NASA Mass Growth Analysis

Spacecraft & Subsystems

2014 NASA Cost Symposium
LaRC, August 14th, 2014

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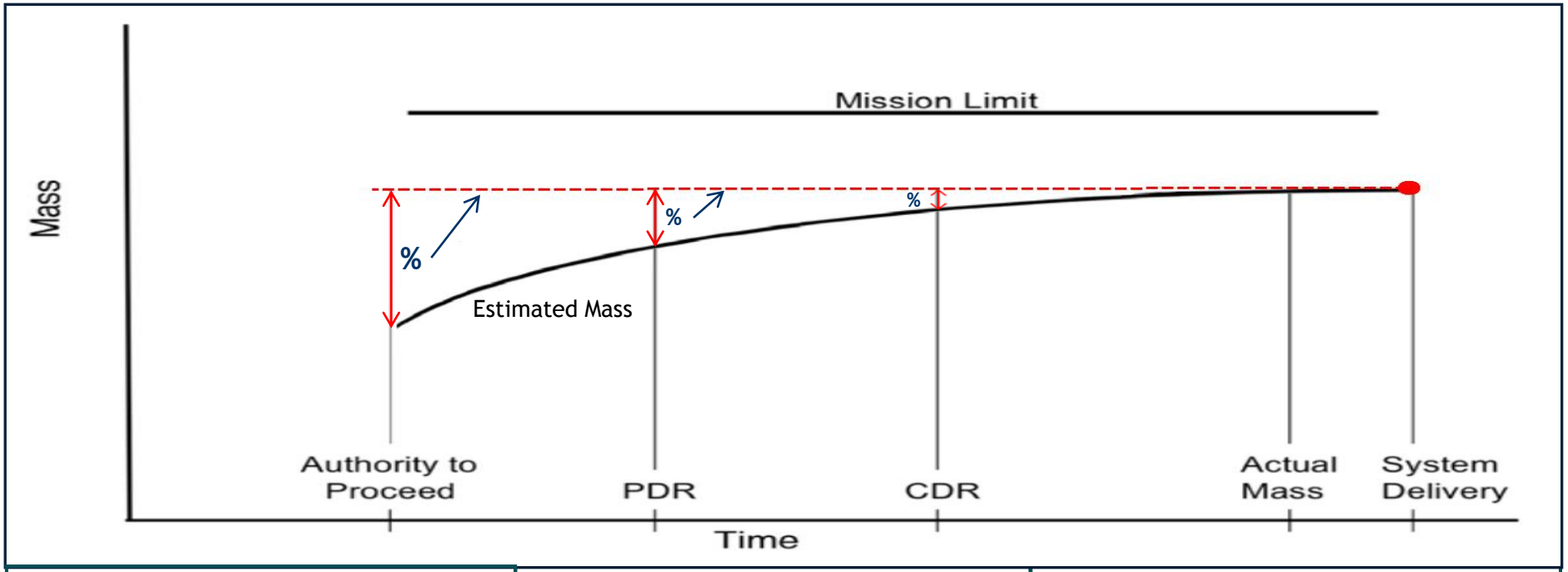
Acknowledgements

The NASA Subsystem Mass Growth Analysis was formulated with contributions and guidance by the following employees:

- Matt Blocker, Darren Elliott & Antonio Rippe: NASA Office of Evaluation's Cost Analysis Division (OE/CAD) - Dashboard Datasheets
- Mike Ross: A Probabilistic Method for Predicting Software Code Growth
- Mohamed Elghefari – Tecolote Instrument Mass Growth Model
- Eric Plummer –NASA HQ CADRe
- James Johnson – NASA HQ Study Point of Contact

Calculating % Growth (from Milestone to Launch)



Objective:

Determine trends of mass decay at high level data when compared at major milestones

Data analyzed:

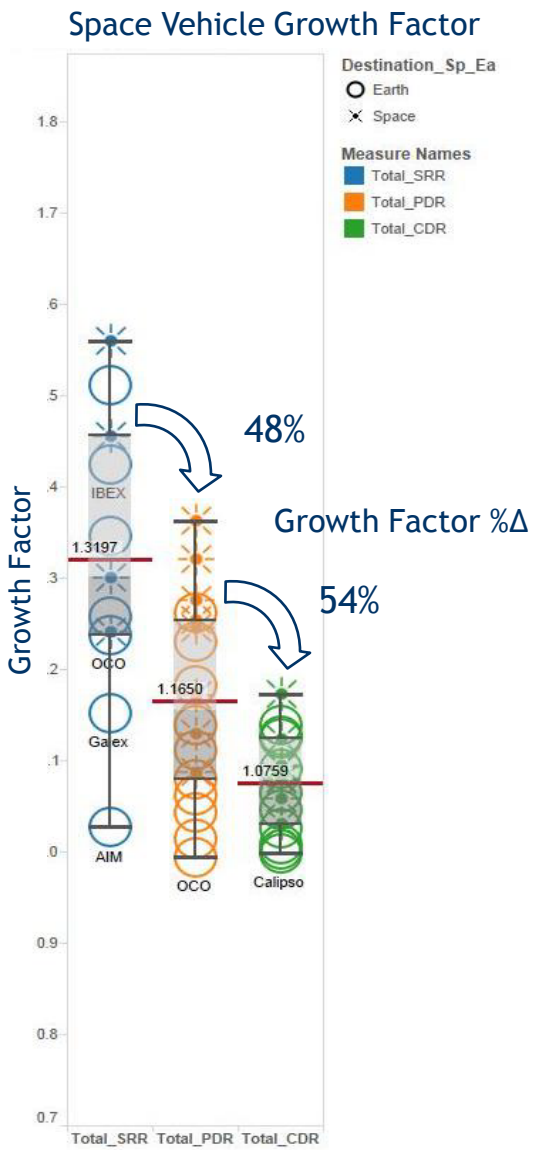
- Space Vehicle
- *Payload*
  - *Instruments*
- *Spacecraft - Bus*
  - *Structure & Mechanisms*
  - *Thermal Control*
  - *Electrical Power System & Wire Harness*
  - *Guidance Navigation & Control/ Attitude Determinate Control System*
  - *Propulsion System*
  - *Communication System*
  - *Control & Data Handling*

Data Collection:

Collected via Cost Analysis Data Requirement (CADRe) at PDR, CDR & Launch milestones

Normalized and mapped concisely

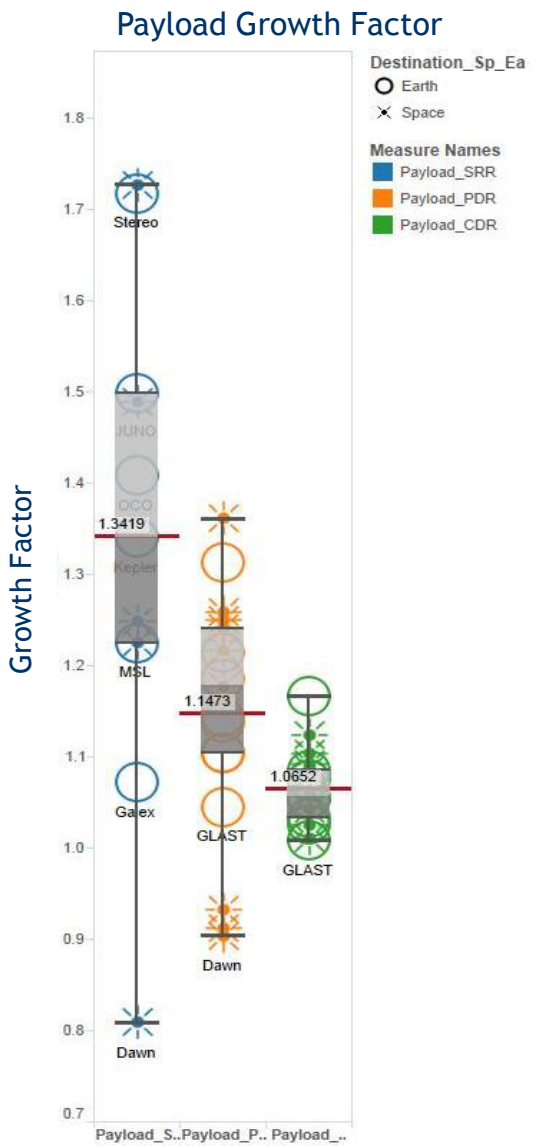
Space Vehicle (Bus & Payload) Mass Growth



	CSR/SRR	PDR	CDR
Space Vehicle Mass Growth Factor	1.3197	1.165	1.0759

- 32% from CSR/SRR to Launch
- Seems to be a mass growth decay as mission progresses

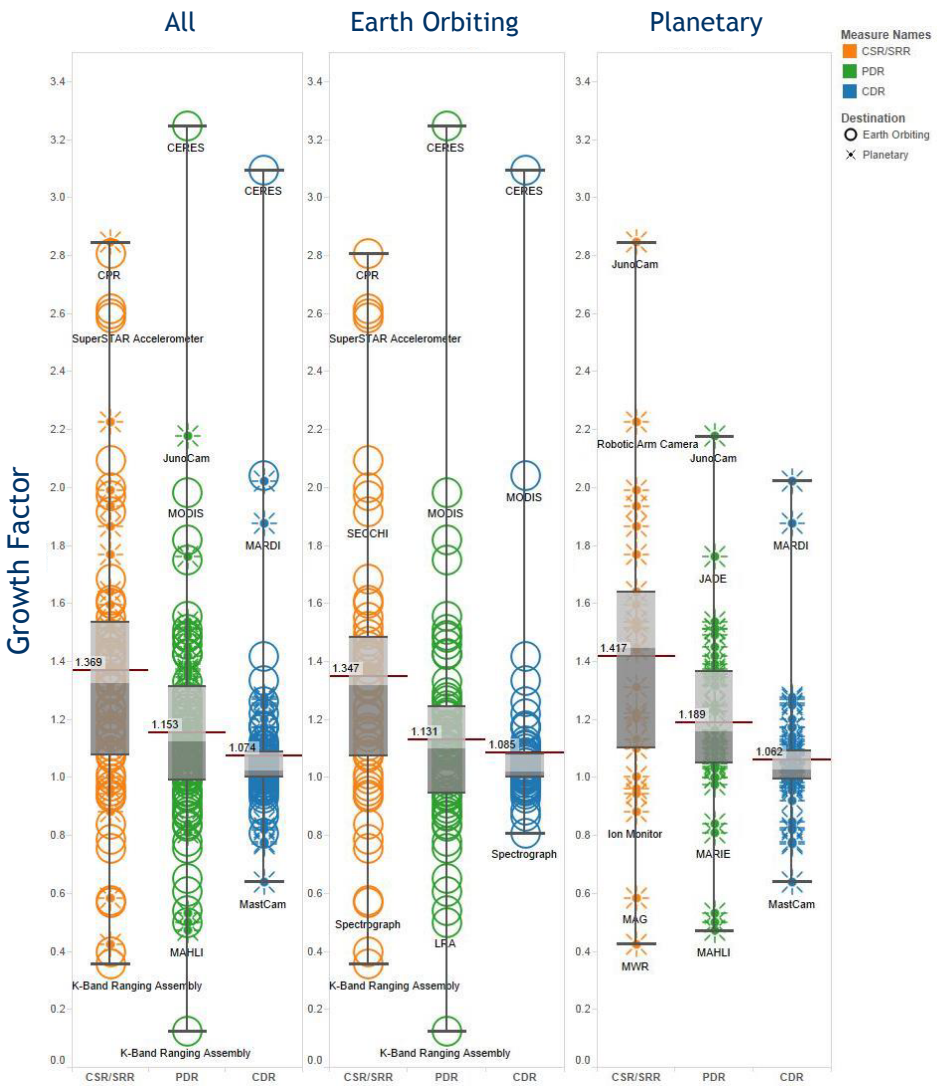
Total Payload Mass Growth



	CSR/SRR	PDR	CDR
Payload Mass Growth Factor	1.3416	1.1473	1.0652

- 34% from CSR/SRR to Launch
- Noise in data as instrument content varies due to instrument reduction & increase

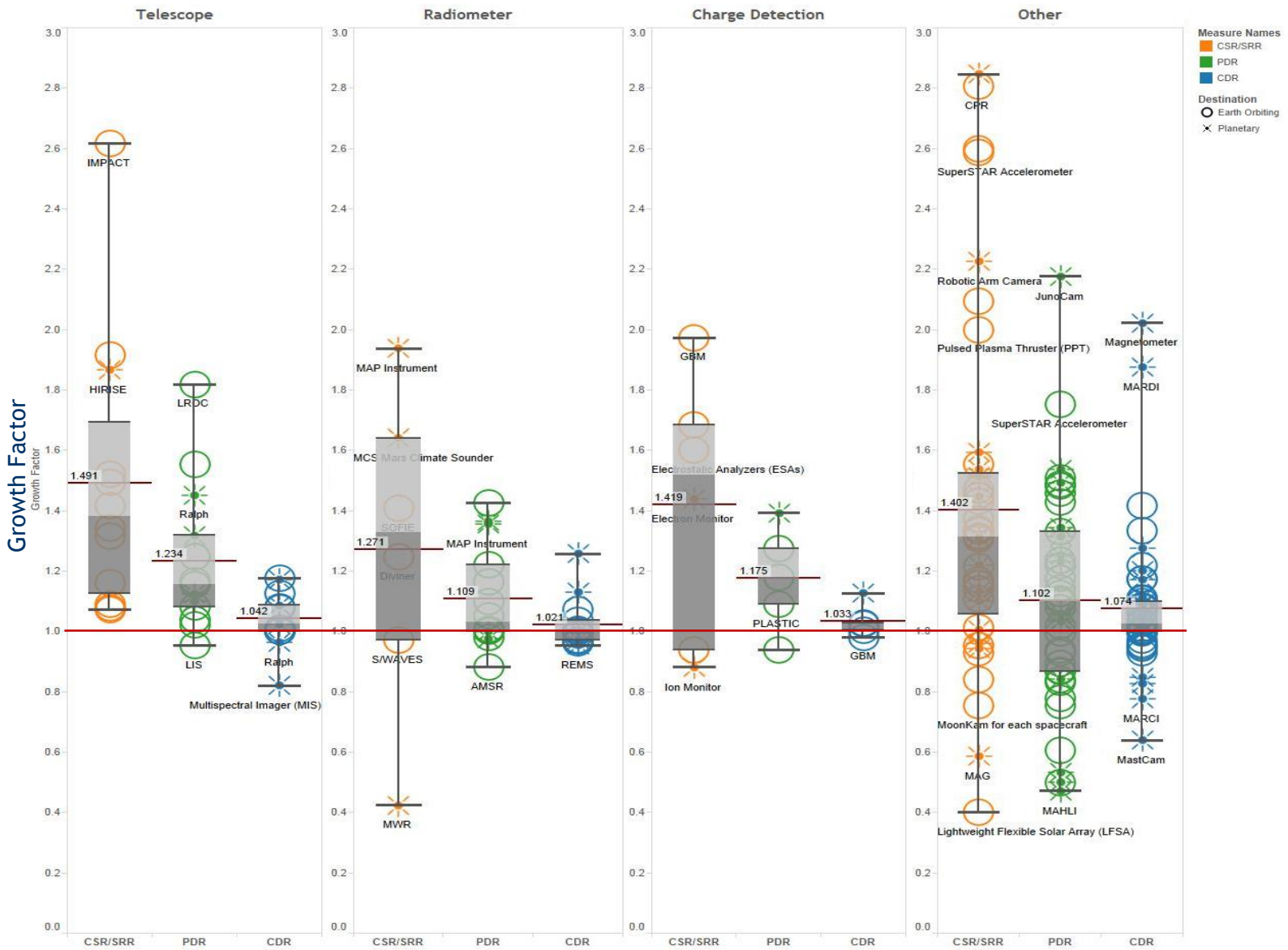
Total Instrument Mass Growth



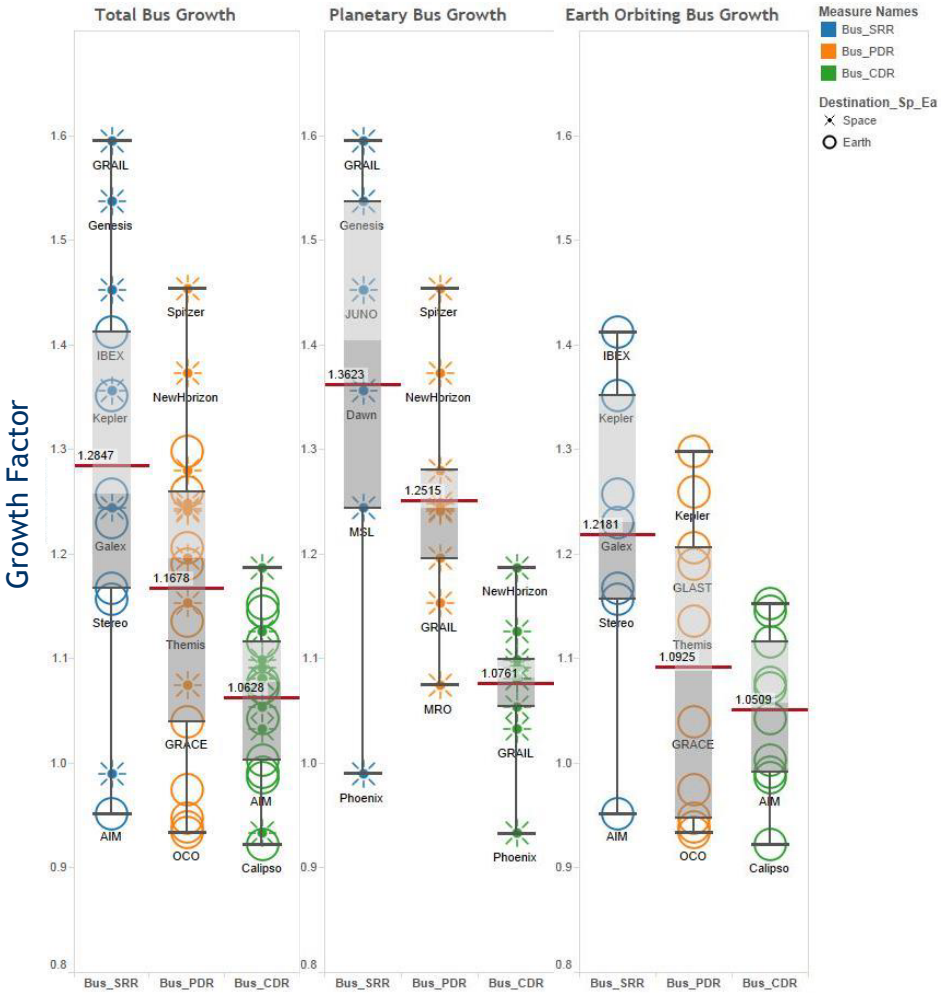
Mass Growth Factor	CSR/SRR	PDR	CDR
Total Instrument	1.369	1.153	1.074
Earth Orbiting	1.347	1.131	1.085
Planetary	1.417	1.189	1.062

- 37% from CSR/SRR to Launch
- Planetary instruments have higher growth than Earth Orbiting instruments

Instrument Mass Growth by Type



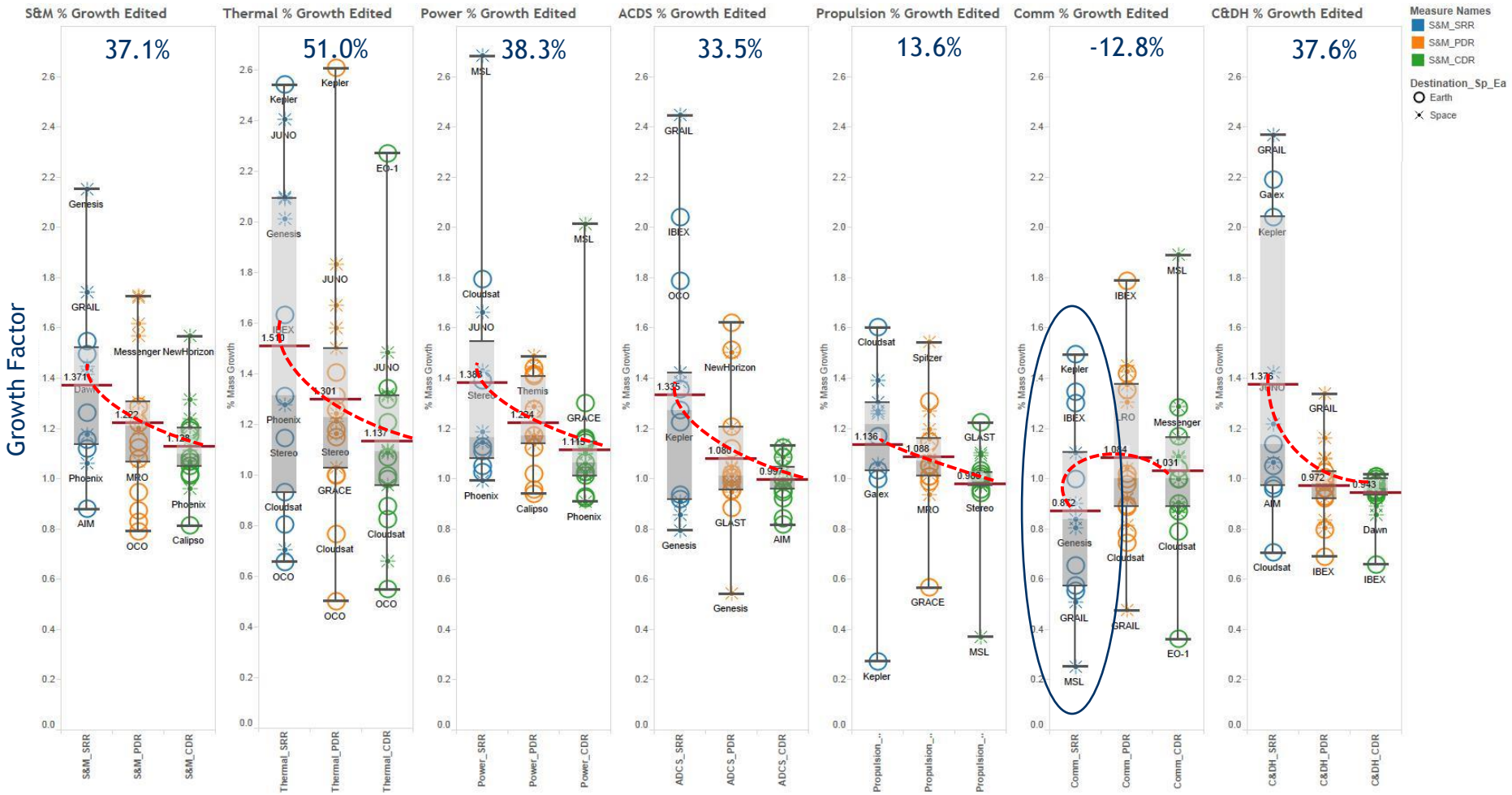
Spacecraft (Bus) – Mass Growth



Mass Growth Factor	CSR/SRR	PDR	CDR
Total Space Vehicle	1.2847	1.1678	1.0628
Planetary	1.3623	1.2515	1.0761
Earth Orbiting	1.2181	1.0925	1.0509

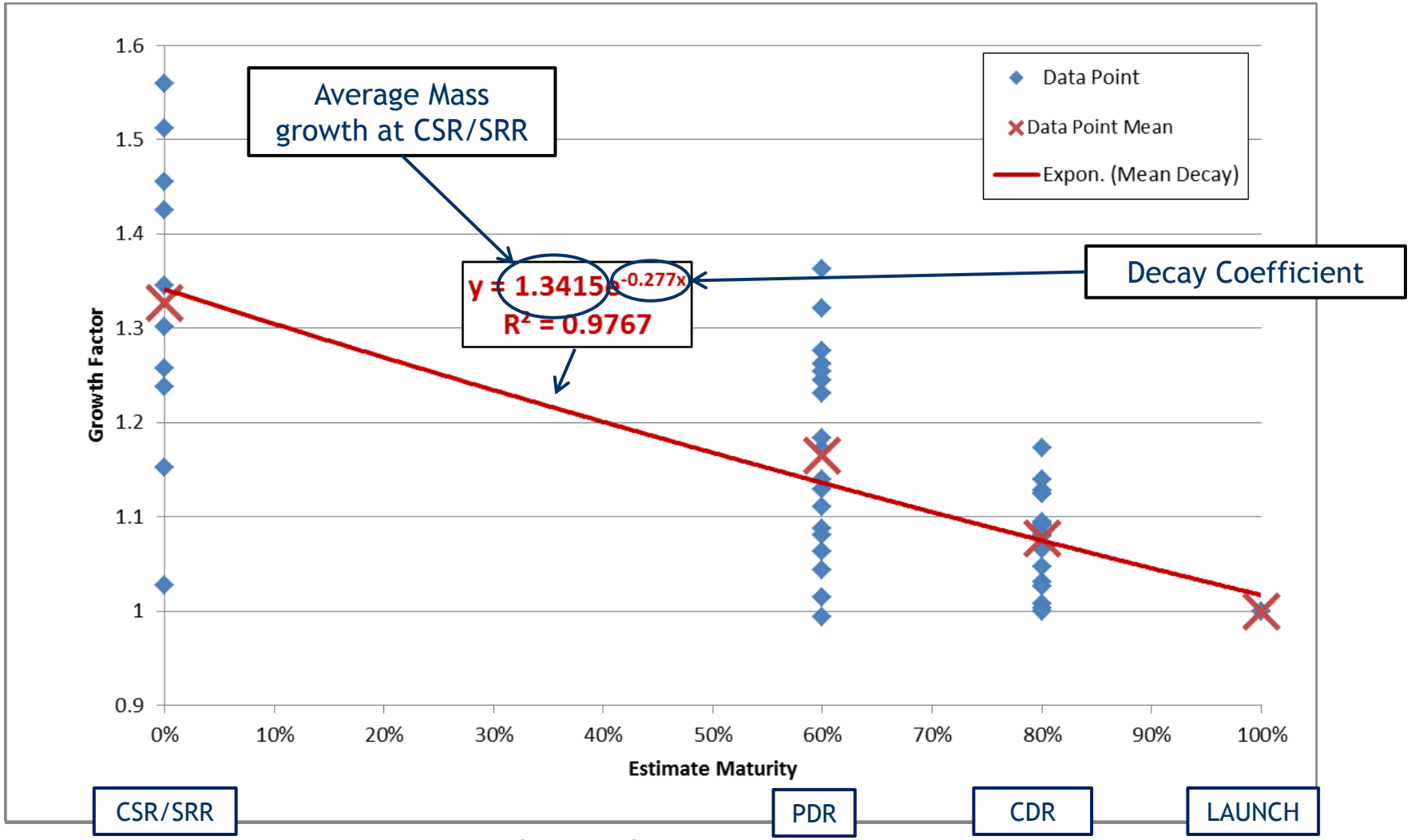
- 28% from CSR/SRR to Launch
- Earth Orbiting missions seem to have lower mass growth

Spacecraft Subsystems Mass Growth



Communication mass growth goes against decay trend of other subsystems

Calculating Mass Growth Using a Decay Model



Based on Milestone Means

Comparison to Current Guidelines

CSR/SRR to Launch

Variable ID	AIAA 1999: Recommended practice for Mass Properties Control for Satellites, Missles, and Launch Vehicles	AIAA 2006: Mass Growth Allowance and Depletion Schedule	NASA 2009 : Rules for the Design, Development, Verification, and Operation of Flight Systems	Tecolote 2014: NASA Mass Growth Analysis
Space Vehicle	1.25		1.25	1.32
Instrument/Payload	1.5	1.55	1.55	1.34
Spacecraft				1.28
Structures & Mechanisms				1.37
Structure	1.18	1.25	1.25	
Mechanisms	1.18	1.25	1.25	
Brackests, Clips, Hardware		1.3	1.3	
Thermal Control	1.18	1.25	1.25	1.51
Power				1.38
Batteries	1.2	1.25	1.25	
Electrical Components	1.15			
Solar Array		1.3	1.3	
Wire Harness	1.5	1.55	1.55	
Attitude Control & Determination System				1.34
Propulsion				1.13
Propulsion	1.18	1.25	1.25	
Solid Rocket Motor		1.1		
Communication				0.87
Control & Data Handling				1.38

1. "Recommended Practice for Mass Properties Control for Satellites, Missiles, and Launch Vehicles", R-020A-1999, AIAA.
2. "Space Systems – Mass Properties Control for Space Systems", S-120-2006e, AIAA.
3. "Goddard Space Flight Center Rules for the Design, Development, Verification, and Operation of Flight Systems", GSFC-STD-1000E*, 2009, GSFC.
   I. Has been superseded by GSFC-STD-1000F: Reverted back to "E" for use of table

Summary

- **Overall, mass growth decreases by milestone**
  - Certain subsystems are more predictable than others (e.g. S&M, Thermal, Power)
  - Some subsystems stabilize faster than others (e.g. Propulsion)
- **Average mass growth is actually higher than guidelines for majority of elements by approximately 10%**
- **Moving forward we have a framework to continue growth study that encompasses all projects**
- **Next steps are to create uniform data sources for consistent mapping**

Thank You

For More Information:

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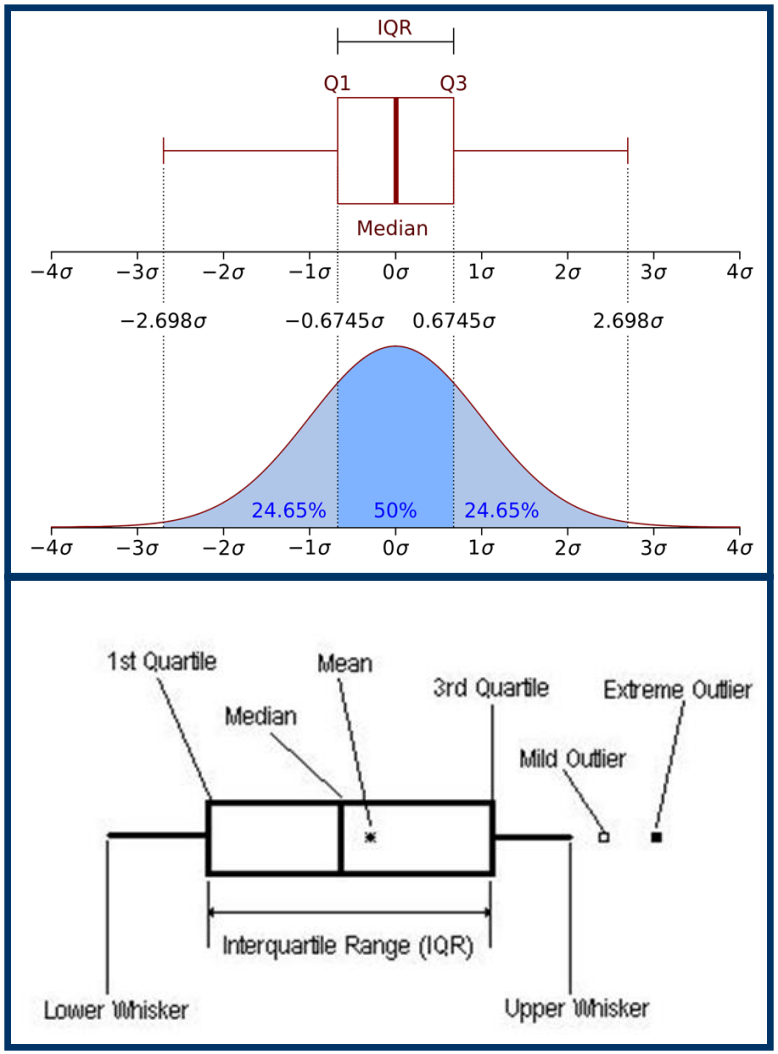
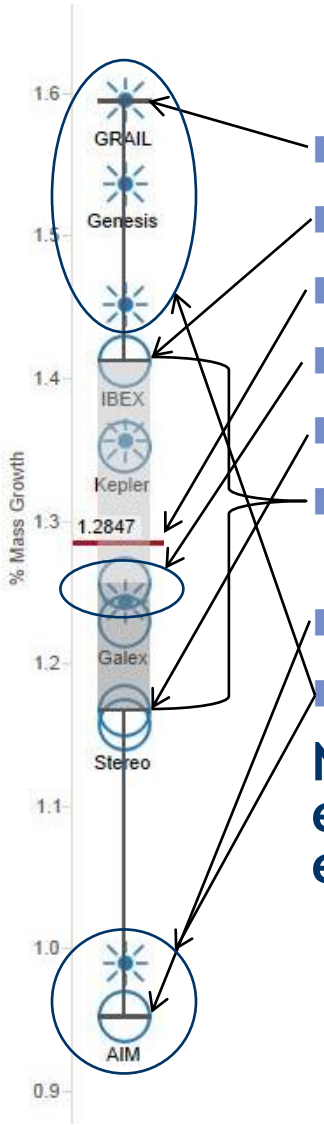
How to interpret Box & Whisker chart



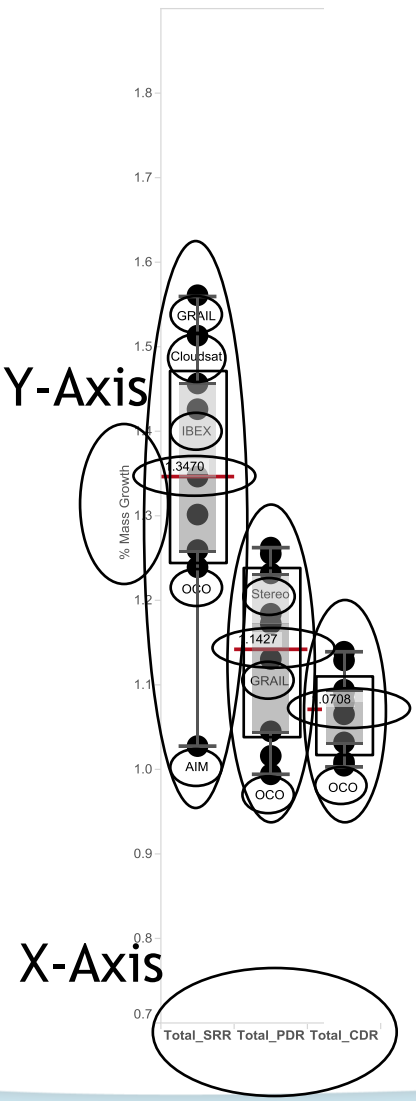


- Upper Whisker
- 3rd Quartile
- Median
- Mean
- 1st Quartile
- Interquartile Range (IQR)
- Lower Whisker
- Outliers

Note: Whiskers extend to Maximum extent of the data

1. Data Drop 2 GSDO JCL Uncertainity 12-10-13

How to Read the Simple Box & Whisker Chart



Axes

- X-Axis : Reviews (SRR, PDR, CDR)
- Y-Axis : Percent Mass Growth

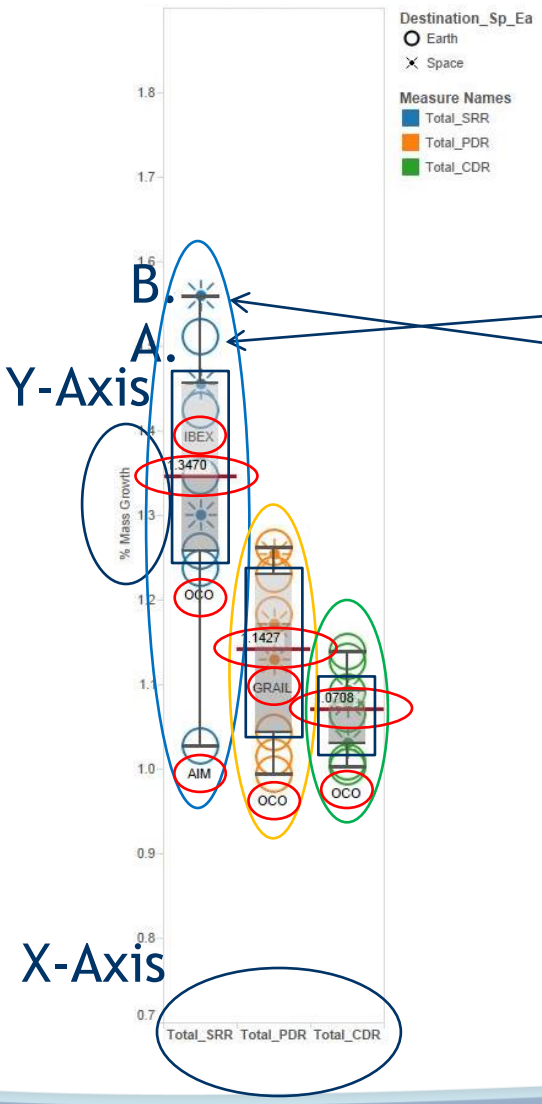
Color

- System Requirement Review (SRR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)

Details

- Red line: Average Percent Mass Growth
- Shaded Area: Interquartile Range (IQR=Q3-Q1)
- Labels : Mission Names

How to Read the Analytical Box & Whisker Chart



Axes

- X-Axis : Reviews (SRR, PDR, CDR)
- Y-Axis : Percent Mass Growth

Icons

A. Circle Icon: Earth Orbiting Mission
B. Sun Icon: Planetary Mission

Color

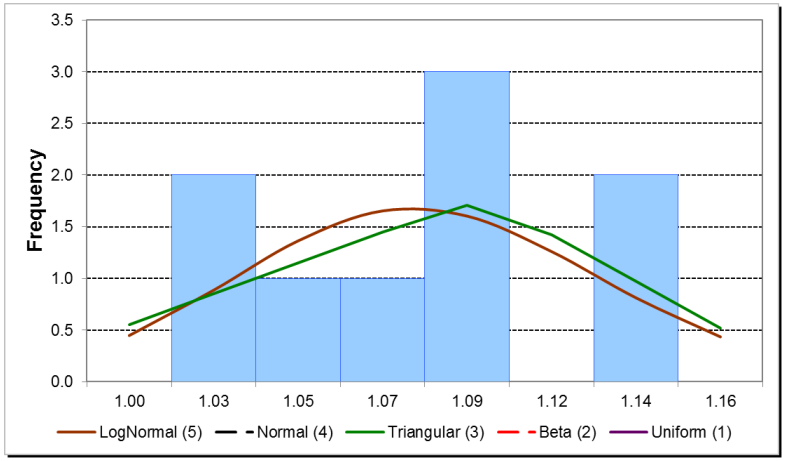
- Blue: System Requirement Review (SRR)
- Orange: Preliminary Design Review (PDR)
- Green: Critical Design Review (CDR)

Details

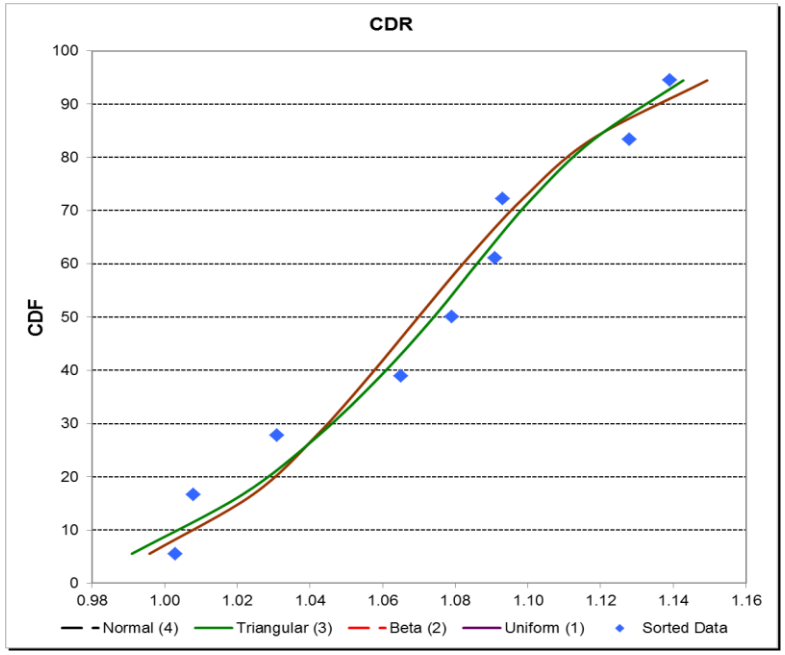
- Red line: Average Percent Mass Growth
- Shaded Area: Interquartile Range (IQR=Q3-Q1)
- Labels : Mission Names

How to Read the Best Fit Distribution Chart

- **Axes**
  - X-Axis : Growth Factor Range
  - Y-Axis : Frequency of data points within each bin
- **Lines**
  - Green – Triangular
  - Brown – Lognormal
- **Data**



X-Axis values identify the bin upper bound



CV	0.04
Low	
Mode	1.06
High	
Data Count	% < 0
	0.01
Rank	
SEE / Fit Mean	1.06
	Good (80