Jet Propulsion Laboratory
California Institute of Technology

NASA Space Flight Instruments: Cost Time Trends

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Is There a Downward Cost Trend?

Yes?

Potential Downward Drivers:

- Increased supply
- More frequent use of COTS hardware
- Technology advances
- Better simulation/design tools
- Changes in how mass design constraints impact instrument development.

No?

Potential Stabilizers/Uppers:

- “Business as usual” ($/kg)
- Lack of production mode mentality at NASA
- Changing NASA risk posture over the years (Faster-Better-Cheaper)
- Changing NASA priorities and funding (i.e. manned vs unmanned, science vs exploration)

Abstract

- Are NASA's space flight instruments becoming cheaper or more expensive as time marches forward? After analyzing the costs of hundreds of instruments launched over the last 30 years, the short answer to this question is:

no… and yes.

Terms and Normalized Data

- Space Flight Instruments = only instruments that fly in space (i.e. not ground based, air-based, balloon-based) on NASA missions.
- The instrument cost data utilized has been normalized to offset inheritance arguments.

Terms and Normalized Data

- Data binned by 4 Instrument types: Optical, Particles, Fields, and Microwave Instruments.
- Optical further split between Earth Orbiting (geocentric) vs. Planetary (non-geocentric) missions.
- Note: In situ instruments not addressed (sparse data)

Why One Might Suspect a Trend… Or Not.

Maybe ***Yes***

Engineering subject matter experts cited the following reasons for why a downward trend would be reasonable

- Increased supply
- More frequent use of COTS hardware
- Technology shifts/advances
- Better tool simulations
- Changes in how mass design constraints impact instrument development.

Maybe ***No***

Reasons why no downward (or upward) trend would be expected

- "Business as usual" ($/kg)
- Lack of production mode mentality at NASA
- Changing NASA risk posture over the years (Faster-Better-Cheaper)
- Changing NASA priorities and funding (i.e. manned vs unmanned, science vs exploration)

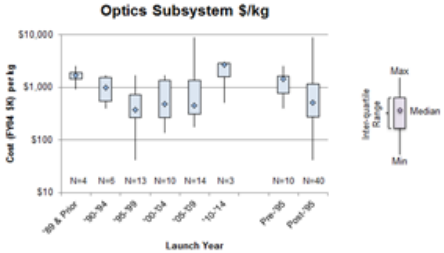
What Does the Data Tell Us?

- Analysis shows a drop in the median dollar-per-kg value across some instrument types.
  - A downward trend elasticity is sometimes (but not always) statistically significant
  - Potential confounding variables (e.g. operating environment, radiation, funding) still require assessment
- Noise exists in data and scatter in models can be substantial.

Time Trend Evaluation Process

Data Exploration & Visual Inspection

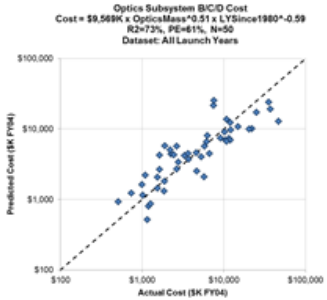
Identify data clusters and group for homogeneity → Calculate $/kg for each instrument → Bin into 5-year intervals



How has cost been moving over time at a top-level?

Time Trend as an Elasticity: A Preliminary Statistical Assessment

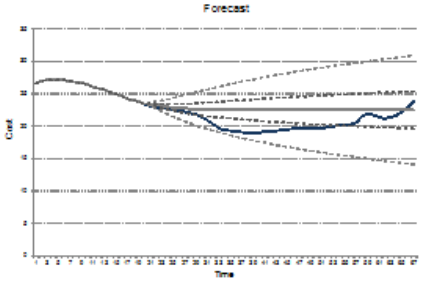
Identify data clusters and group for homogeneity → Identify Significant Variables → Add Time Variable to CER (Launch Year – 1980) → Significance Testing (Null Hypothesis: No Trend) / Signal-to-Noise Ratio



Has there been a significant time-driven impact in the historical data?

Time Series Detailed Statistical Assessment (Future Work)

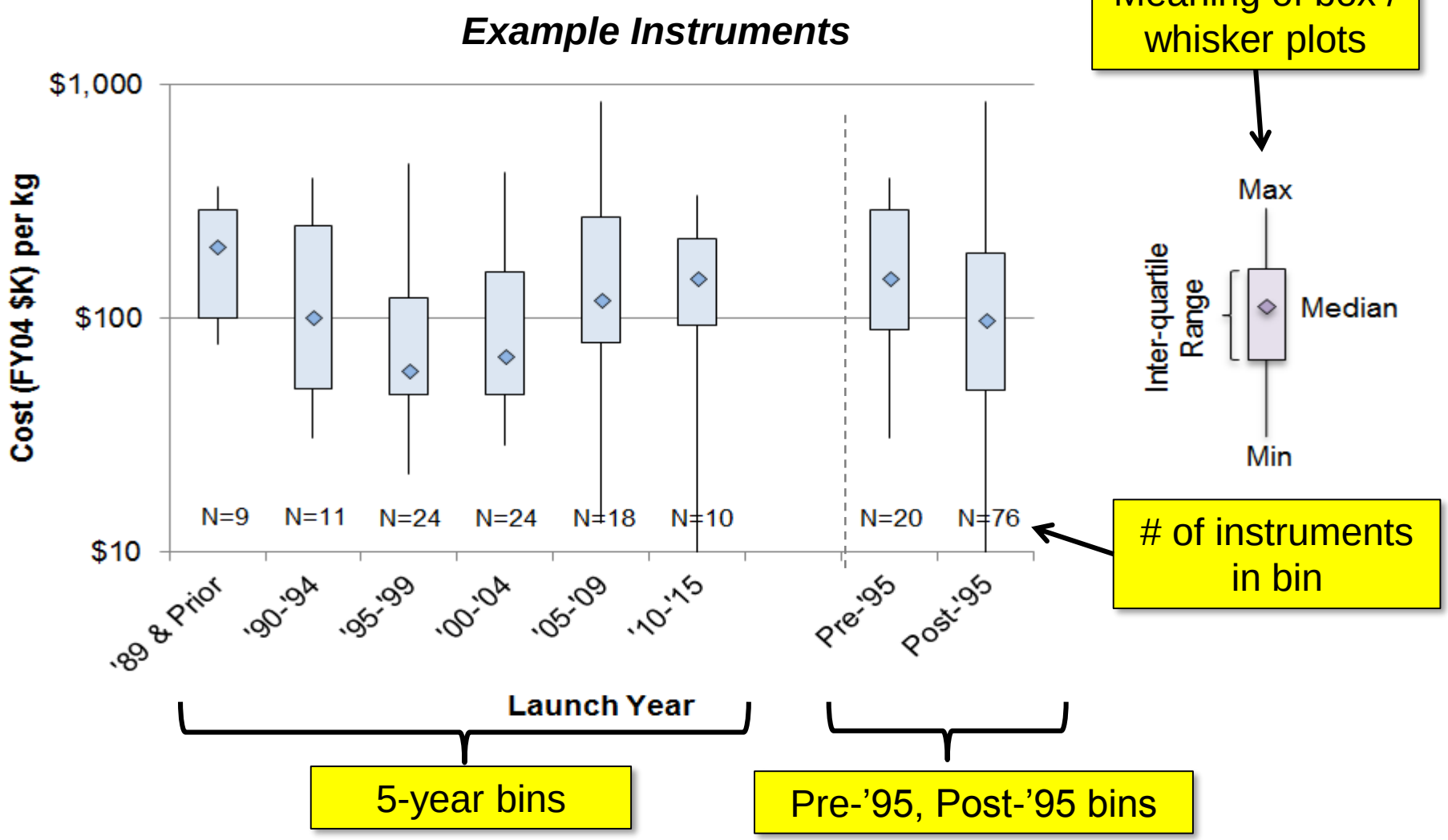
Identify data clusters and group for homogeneity → Autocorrelation & Partial Autocorrelations Analysis → Model Selection, Fitting, Validation and Forecasting



What kind of trend are we experiencing?
What can we say about the future?

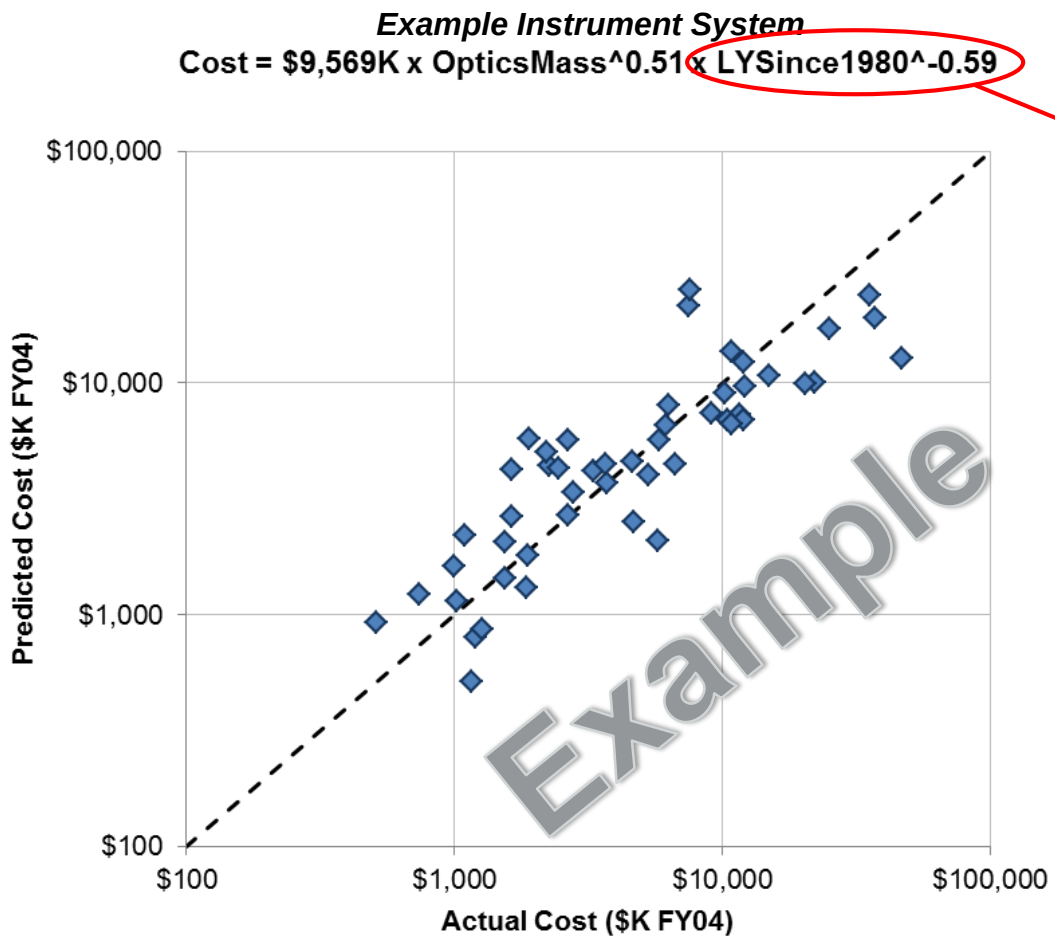
Example of What We Will Be Looking at…

Visual Inspection of $-per-kg



Example of What We Will Be Looking at…

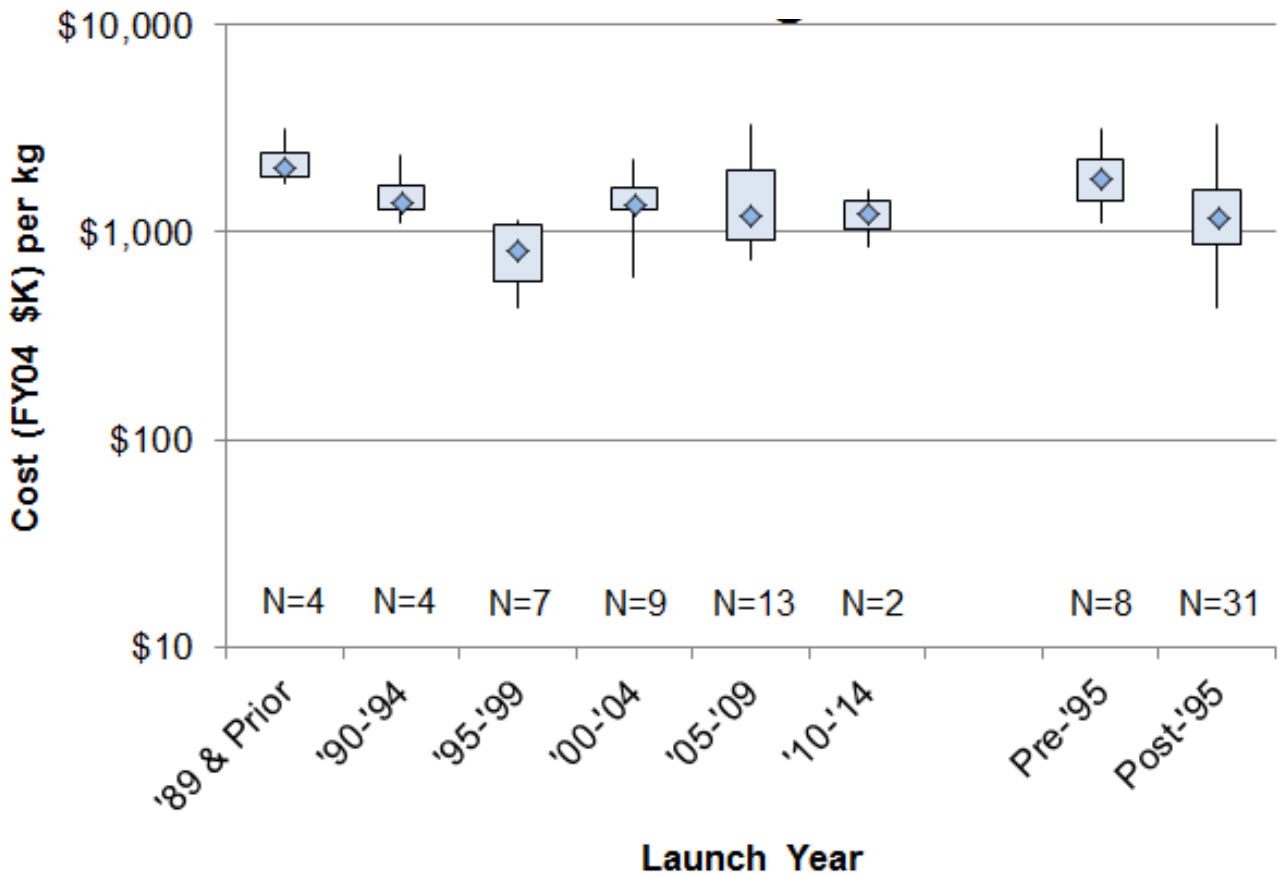
Significance of adding an elastic trend variable

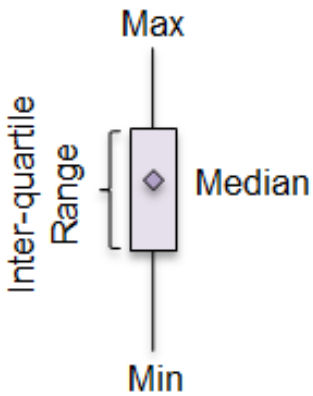


When we add a time trend variable to CERs, do we see statistical significance?

Instrument Type Trend Discussions

Optical (Planetary) Instruments
$/kg Trend Observations

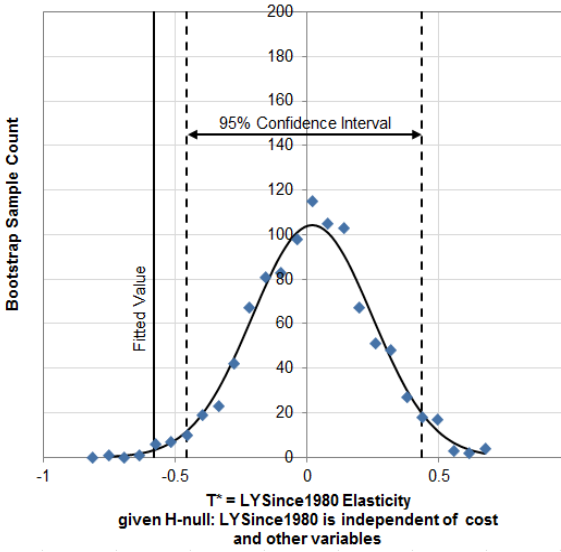




Optical (Planetary) Instruments

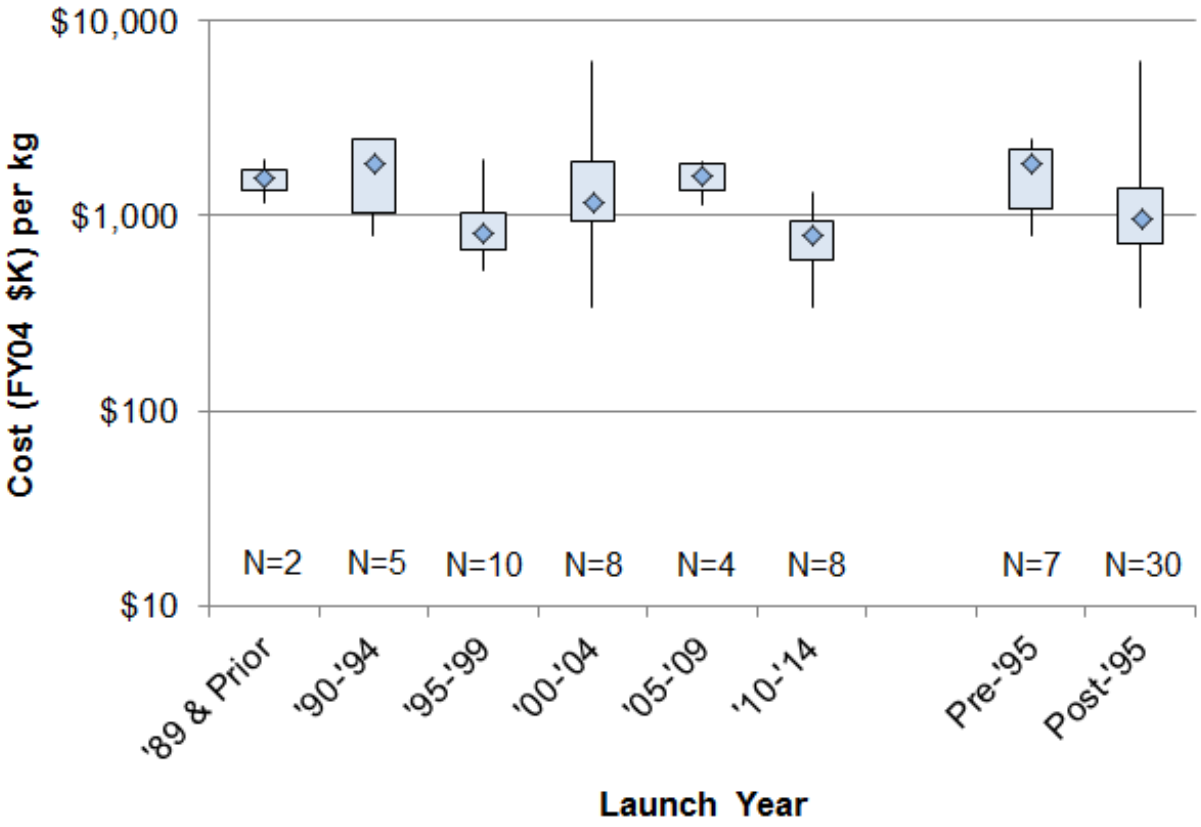
Time Trend Significance Test

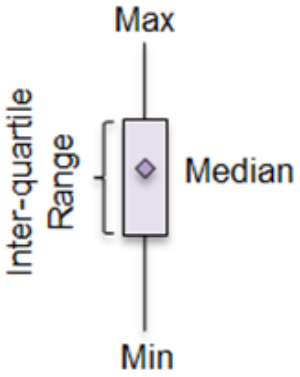
- Apply the model $Y = \beta_0 \left[\prod_{i=1}^{n} X_i^{\beta_i}\right] \epsilon$ to the data
  - Fit in log-log space using principal components analysis
- Variables showing significance
  - X_1 = Total Instrument Mass
  - X_2 = Max Instrument Power
  - X_3 = Launch Year - 1980



Statistical significance warranting further analysis.

Particles Instruments
$/kg Trend Observations

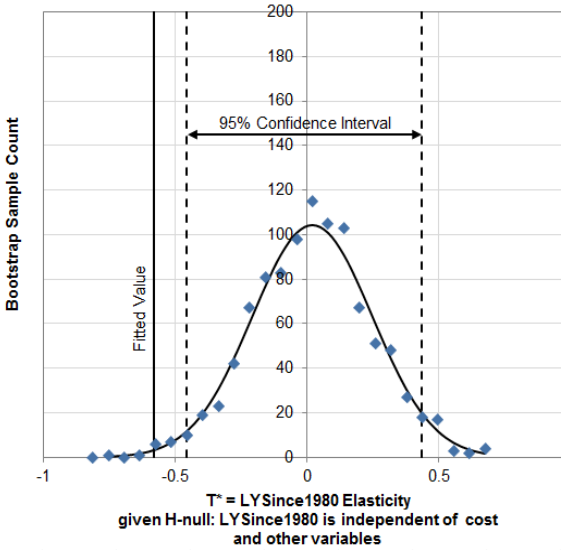




Particles Instruments

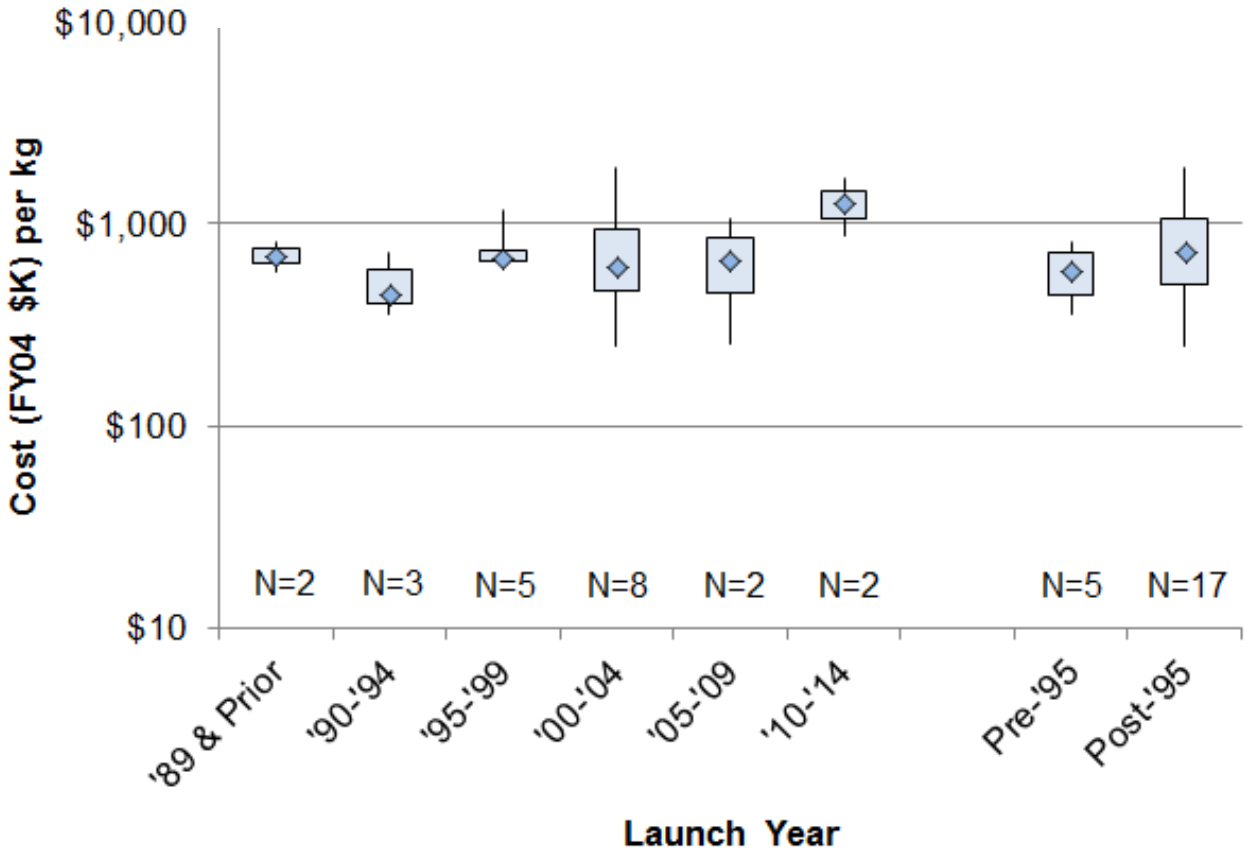
Time Trend Significance Test

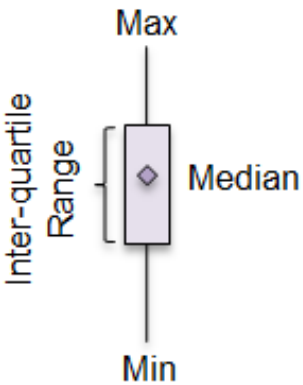
- Apply the model $Y = \beta_0 \left[\prod_{i=1}^{n} X_i^{\beta_i}\right] \epsilon$ to the data
  - Fit in log-log space using principal components analysis
- Variables showing significance
  - X_1 = Total Instrument Mass
  - X_2 = Max Instrument Power
  - X_3 = Design Life
  - X_4 = Launch Year - 1980 →



Statistical significance warranting further analysis.

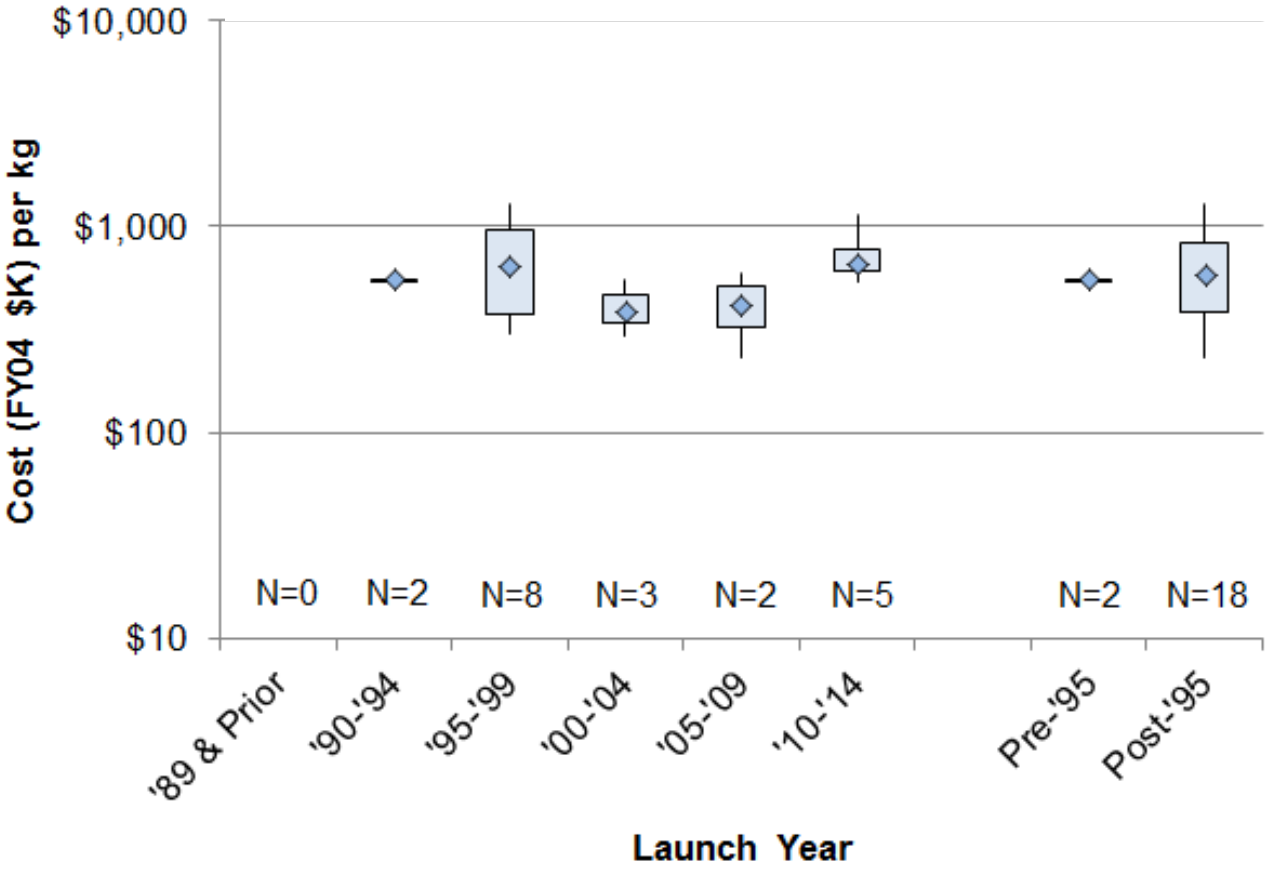
Microwave Instruments
$/kg Trend Observations

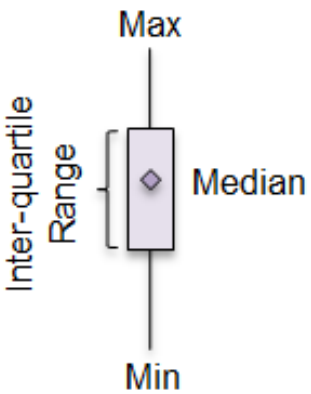




While the last five years have seen a couple instruments with a higher $/kg, an upward trend is not evident.

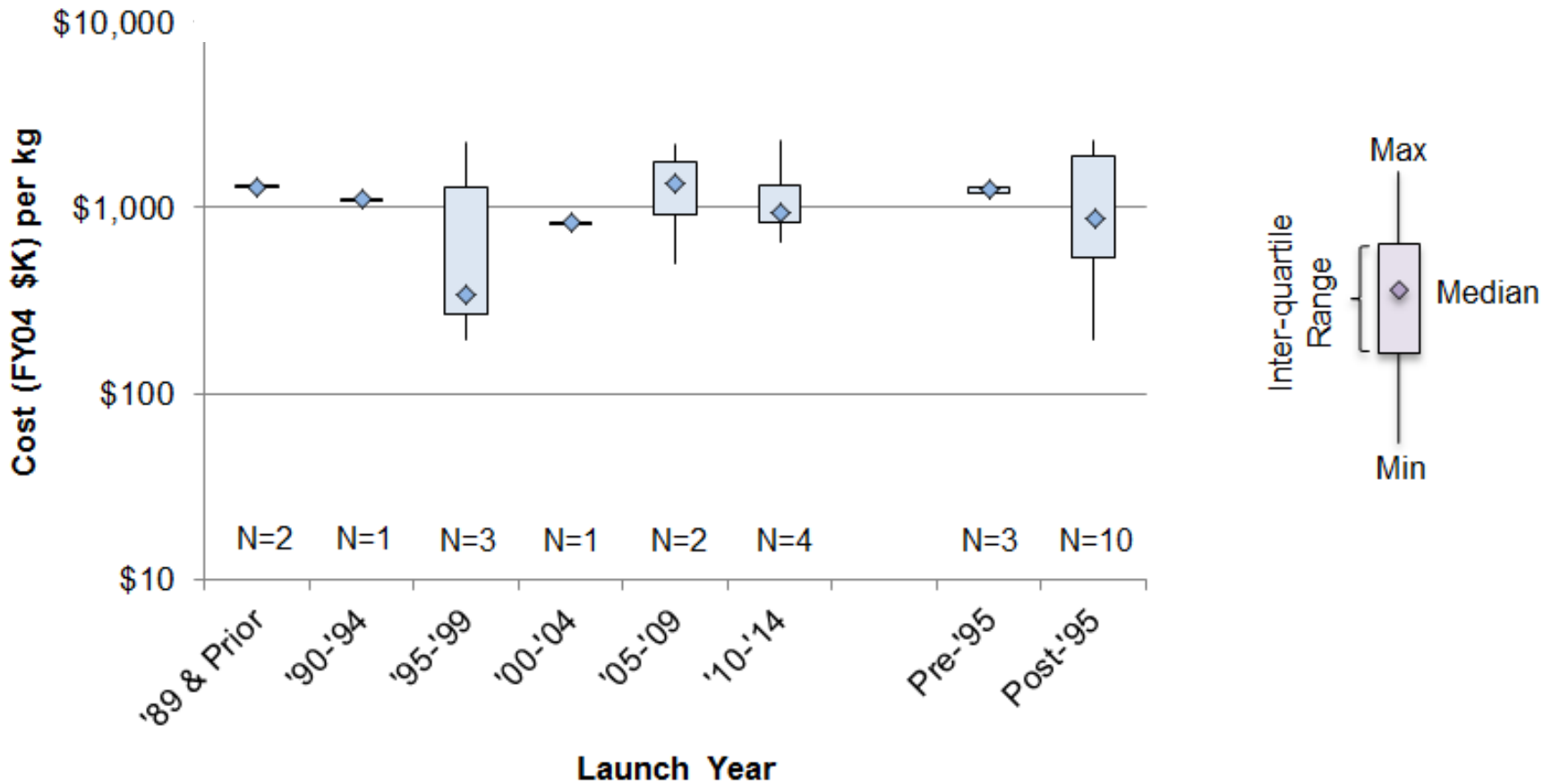
Optical (Earth Orbiting) Instruments
$/kg Trend Observations





No significant evidence for a trend at this point in time.

Fields Instruments
$/kg Trend Observations

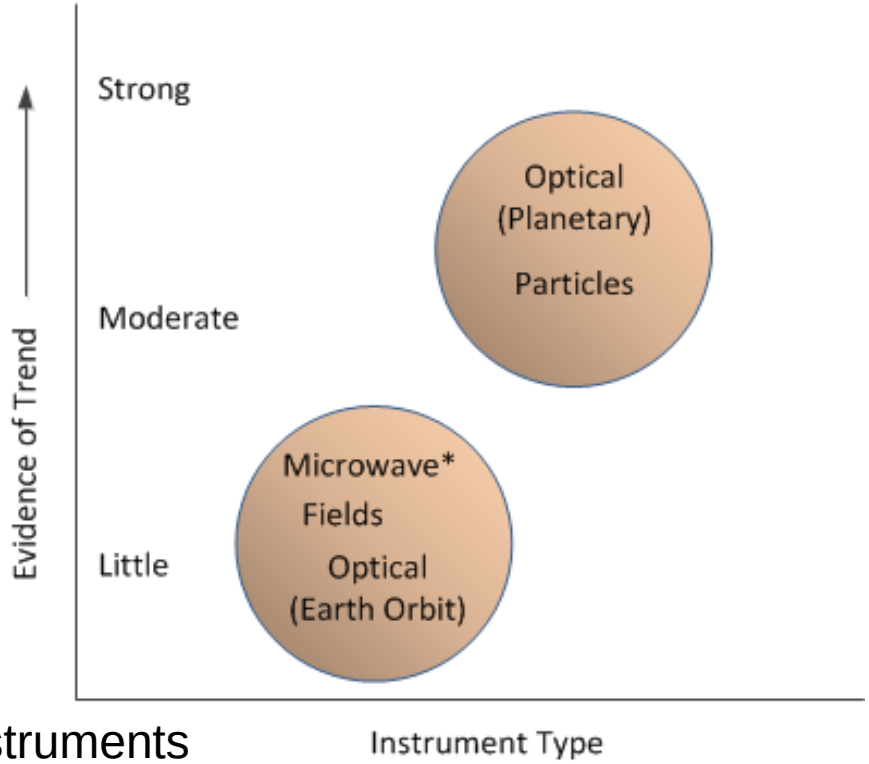


Too little data to assess trends or draw conclusions at this point in time.

Preliminary Conclusions

There is evidence in favor of a drop in the median dollar-per-kg value across some instrument types, but this requires further research to substantiate.

Instrument Type	Evidence
Optical, Planetary	Moderate to Strong
Particles	Moderate to Strong
Microwave*	Little evidence
Fields	Little evidence
Optical, Earth Orbit	Little evidence

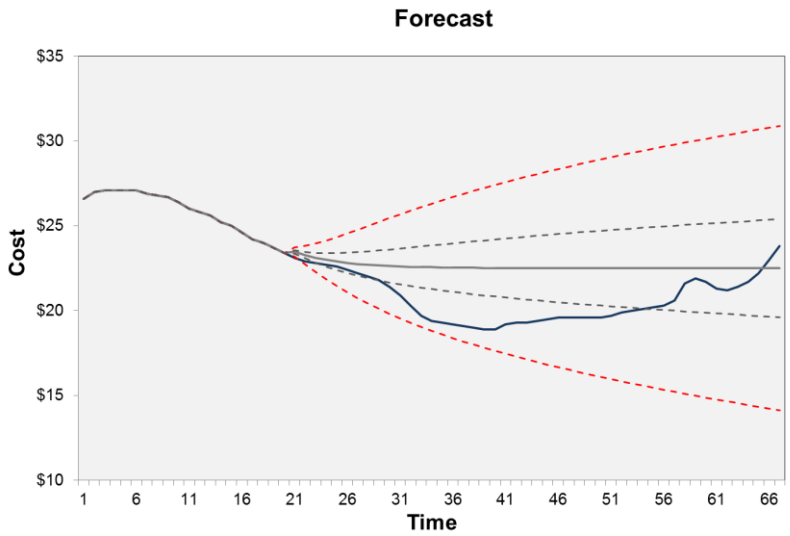


*includes active & passive microwave instruments

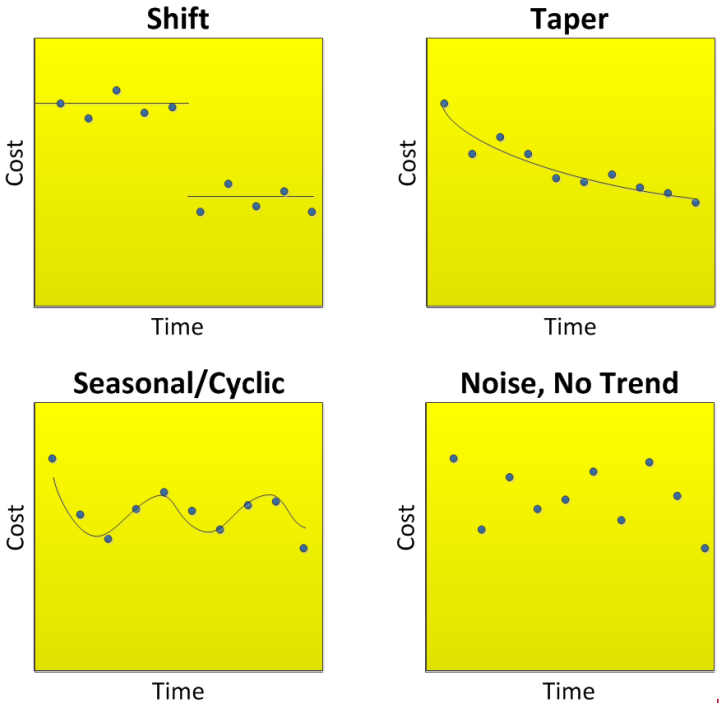
Further Research to Assess Time Trend

Time series analysis is the next step to further explore data and draw conclusions

What can we say about the future?



What kind of trend are we experiencing?



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