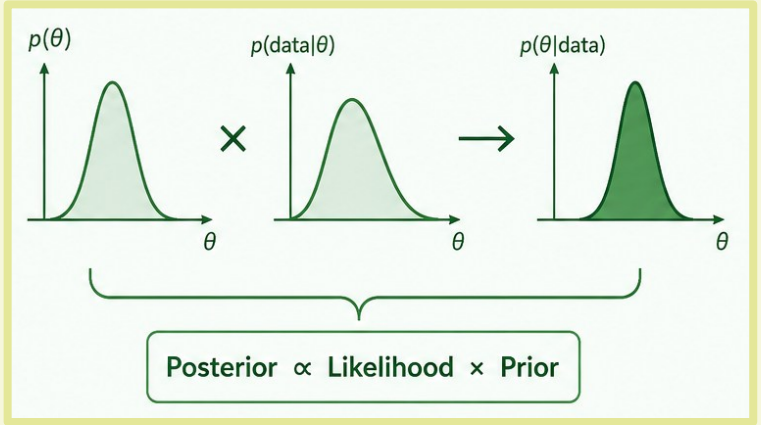
Statistical Analysis

Frequentist Approach



- Classical Welch's t-tests test whether the observed difference of means between two groups is statistically significant or due to chance
- Reports a p-value:
  - Smaller values = stronger evidence the difference of means matters and is statistically significant
- Analysis completed in Excel

Bayesian Approach



- Complement classical t-tests with a simple Bayesian Gaussian regression
- Allows us to quantify the probability and magnitude of differences in cost growth between developer types and to represent the substantial uncertainty present in small, noisy samples
- Analysis completed in RStudio using R (programming language)

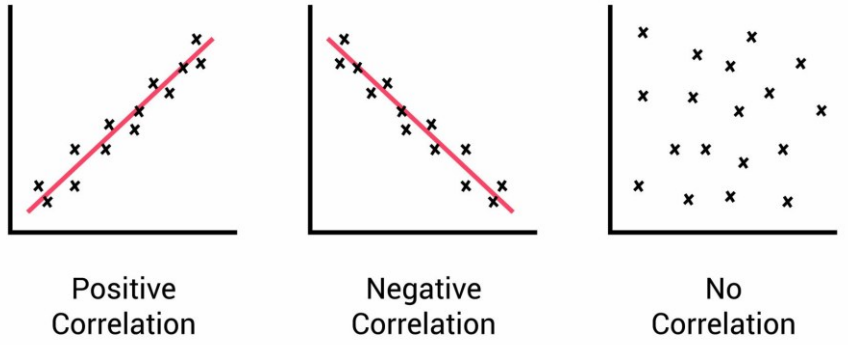
Correlation and Causation

- **Correlation**: a statistical measures that describes the relationship between two variables (quantified by a correlation coefficient, R, that ranges from -1 to 1)
- **Causation**: a relationship where a change in one variable directly produces or causes a change in another variable

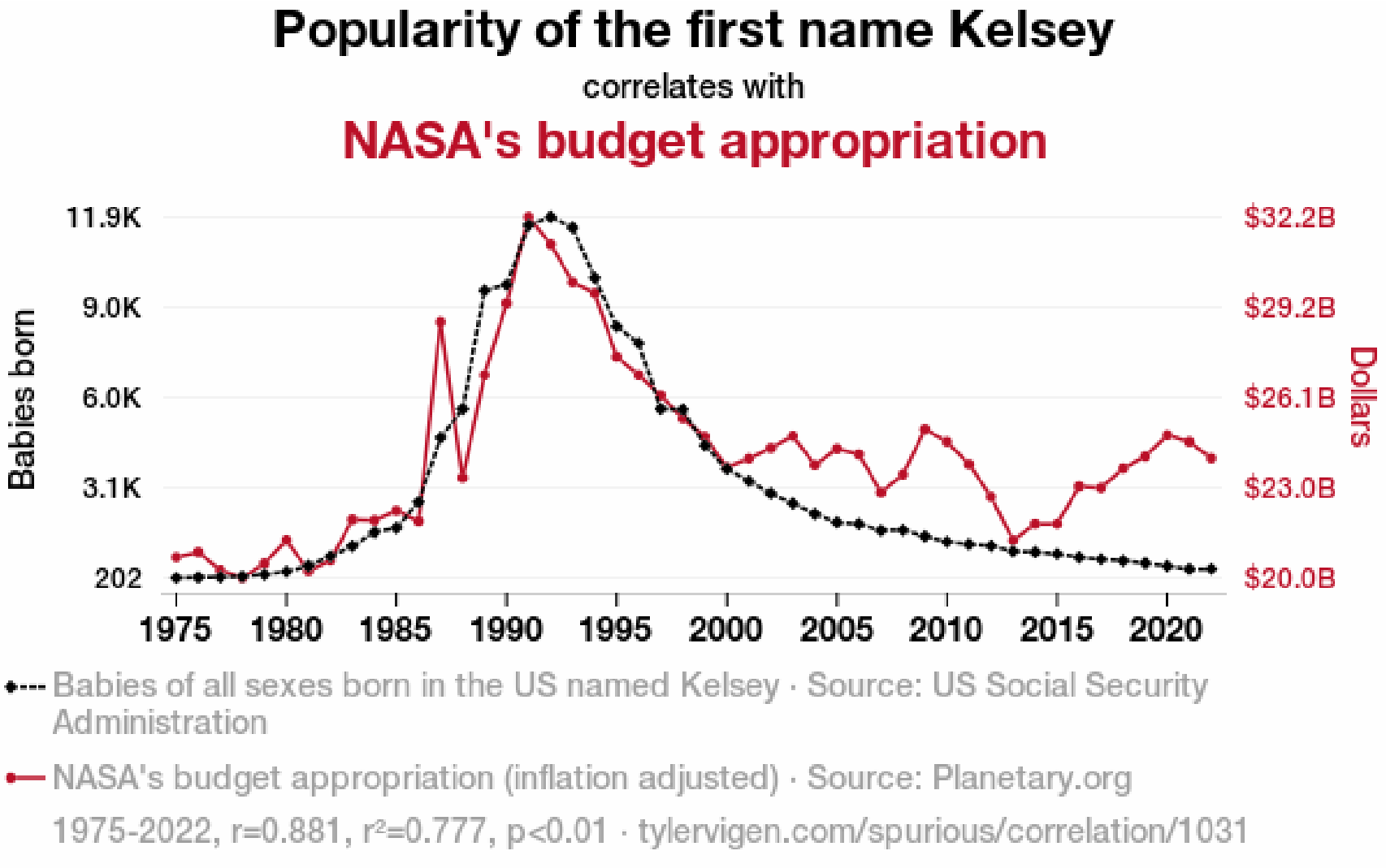


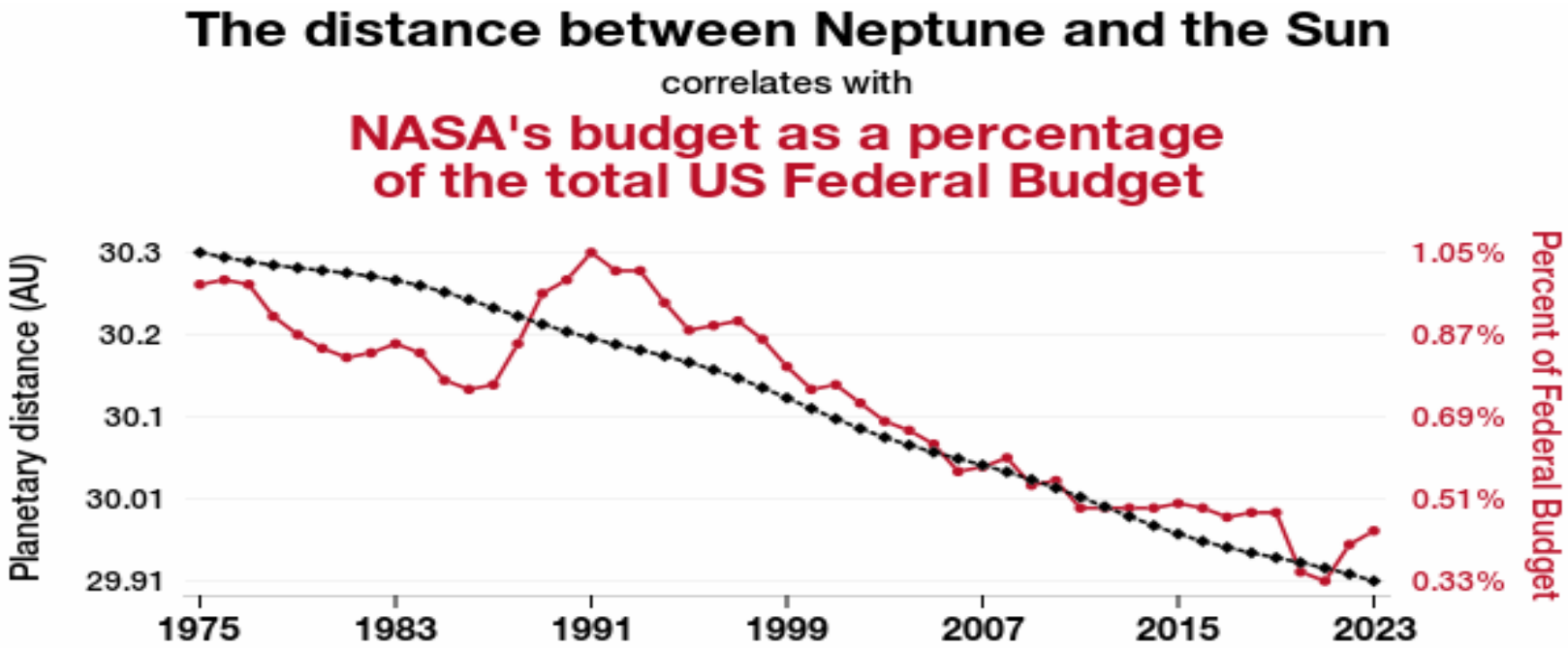
- **Why?**
  - Confounding variables
  - Reverse causation
  - Coincidence

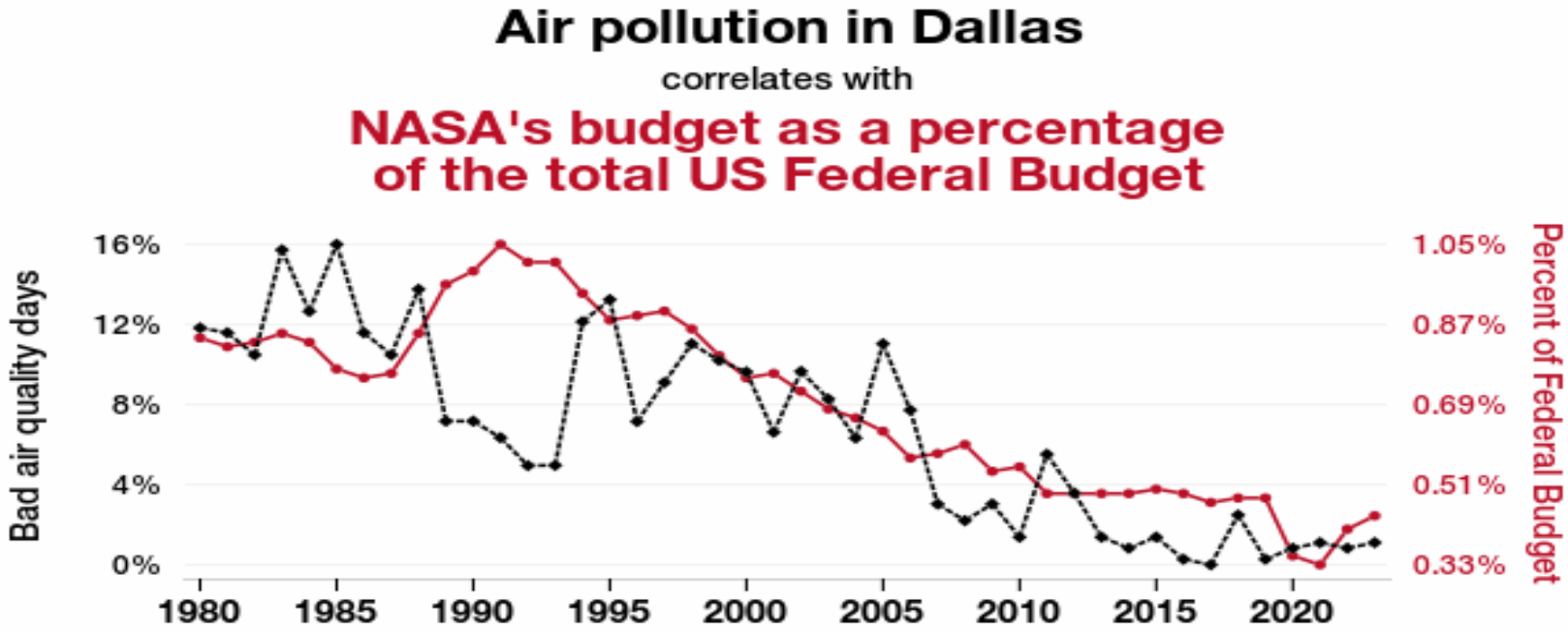
    → ***spurious correlations***



Spurious Correlations



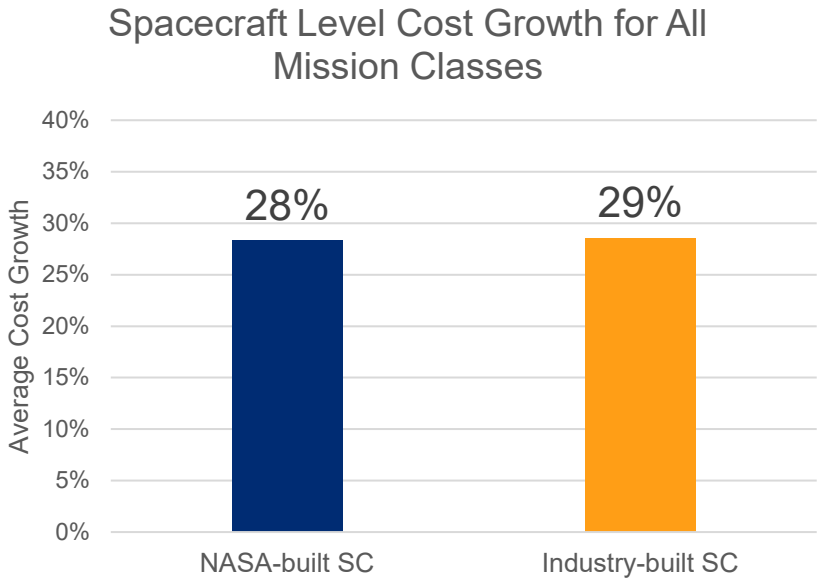

The distance between Neptune and the Sun
correlates with
NASA's budget as a percentage of the total US Federal Budget
Planetary distance (AU)
30.3
30.2
30.1
30.01
29.91
1.05%
0.87%
0.69%
0.51%
0.33%
Percent of Federal Budget
1975
1983
1991
1999
2007
2015
2023

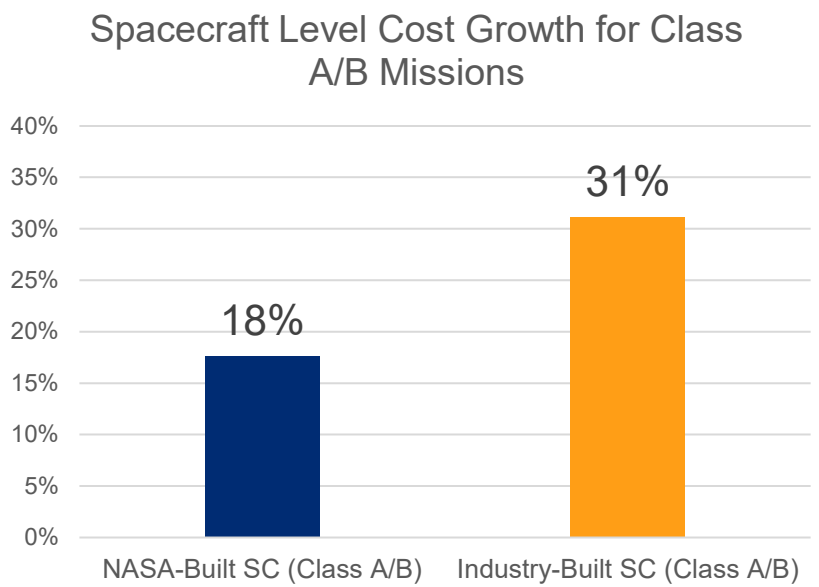

Air pollution in Dallas
correlates with
NASA's budget as a percentage of the total US Federal Budget
Bad air quality days
16%
12%
8%
4%
0%
1.05%
0.87%
0.69%
0.51%
0.33%
Percent of Federal Budget
1980
1985
1990
1995
2000
2005
2010
2015
2020

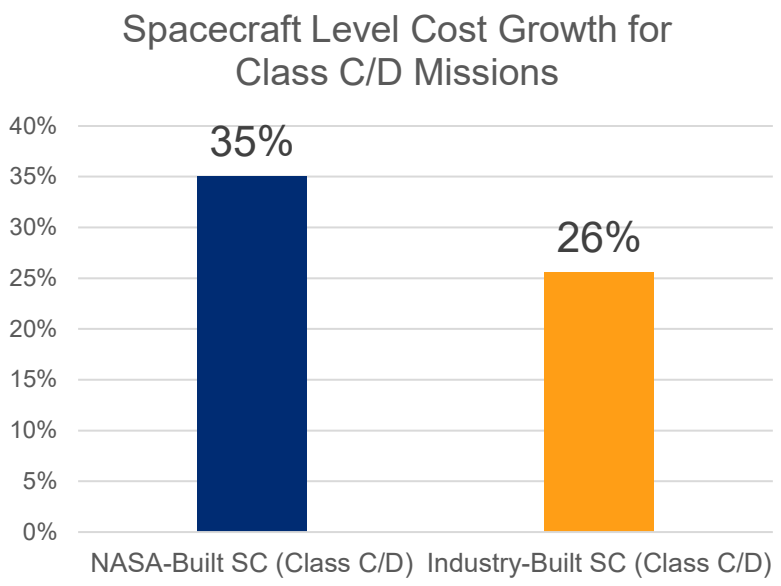
Spacecraft Level Analysis

Cost Growth Analysis – Spacecraft Level

T-Test





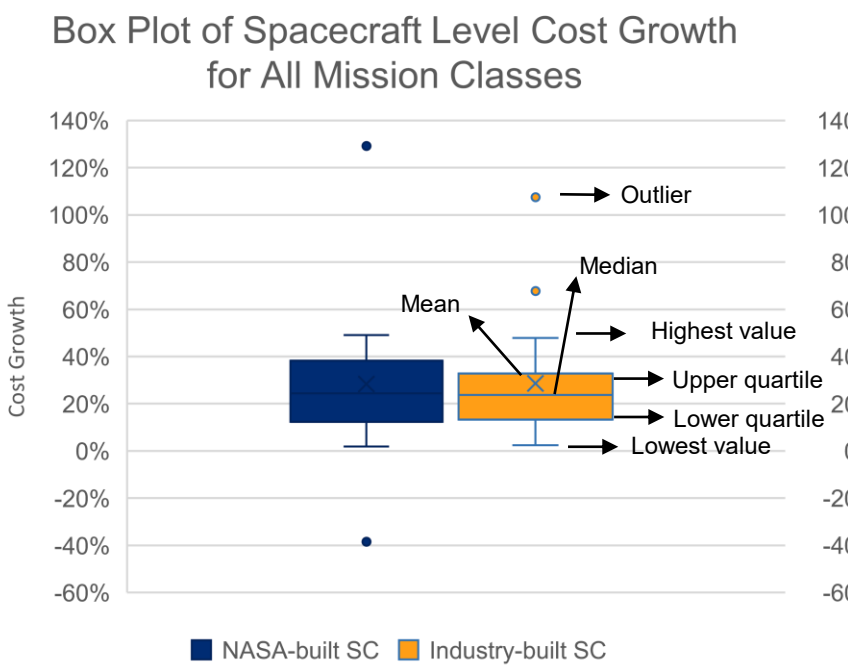


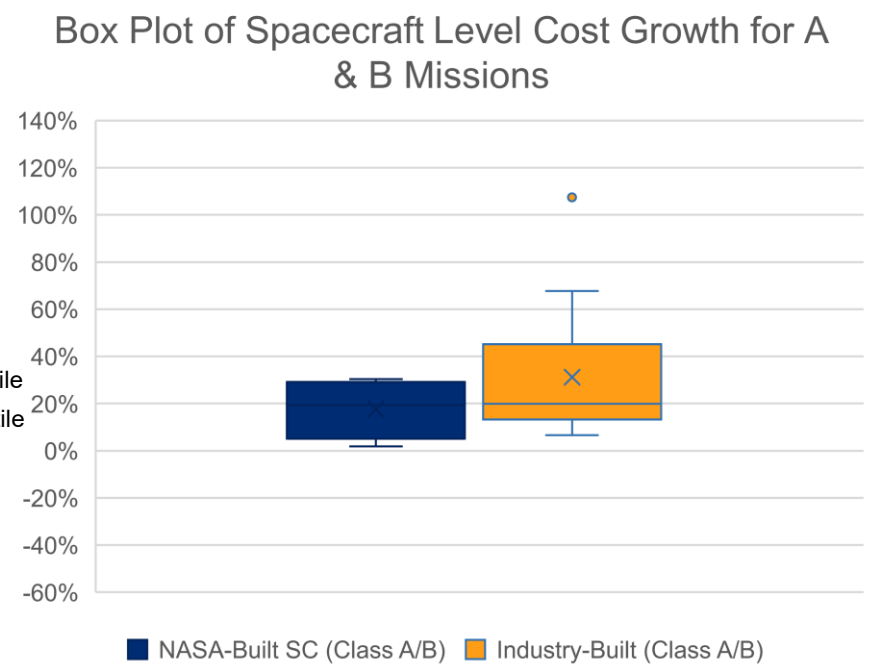
	Class Agnostic	Class A/B	Class C/D
P-Value	0.49	0.07	0.30
Significant?	No ✗	No ✗	No ✗

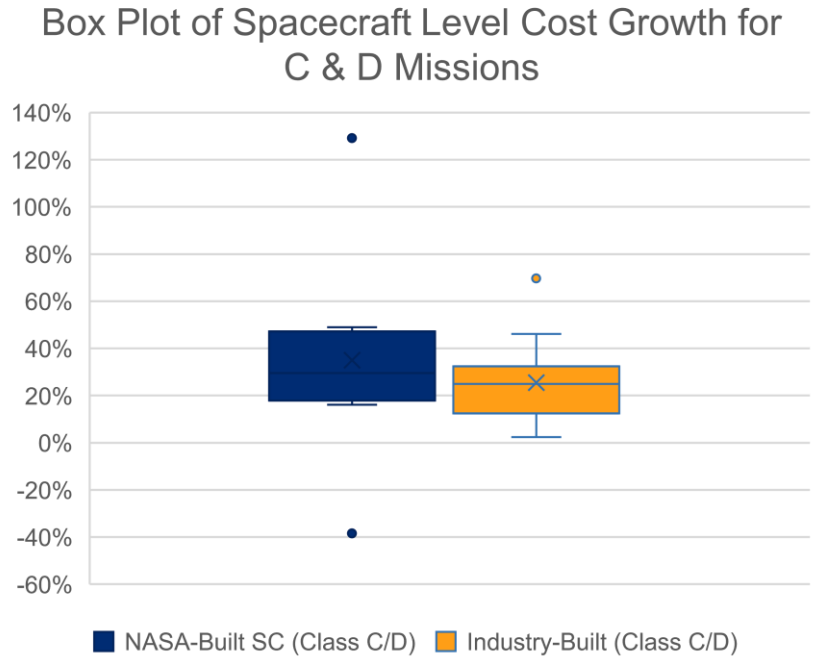
The evidence for an industry–NASA difference is stronger for Class A/B missions than for Class C/D missions. In both cases, the data falls short of conventional thresholds for statistical significance.

Cost Growth Analysis – Spacecraft Level

Box Plots







All Missions: NASA- and industry-built spacecraft have similar averages and similar spreads.

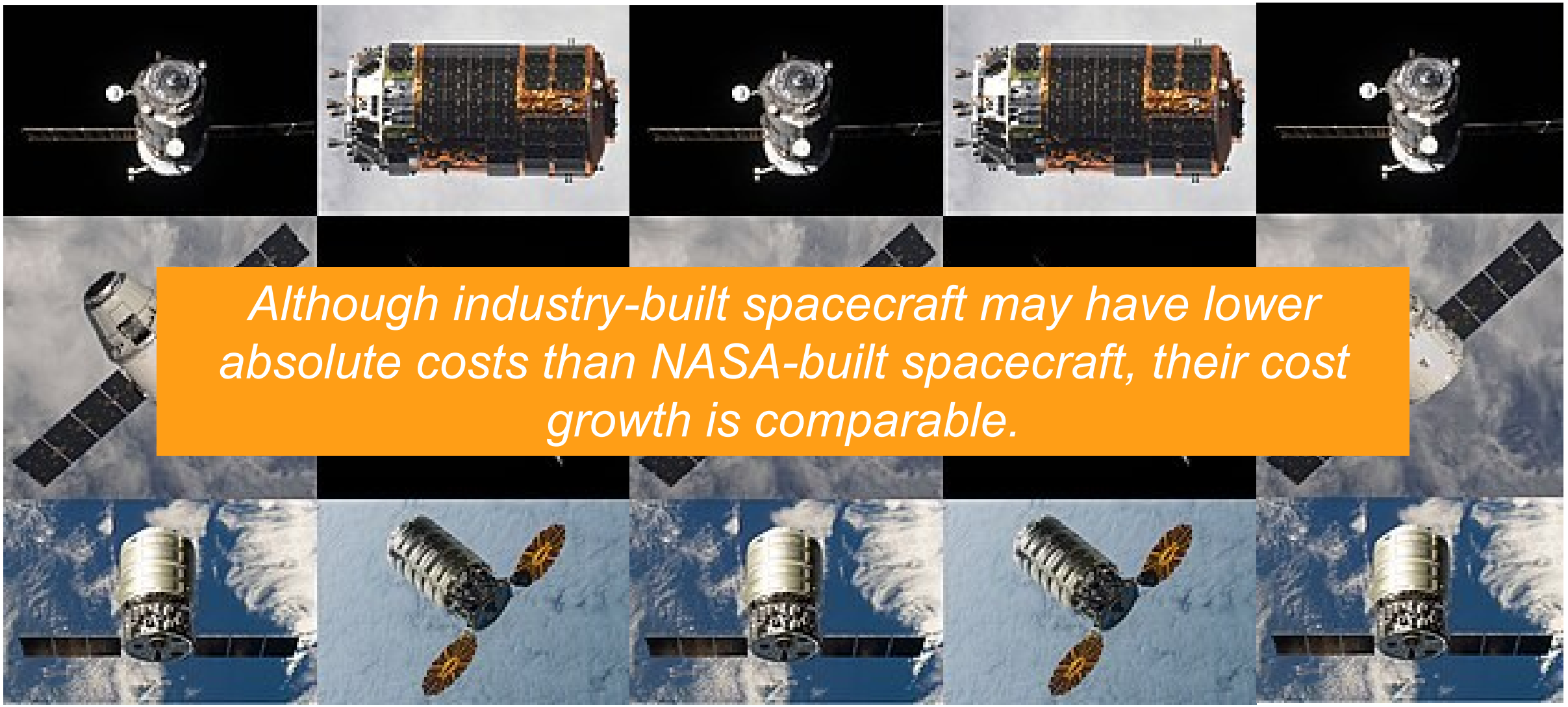
Class A/B: Industry spacecraft exhibit higher cost growth and a slightly wider distribution than NASA spacecraft.

Class C/D: NASA spacecraft have a slightly larger spread, but the means/medians are closer together.

Spacecraft Level Summary

Mission Risk Classification	Prior Finding (Kim, Hyde)	Current Finding (Sholder, Kha)	Interpretation of Current Finding
Class Agnostic (A, B, C, D)	Industry-built spacecraft **are** associated with lower costs.	Industry built spacecraft **are not** associated with lower cost growth (NASA and industry have nearly identical mean cost growth).	Decisions on spacecraft developer type should be based on other factors (e.g., schedule, risk, capabilities) rather than anticipated cost-growth or initial bid prices.
Class A/B	Spacecraft developer has **no** significant effect.	There is an observable difference in cost growth (with NASA-built spacecraft exhibiting less cost growth on average), but **it isn't significant**. However, the difference is more pronounced for Class A/B than Class C/D.	Allow NASA centers to focus their expertise and resources on building spacecraft for the bespoke Class A/B missions.
Class C/D	Industry-built spacecraft **are** associated with lower costs.	There is an observable difference in cost growth (with industry-built spacecraft exhibiting less cost growth on average), but **it isn't statistically significant**.	Benefit to leveraging commercially procured spacecraft from industry for Class C/D may come in the form of less technical risk (higher TRL) and shortened development schedules.

Spacecraft Level Key Takeaway



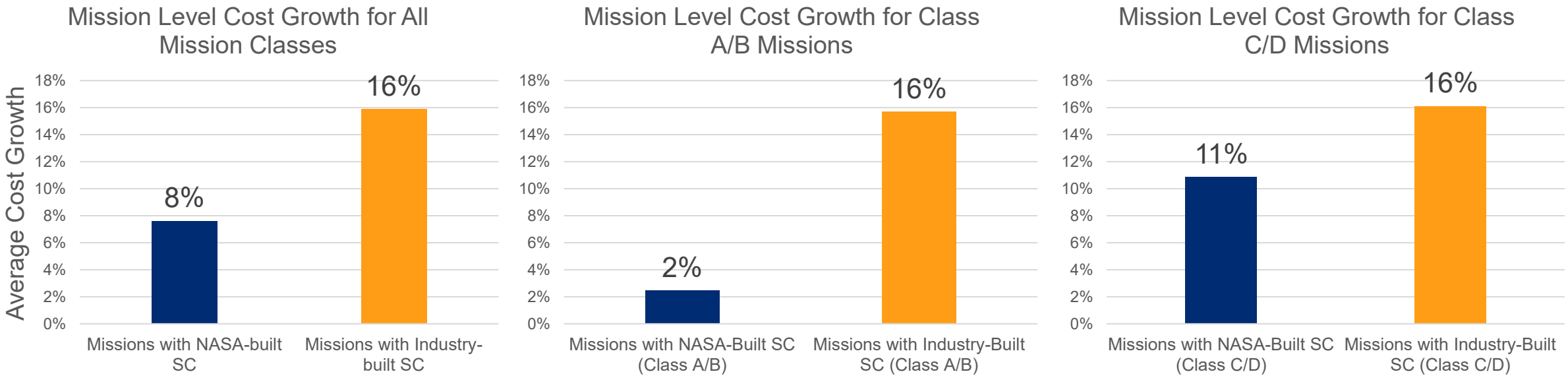
Although industry-built spacecraft may have lower absolute costs than NASA-built spacecraft, their cost growth is comparable.

Image credit: ISS

Mission Level Analysis

Cost Growth Analysis – Mission Level

T Test

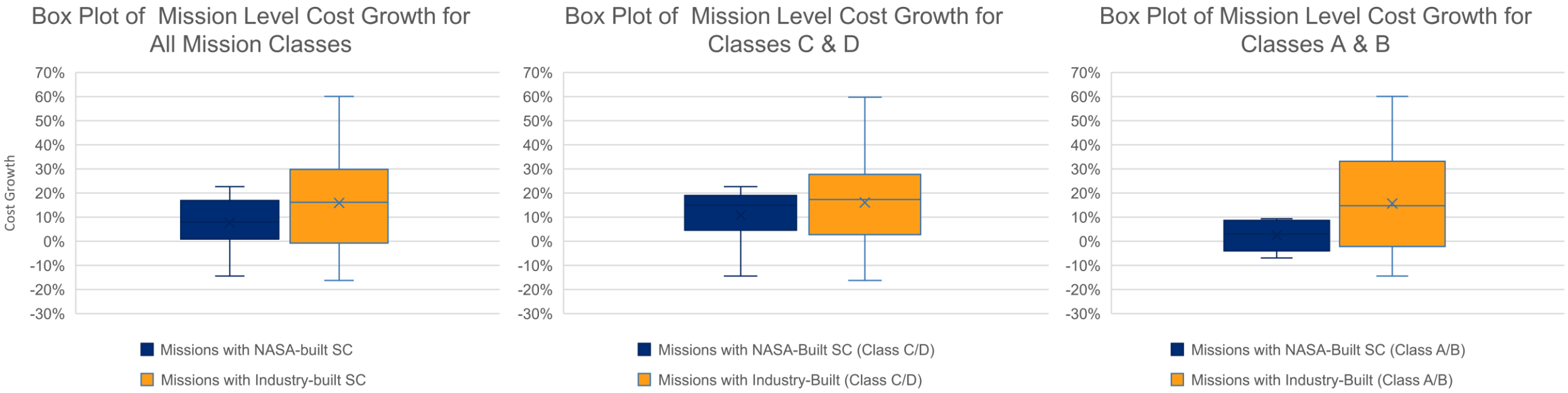


	Class Agnostic	Class A/B	Class C/D
P-Value	0.05	0.03	0.23
Significant?	Yes ✓	Yes ✓	No ✗

At the mission level, missions with industry-built spacecraft show higher average cost growth than missions with NASA-built spacecraft overall and for Class A/B, but not for Class C/D.

Cost Growth Analysis – Mission Level

Box Plots



Across all mission classes, missions with industry-built spacecraft exhibit higher and more variable cost growth. The box plots for missions with industry-built spacecraft consistently exhibit wider spreads than missions with NASA-built spacecraft.

Mission Level Summary

Mission Risk Classification	Prior Finding (Kim, Hyde)	Current Finding (Sholder, Kha)	Interpretation of Current Finding
Class Agnostic (A, B, C, D)	Spacecraft developer type **does not** significantly affect total project cost.	Missions with NASA-built spacecraft experience **statistically significantly** less cost growth than missions with industry-built spacecraft.	Hardware procurements (payload and spacecraft) make up the largest percentage of a program's development budget. How efficiently a spacecraft developer can respond to changing requirements posed by the instruments will influence overall mission cost.
Class A/B	Spacecraft developer type **does not** significantly affect total project cost.	Missions with NASA-built spacecraft experience **statistically significantly** less cost growth than missions with industry-built spacecraft.	The depth of experience NASA centers have in their areas of expertise allow for more efficient response to changing requirements, mission redesigns, etc.
Class C/D	Spacecraft developer type **does not** significantly affect total project cost.	Missions with NASA-built spacecraft experience less cost growth than missions with industry-built spacecraft, but **the difference is not significant**.	Class C/D missions that prioritize cost and schedule and can accept higher technical risk may benefit from exploring more industry-built spacecraft options, especially as the industry shifts towards offering more commercial spacecraft options.

Mission Level Key Takeaway

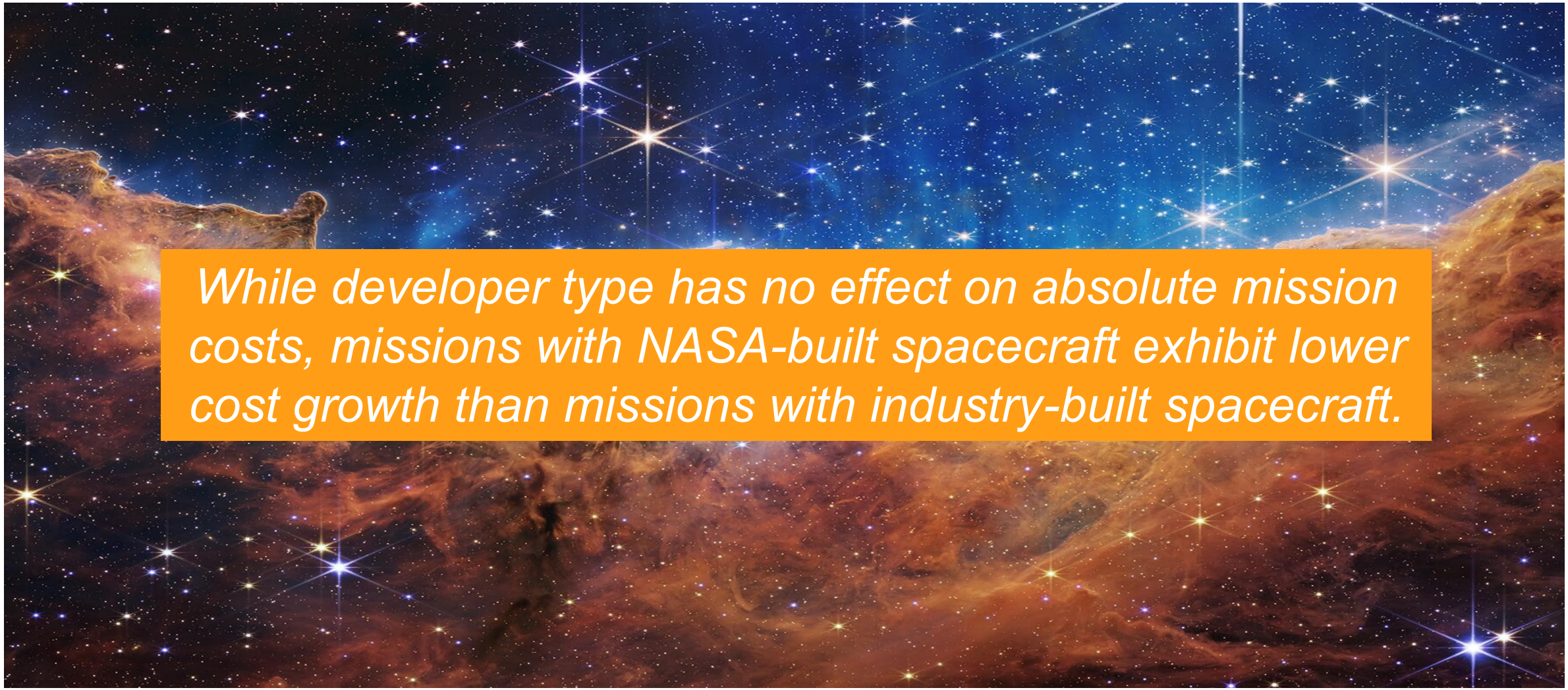
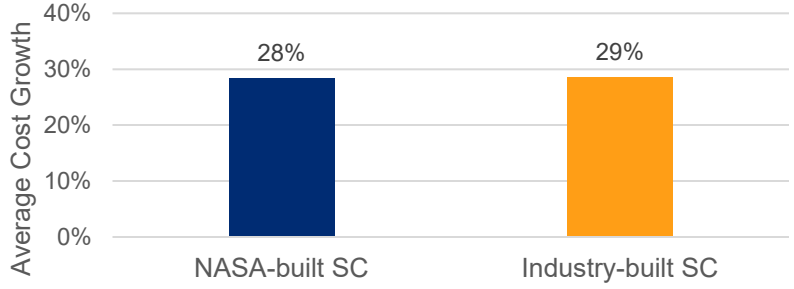


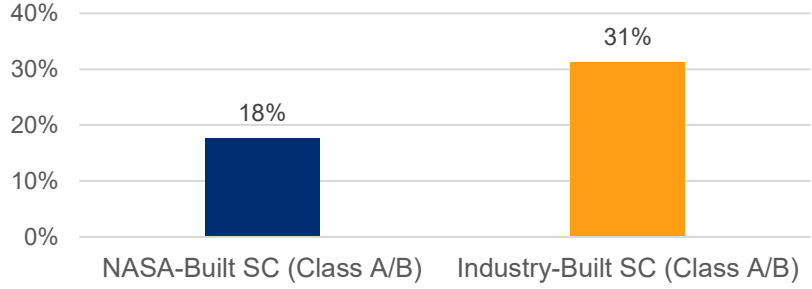
Image credit: JWST

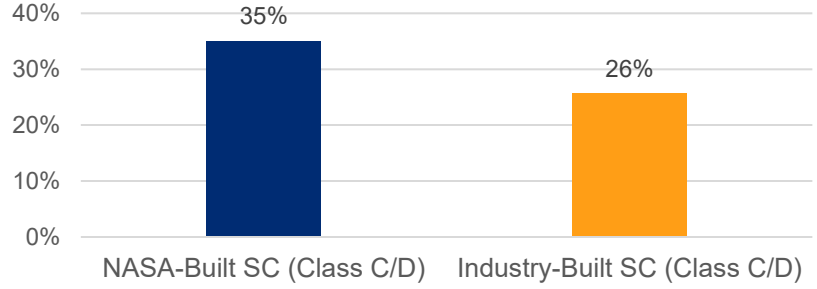
Summarized Findings & Conclusions

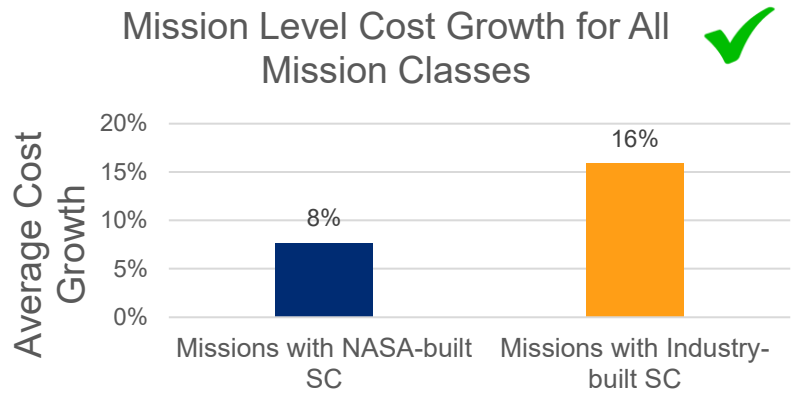
Spacecraft Vs Mission Level Results

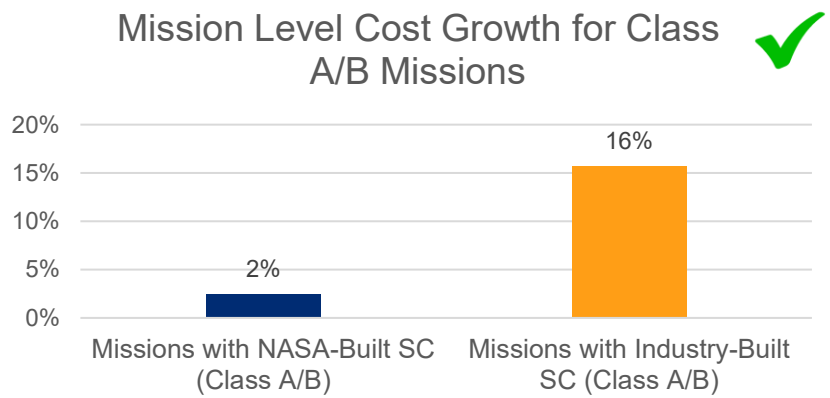
✗ = *not statistically significant diff. of means*
✓ = *statistically significant diff. of means*

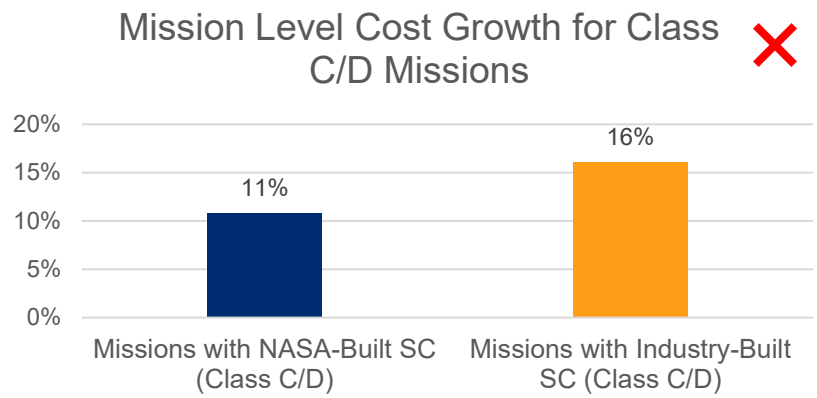












All Missions: Difference between developer type is not significant at the spacecraft level, but is significant at the mission level: missions with industry-built spacecraft have higher cost growth.

Class A/B Missions: Difference between developer type is not significant at the spacecraft level, but is significant at the mission level, with missions with industry-built spacecraft showing higher cost growth.

Class C/D: Difference between developer type is not significant at either the spacecraft or mission level, and the observable direction of the difference flips between the spacecraft and mission level.

Summarized Comparison - Methodology & Findings

Prior Methodology (Kim, Hyde)	Current Methodology (Sholder, Kha)
Removed missions with duplicate spacecraft	Included missions with duplicate spacecraft, normalized using cost to copy factors (Whitley & Hahn, 2013)
Unclear what costs are included in total project costs	Clear normalization (A-D costs, excluded LV, etc.)
Used “NASA”/“in-house” and “industry”/“out-of-house” interchangeably	Clear definition of “NASA-built” and “Industry-built”
Unclear descriptive statistics results	Clear descriptive statistics results
Reported findings in terms of absolute dollars	Reported findings in terms of cost growth

Prior Findings (Kim, Hyde)	Current Findings (Sholder, Kha)
Industry-built spacecraft are associated with lower costs, especially for Class C and D missions	Industry-built spacecraft are not associated with lower cost growth, including for Class C and D missions
For higher-risk class A and B projects, spacecraft developer has no significant effect	For higher-risk class A and B projects, spacecraft developer is not statistically significant at the 5% level, but is significant at the 10% level
Spacecraft developer does not significantly affect total project cost, regardless of the risk classification	Spacecraft developer is statistically significant at the mission level, including for Class A and B missions

Conclusions

***Spacecraft Level Key Takeaway**: Although industry-built spacecraft may have lower absolute costs than NASA-built spacecraft, their cost growth is comparable.*

***Mission Level Key Takeaway:** While developer type has no effect on absolute mission costs, missions with NASA-built spacecraft exhibit lower cost growth than missions with industry-built spacecraft.*

- The prior work reported cost advantages in terms of absolute dollars, but this analysis of cost growth patterns tells a different story
- Taken together, these results suggest that industry's absolute dollar cost advantages do not consistently translate into cost-growth advantages over the development lifecycle
  - This underscores the importance of evaluating both absolute cost and cost growth when comparing NASA and industry development approaches
- More broadly, these results suggest that NASA–industry spacecraft cost differences can appear differently when viewed "in and out of context"
  - Multiple complementary studies are needed to fully characterize these relationships

Path Forward

- With another year of proposed budget cuts to NASA (e.g., the 2026 House budget bill includes a 17% cut to science), it is important that funds are used as efficiently as possible
  - Having clear data to see where the cost growth risks are when formulating missions is the first step in ensuring effective cost control
- Next steps include getting cost performance data on missions utilizing spacecraft procured via the NASA RSDO Catalog to see how they perform
  - These missions mostly fall in the Class C/D category
- Continuing to update the dataset as new missions launch, to include more new industry partners to the analysis
- Closely monitor spacecraft procurement trends as the industry continues to rapidly evolve

Acknowledgements

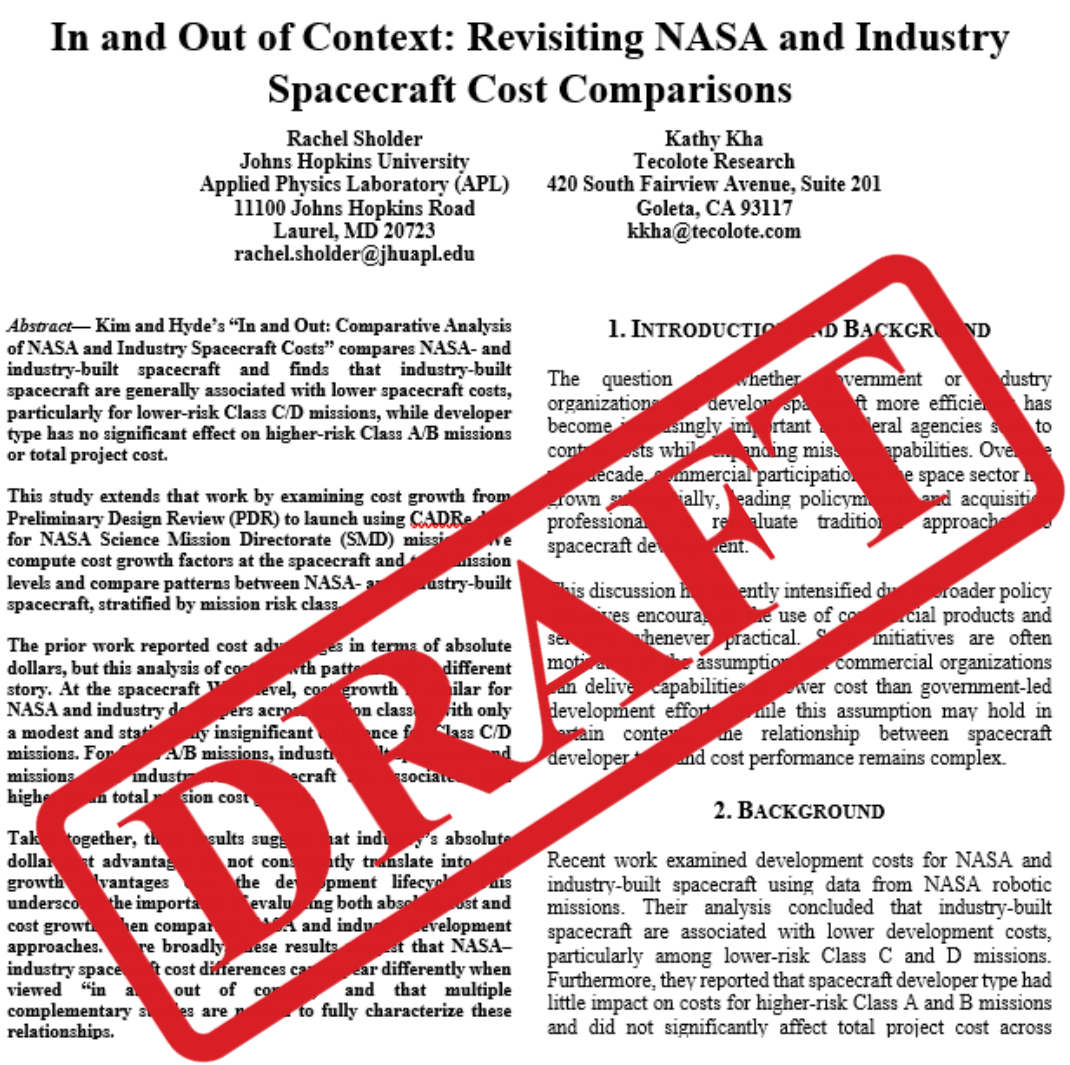
- The data analysis was carried out at JHU/APL. The interpretation and presentation of results were developed at JHU/APL and Tecolote Research
- We thank Dr. Tupper Hyde (APL, formerly NASA GSFC), co-author of the aforementioned previous work, for his invaluable insight



Paper



- Abstract accepted for 2027 IEEE Aerospace Conference
  - Session 13.03 – Cost and Schedule Tools, Methods, and Processes
- Please reach out if you'd like a copy when it is ready for publication



In and Out of Context: Revisiting NASA and Industry Spacecraft Cost Comparisons

Rachel Sholder
Johns Hopkins University
Applied Physics Laboratory (APL)
11100 Johns Hopkins Road
Laurel, MD 20723
rachel.sholder@jhuapl.edu

Kathy Kha
Tecolote Research
420 South Fairview Avenue, Suite 201
Goleta, CA 93117
kkha@tecolote.com

Abstract— Kim and Hyde's "In and Out: Comparative Analysis of NASA and Industry Spacecraft Costs" compares NASA- and industry-built spacecraft and finds that industry-built spacecraft are generally associated with lower spacecraft costs, particularly for lower-risk Class C/D missions, while developer type has no significant effect on higher-risk Class A/B missions or total project cost.

This study extends that work by examining cost growth from Preliminary Design Review (PDR) to launch using CADRe for NASA Science Mission Directorate (SMD) missions. We compute cost growth factors at the spacecraft and mission levels and compare patterns between NASA- and industry-built spacecraft, stratified by mission risk class.

The prior work reported cost advantages in terms of absolute dollars, but this analysis of cost growth patterns tells a different story. At the spacecraft level, cost growth is similar for NASA and industry developers across mission classes, with only a modest and statistically insignificant difference for Class C/D missions. For A/B missions, industry and missions industry spacecraft associated higher total mission cost.

Taken together, the results suggest that industry's absolute dollar cost advantages do not consistently translate into growth advantages. The development lifecycle thus underscores the importance of evaluating both absolute cost and cost growth when comparing NASA and industry development approaches. More broadly, these results suggest that NASA–industry spacecraft cost differences can appear differently when viewed "in and out of context" and that multiple complementary studies are needed to fully characterize these relationships.

1. Introduction and Background

The question of whether government or industry organizations develop spacecraft more efficiently has become increasingly important as federal agencies seek to contain costs while expanding mission capabilities. Over the last decade, commercial participation in the space sector has grown substantially, leading policymakers and acquisition professionals to re-evaluate traditional approaches to spacecraft development.

This discussion has recently intensified due to broader policy initiatives encouraging the use of commercial products and services whenever practical. Such initiatives are often motivated by the assumption that commercial organizations can deliver capabilities at lower cost than government-led development efforts. While this assumption may hold in certain contexts, the relationship between spacecraft development type and cost performance remains complex.

2. Background

Recent work examined development costs for NASA and industry-built spacecraft using data from NASA robotic missions. Their analysis concluded that industry-built spacecraft are associated with lower development costs, particularly among lower-risk Class C and D missions. Furthermore, they reported that spacecraft developer type had little impact on costs for higher-risk Class A and B missions and did not significantly affect total project cost across

DRAFT



JOHNS HOPKINS

APPLIED PHYSICS LABORATORY



TECOLOTE

RESEARCH

Backup

Policy Spotlight

- In an effort to “do more with less”, Trump signed Executive Order 14271 in April 2025
- EO 14271 legally mandates a “commercial-first” approach to procurement
  - Mandated to use commercial-off-the-shelf (COTS) and modified commercial products to the maximum extent possible
  - Deviation requires justification and formal approval process
- But does the data show that NASA space science missions are reaping the benefits of this policy?



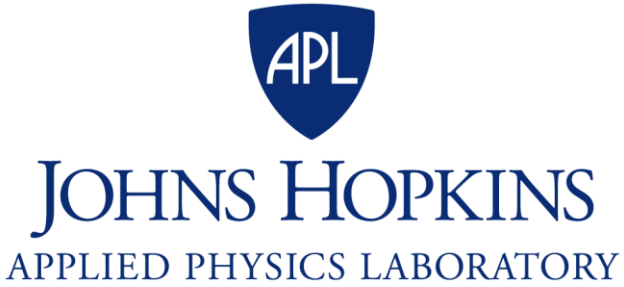
Does this EO follow what the data says?

NASA-built versus Industry-built

NASA: The spacecraft is designed, integrated, and built by a NASA center, FFRDC, and/or UARC.







Commercial: The spacecraft is built by a commercial company.







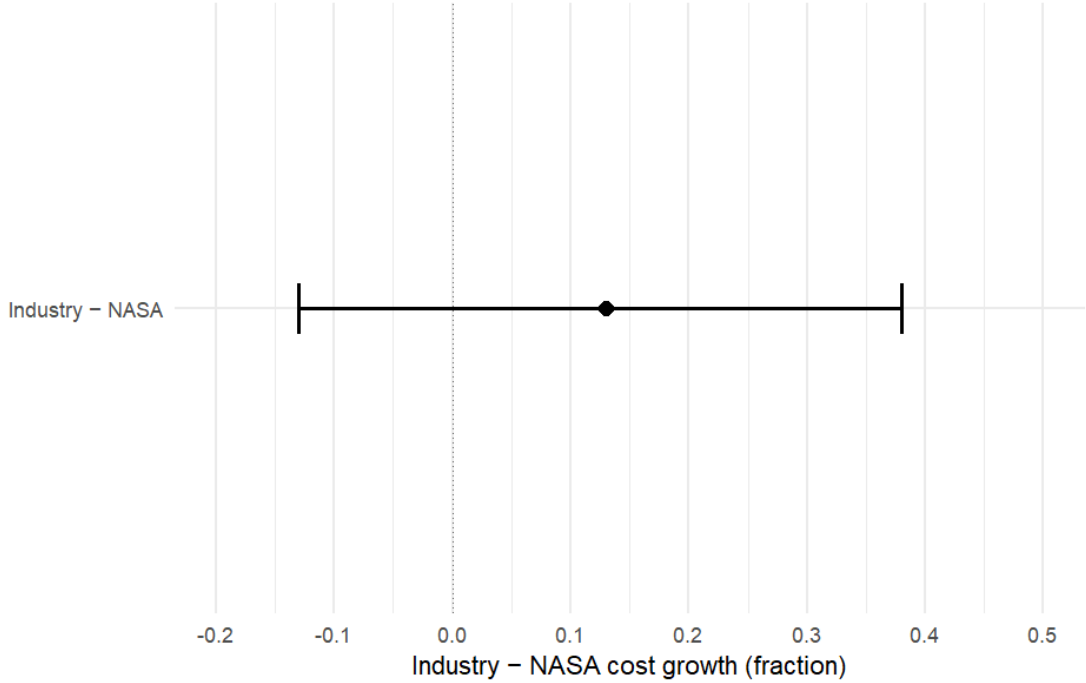


Cost Growth Analysis – Spacecraft Level (Class A/B)

Bayesian Analysis

- Point estimates favor higher industry cost growth, but with wide credible intervals
  - Posterior mean difference (Industry − NASA) ≈ +0.13 (≈ 13 percentage points)
  - 95% credible interval: [−0.13, +0.38] → includes 0
  - Posterior probability that Industry > NASA ≈ 85%
- Interpretation: Bayesian posterior indicates ~85% probability that Industry-built spacecraft exhibit higher cost growth

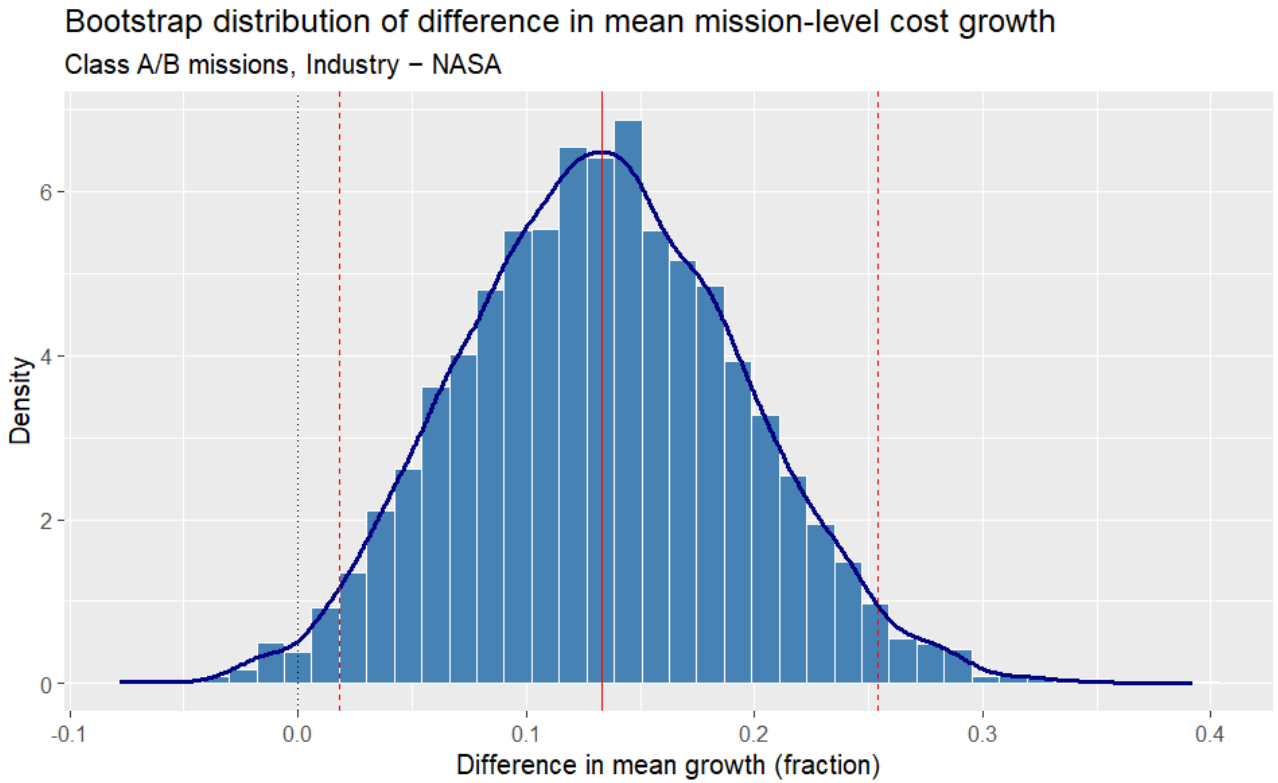
Parameter	Estimate	95% CI
Intercept	0.18	[-0.04, 0.40]
developer	0.13	[-0.13, 0.38]



Cost Growth Analysis – Mission Level (Class A/B)

Non-Parametric Bootstrap

- A non-parametric bootstrap of the difference in mean Class A/B mission-level cost growth (industry − NASA) yielded an average difference of 13.3 percentage points, with a 95% bootstrap interval of 1.8 to 25.4 percentage points
- This supports the conclusion that missions with industry-built spacecraft tend to experience higher mission-level cost growth than those with NASA-built spacecraft, while still indicating considerable uncertainty in the magnitude of the difference



Cost Growth Analysis – Mission Level (Class A/B)

Non-Parametric Bootstrap (Continued)

- Using non-parametric bootstrapping, the 95% intervals for the mean Class A/B mission-level cost growth are about 5–27% for missions with industry-built spacecraft and −2–7% for missions with NASA-built spacecraft
- This supports higher typical cost growth for industry missions, while highlighting considerable uncertainty, particularly on the industry side

