MT23: *Instrument Schedule Delays Potential Impact on Mission Development Cost for Recent NASA Projects (Follow-On Study)*

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Abstract: This study explores instrument schedule delays and their potential impacts on mission development cost for recent NASA projects. Schedule data collected at key milestones for a number of NASA instruments is used to compare planned and actual instrument development times. The study shows average instrument development schedule growth is on the order of 30%. Comparing last instrument delivered development time and mission development cost growth shows a positive correlation, indicating that instrument schedule delays may increase total mission development cost. Instruments are binned by various categories such as instrument type, mass, power, etc. to explore specific trends. The results of this study can be used for planning purposes by project and program managers in charge of future NASA development efforts.

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Instrument Schedule Delays Potential Impact on Mission Development Cost for Recent NASA Projects (Follow-on Study)

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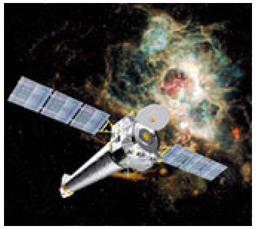
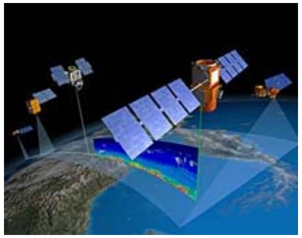
Overview

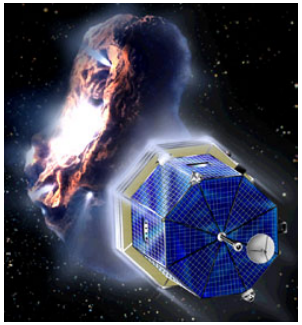
- Background & Motivation
- Study Objective
- Study Approach
- Data Analysis
- Results
- Conclusion

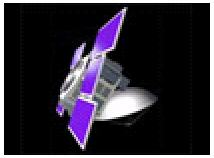
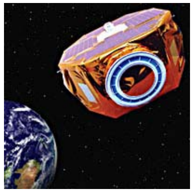
Background

Previous Study

- Initial study presented at 2010 NASA Cost Symposium
  - *“Instrument Schedule Delays Potential Impact on Mission Development Cost for Recent NASA Projects”*
  - *Explore instrument schedule delays and their potential impacts on mission development cost for recent NASA projects*

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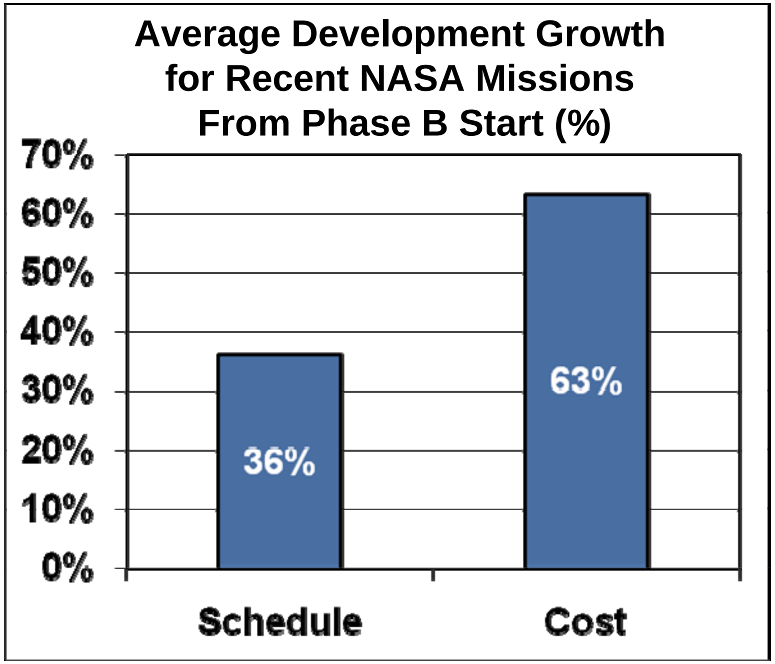
NASA Cost and Schedule Growth Establishes Need for Evaluating Cost & Schedule Drivers



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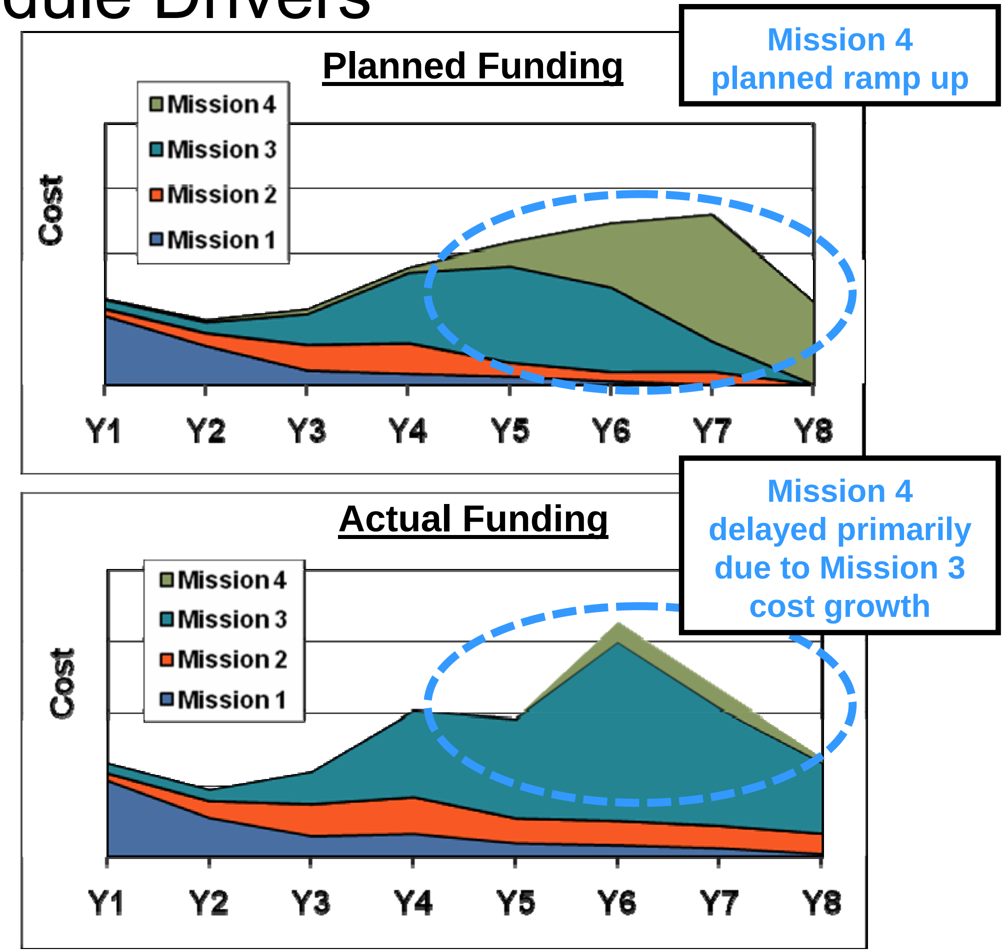

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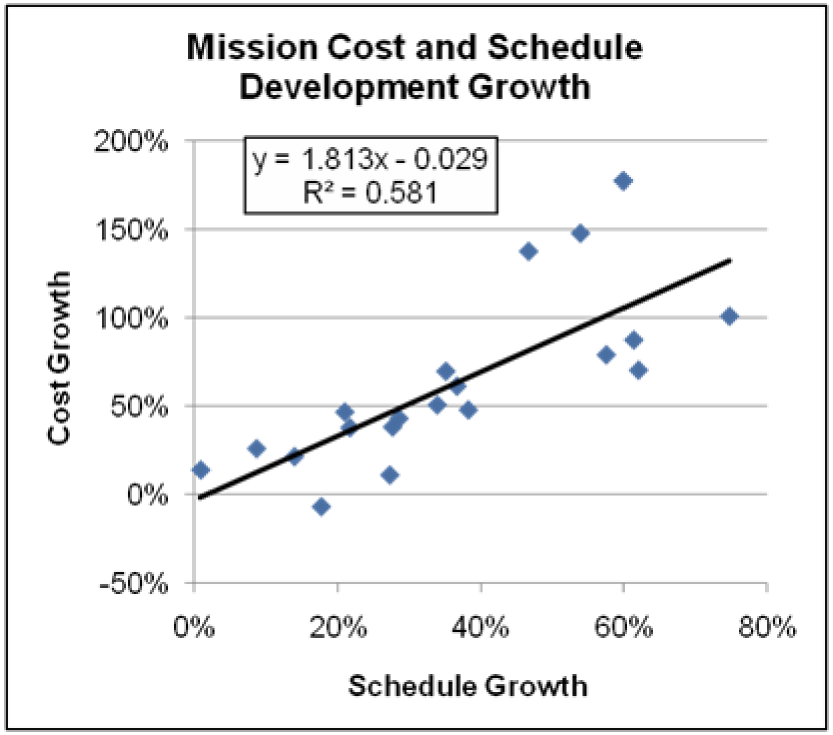
Note:

1. As taken from "SMD Confirmation Metrics Study", Ringler, Rinard, Haas, Bitten, Emmons, 2009 (Average of 20 missions studied, most missions averaged in SMD Confirmation Metrics Study evaluated in this presentation)
2. Historical program data, same y axis scale on each graph

Cost and schedule overruns can affect the implementation of successive missions

Correlation Between Mission Development Cost and Schedule Growth Prompts Further Study



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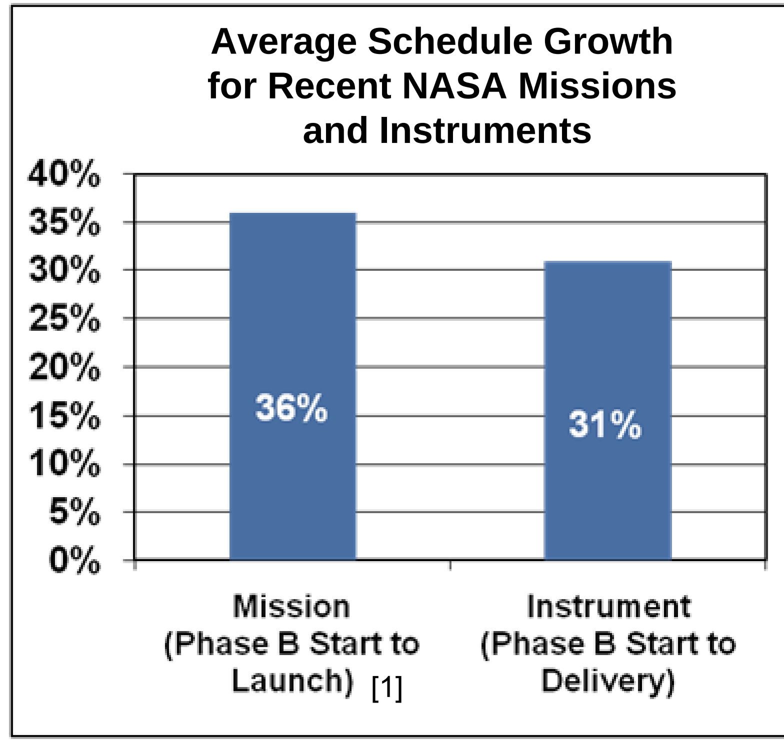

Correlation suggests that minimizing schedule growth could lower cost growth

Can reduction in instrument schedule growth translate to reduction in mission development schedule growth and hence cost growth?

Note:
1. As taken from "SMD Confirmation Metrics Study", Ringler, Rinard, Haas, Bitten, Emmons, 2009

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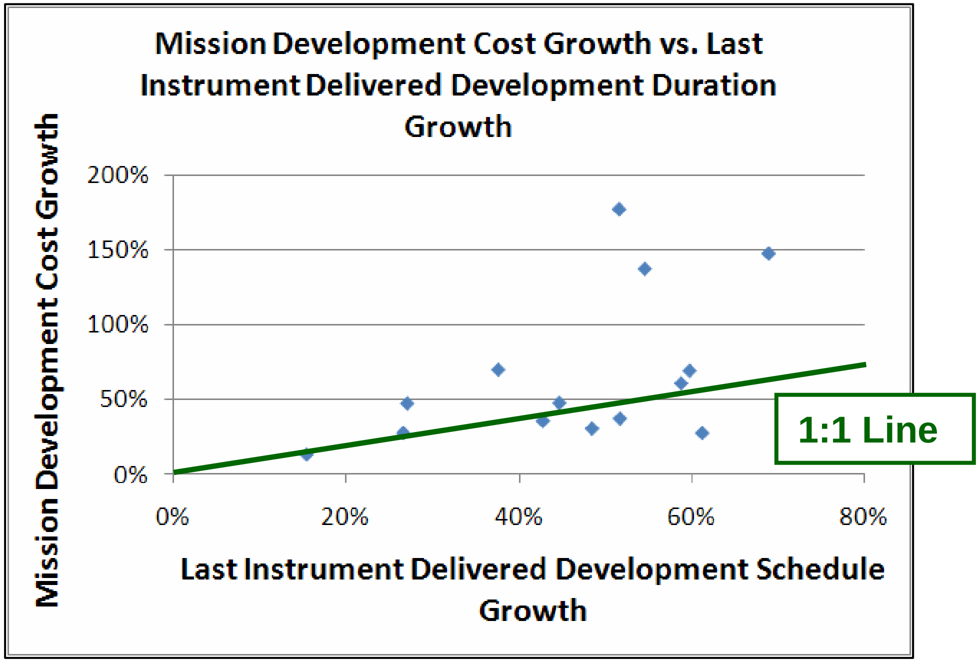
Correlation Between Mission Development Cost and Schedule Growth Prompts Further Study

- Previous study established a correlation between mission schedule and cost growth
  - *Positive correlation between mission schedule growth and instrument schedule growth*
  - *Average instrument development schedule growth is on the order of 30% (10 months)*
  - *Positive correlation between development time of last instrument delivered and mission development cost growth*



*Last Instrument Delivered Development Schedule Growth is the percentage growth of the last instrument to be delivered in a given mission

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Objective of Follow-on Study

- Objective of follow-on study is to further investigate factors correlated to instrument schedule growth
- Determine schedule growth trends based on instrument parameters, such as mass, power, and instrument type
- Provide guidelines that can be used for planning purposes by project and program managers in charge of future NASA development efforts

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Study Approach Overview

Data Collection → Consolidate Database → Data Analysis → Key Findings

Data Collection

- 86 instruments assessed across 32 missions
- Cost Analysis Data Requirements (CADRes)
- Milestone Presentations
- Monthly Management Reports

Consolidate Database

- Data consolidated into instrument schedule database
- Data binned into various categories

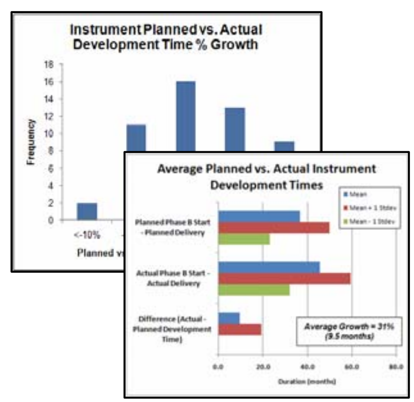
Data Analysis

- Planned vs. actual instrument schedules analyzed

Key Findings

- Key findings reported in this briefing

Mission	Mission Lead Center at Launch	Program at Launch	Destination at Launch
AIM	GSFC, Hampton University,	SMEX	Earth
CALIPSO	LRC	ESSP	Earth
Chandra	GSFC	Physics of the Cosmos	Earth
ICESat	GSFC	Earth Systematic Missions	Earth
Terra	GSFC	Earth Systematic Missions	Earth
MER	JPL	Mars Exploration	Mars
Phoenix	JPL	Mars Exploration	Mars
CloudSat	JPL	ESSP	Earth
Dawn	UCLA, JPL	Discovery	Vesta, Ceres
Deep Impact	UMD, JPL	Discovery	Comet
EO-1 NMP	Swales	New Millennium	Earth
Galex	JPL	SMEX	Earth
Genesis	JPL	Discovery	L1
GLAST	GSFC	DOE/NASA SMD	Earth
GRACE	JPL	ESSP	Earth
IBEX	SwRI	SMEX	Earth
Kepler	JPL/Ames	Discovery	Earth-trailing heliocentric
Messenger	APL	Discovery	Mercury
New Horizons	JHU	New Frontiers	Pluto
OCO	JPL	ESSP	Earth
Spitzer	JPL	Cosmic Origins	Earth-trailing Heliocentric
STEREO	GSFC	Solar Terrestrial Probe	Respectively lagging (STEREO A) and leading (STEREO B) the Earth in
SWIFT	GSFC	MIDEX/	Earth
MRO	JPL	Mars Exploration	Mars
LRO	GSFC	Robotic Lunar	Moon



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Instruments and Missions Included in Study

- Instruments binned using the following categories:
  - *Mass*
  - *Power*
  - *Instrument Type*
  - *Spacecraft Destination*

Schedule data collected for 86 instruments across 32 NASA missions

Mission	Mission Lead Center	Program	Destination
AIM	GSFC, Hampton University, University of Colorado, University of Alaska	SMEX	Earth
AQUA	GSFC	Earth Science	Earth
CALIPSO	APL NASA/French	ESSP	Earth
Chandra	GSFC/MSFC	Astronomical Search for Origins Program	Earth
CHIPS	GSFC/Wallops	UNEX	Earth
CloudSat	JPL	ESSP	Earth
Dawn	UCLA, JPL	Discovery	Vesta, Ceres
Deep Impact	UMD, JPL	Discovery	Comet
EO-1 NMP	GSFC	New Millennium	Earth
FUSE	APL	New Millennium	Earth
GALEX	JPL	SMEX	Earth
Genesis	JPL	Discovery	Earth-Sun L1
GLAST	GSFC	DOE/NASA SMD	Earth
Hinode	JAXA		Earth
IBEX	SwRI	SMEX	Earth
ICESat	GSFC	Earth Science Mission	Earth
IMAGE	GSFC	MIDEX	Earth
Kepler	JPL/ARC	Discovery	Earth-trailing heliocentric
Landsat 7	GSFC	Earth Science Mission	Earth
LRO	GSFC	Robotic Lunar Exploration	Moon
MRO	JPL	Mars Exploration	Mars
New Horizons	JHU	New Frontiers	Pluto
OCO	JPL	ESSP	Earth
Phoenix	JPL	Mars Exploration	Mars
RHESSI	GSFC	Heliophysics Explorers	Earth
SDO	GSFC	Living with a Star	Earth
Spitzer	JPL	Cosmic Origins Program	Earth-trailing Heliocentric
STEREO	GSFC	Solar Terrestrial Probe	respectively lagging (STEREO A) and leading (STEREO B) the Earth in heliocentric orbit around the Sun
SWIFT	GSFC	MIDEX/ Astrophysics Explorer	Earth
Terra	GSFC	Earth Systematic	Earth
WIRE	GSFC	SMEX	Earth
WISE	JPL	Astrophysics Explorers	Earth

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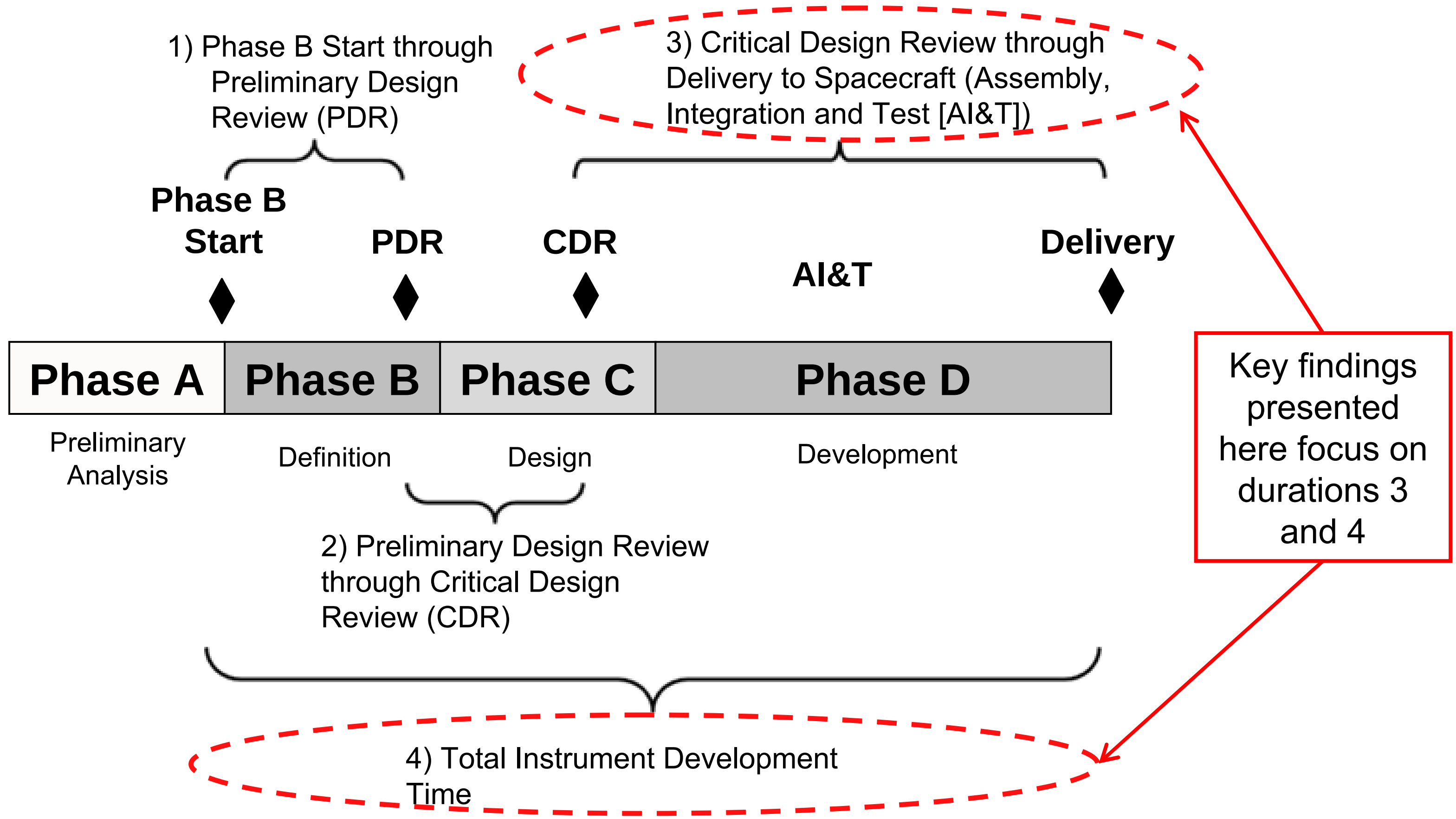
Instrument Durations Studied



Instrument Schedule Milestones and Phases for NASA Missions

Note: All planned durations taken from planned schedule at Phase B Start

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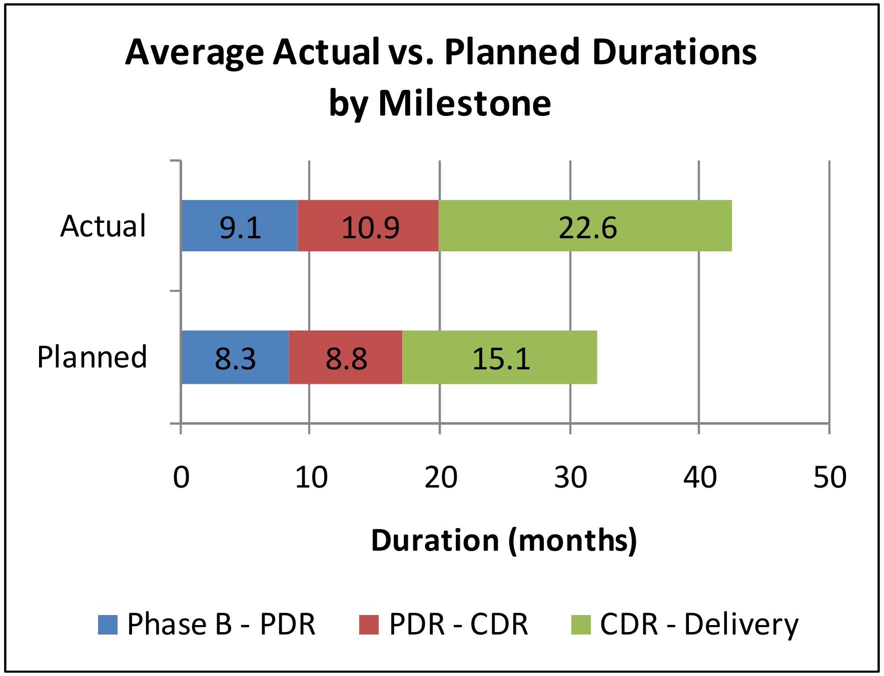
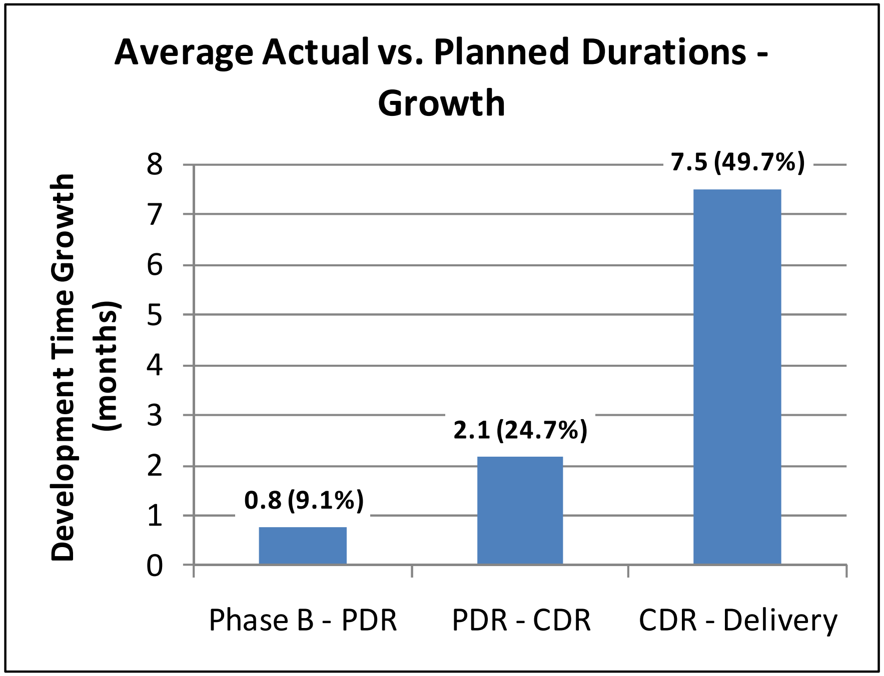
Instrument Schedule Growth by Milestone





A majority of schedule growth (absolute and percent) occurs from CDR to delivery.

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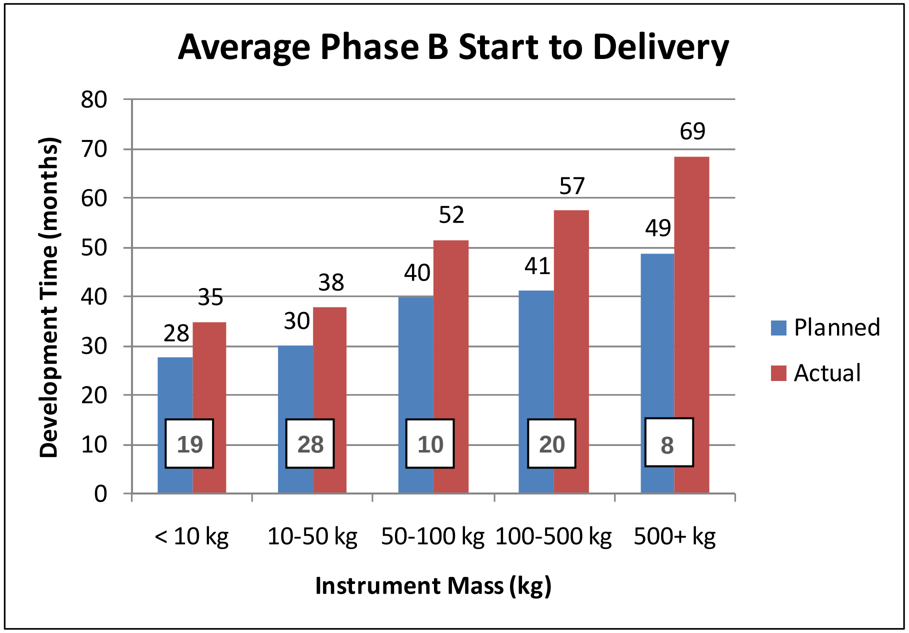
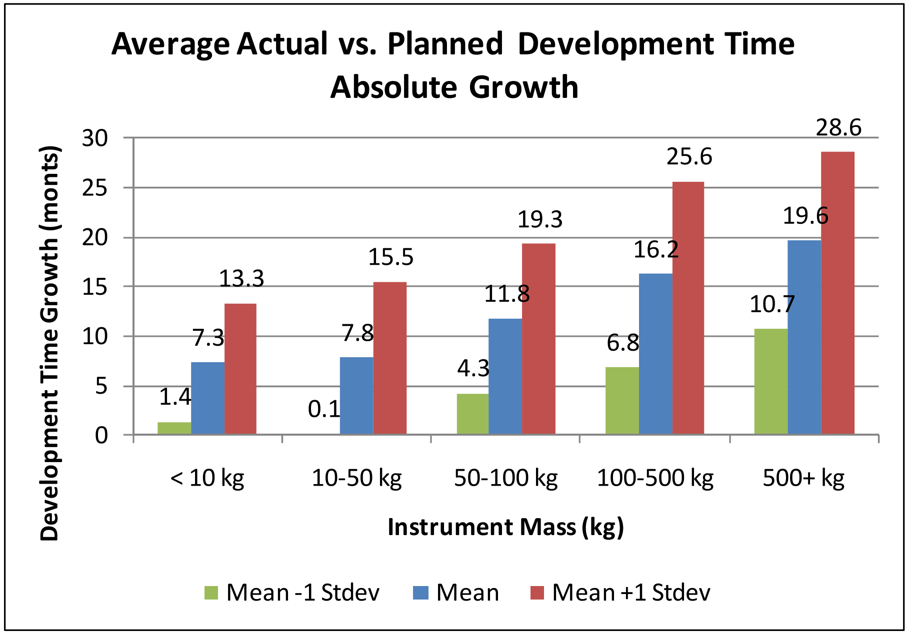
Instrument Schedule Growth Binned by Mass



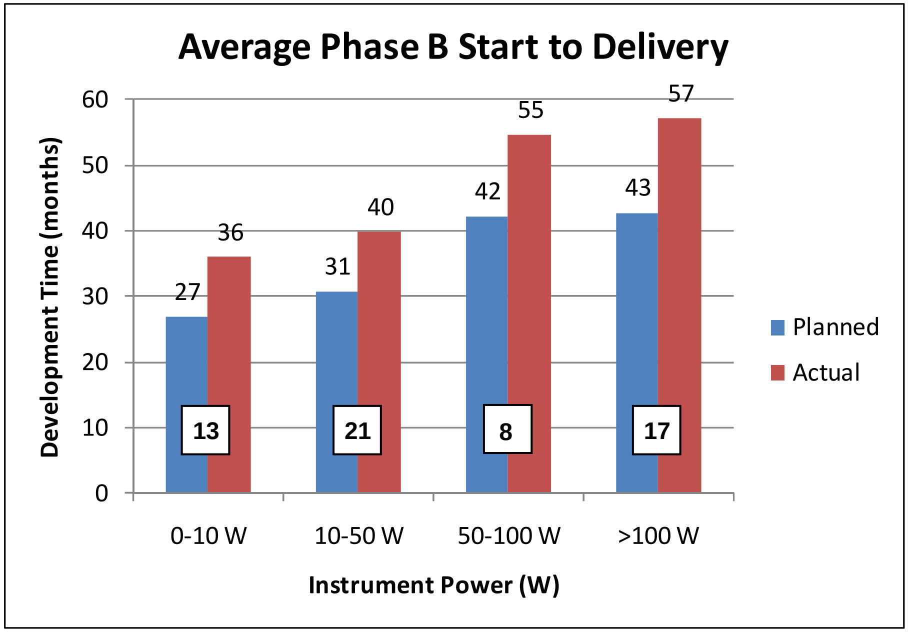


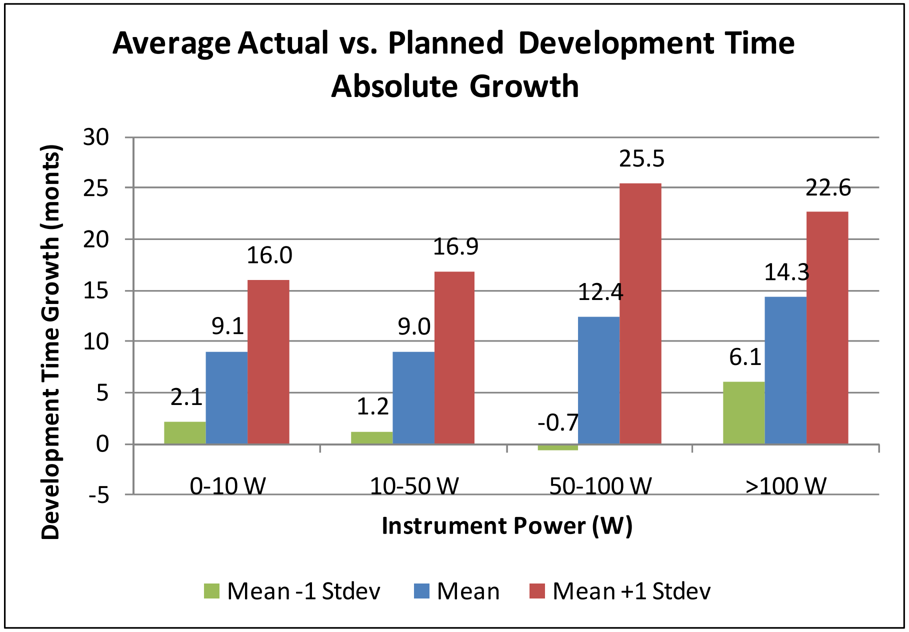
On average, larger mass instruments require longer development durations. Absolute schedule growth is positively correlated with instrument mass.

For instruments >100 kg, 84% had more than 6.8 months schedule growth. It is unlikely that many of these had more than 6 months schedule slack built in.

| # | = number of instruments in each bin

Instrument Schedule Growth Binned by Power





Higher power instruments also require longer development times, and experience longer absolute schedule growth.

For power and mass bins, average development time growth has large standard deviations, indicating that other variables should also be considered.

= number of instruments in each bin

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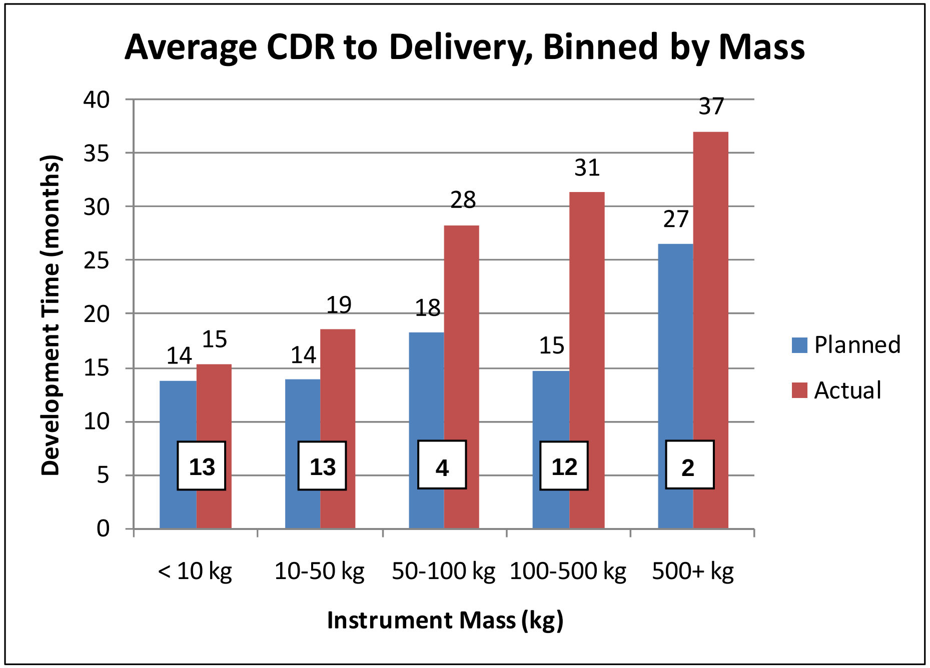
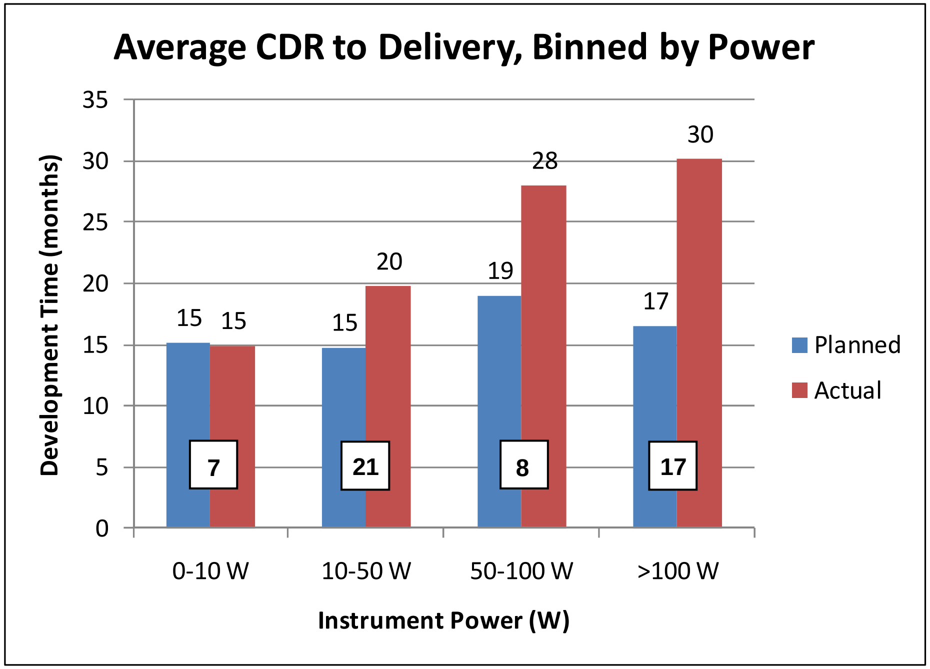
Instruments Binned by Mass and Power

CDR - Delivery





Schedule growth from instrument CDR to instrument delivery is particularly pronounced for higher mass and power instruments.

= number of instruments in each bin

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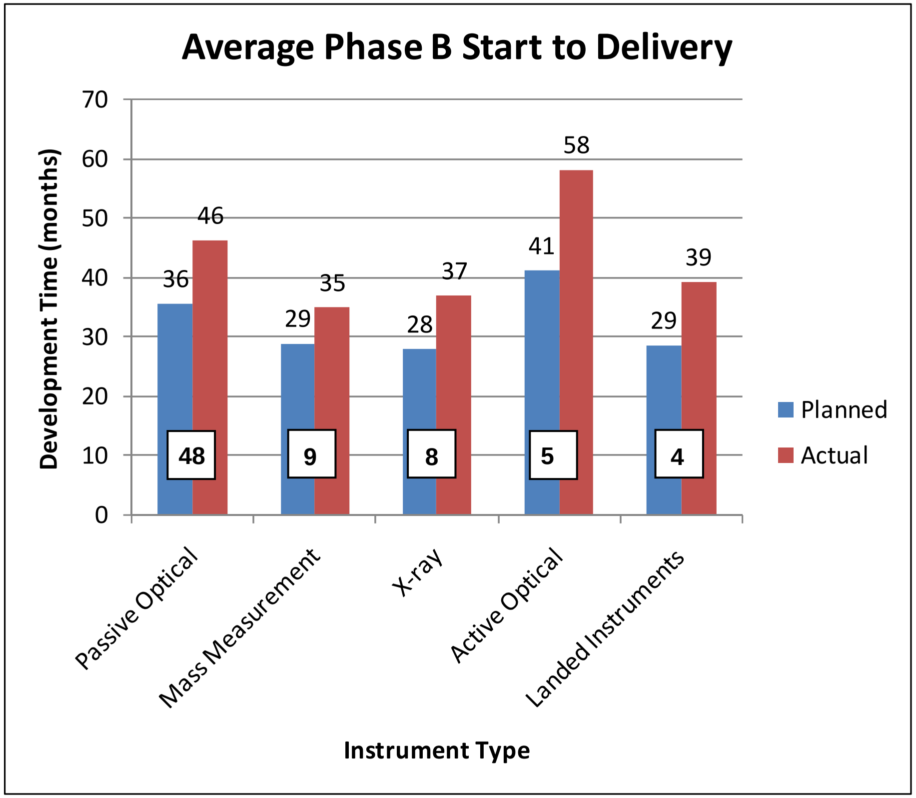
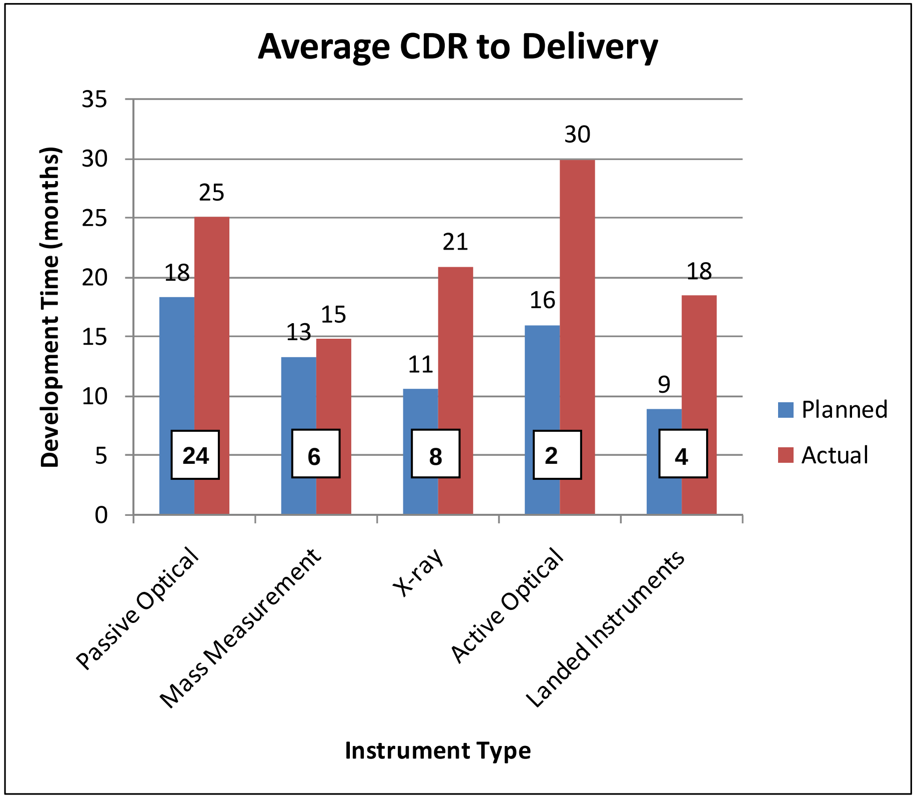
Instruments Binned by Type

Primary Instrument Category	Secondary Instrument Category
Active Optical	Altimeter
	Imager
	Sounder
Passive Optical	Imager
	Multi-spectral
	Hyper-spectral
	Radiometer/Photometer
	Telescope
Landed Instruments	Arm/boom
	Meteorology
	Sample collection
	Sample analysis
	Microscopes
	X-ray
Mass measurement	Neutral Mass
	Ion Mass
	Tunable Laser
X-ray	Imaging
	Non-imaging

Instruments Binned by Type





Largest schedule growth is experienced by optical instruments.

Most of the schedule growth occurs from CDR to Delivery.

= number of instruments in each bin

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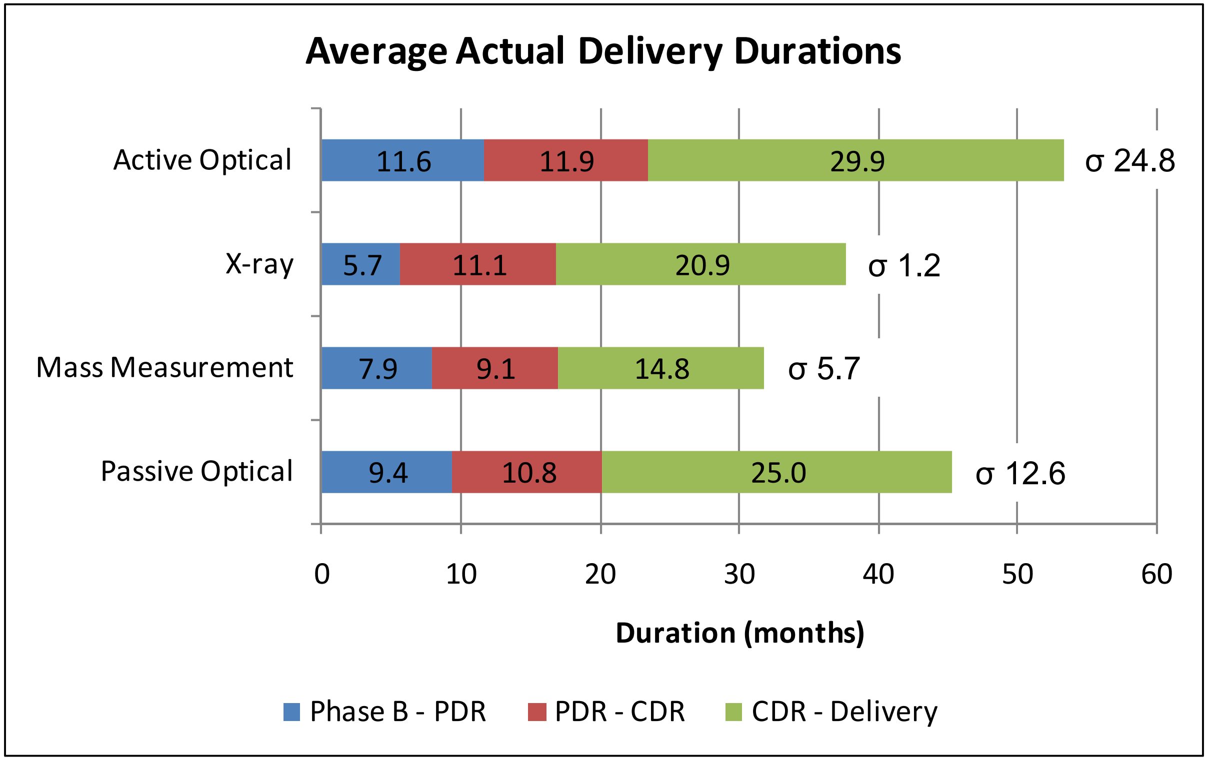
Instruments Binned by Type

Average Actual Durations by Milestone



Standard deviations are for total schedule duration

**Insufficient data for landed instruments*

Typical instrument durations by phase can be used by program and project managers as a sanity check during early planning of instrument delivery schedules.

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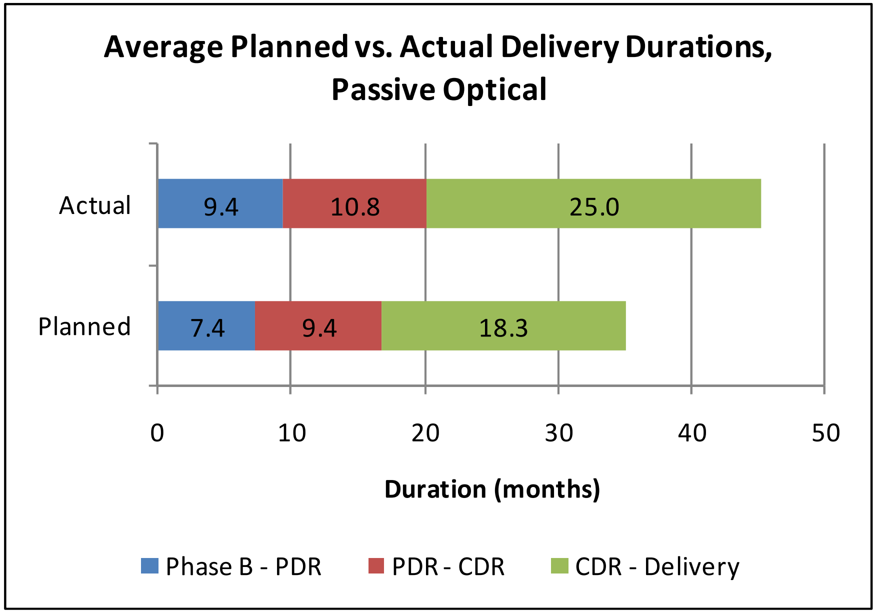
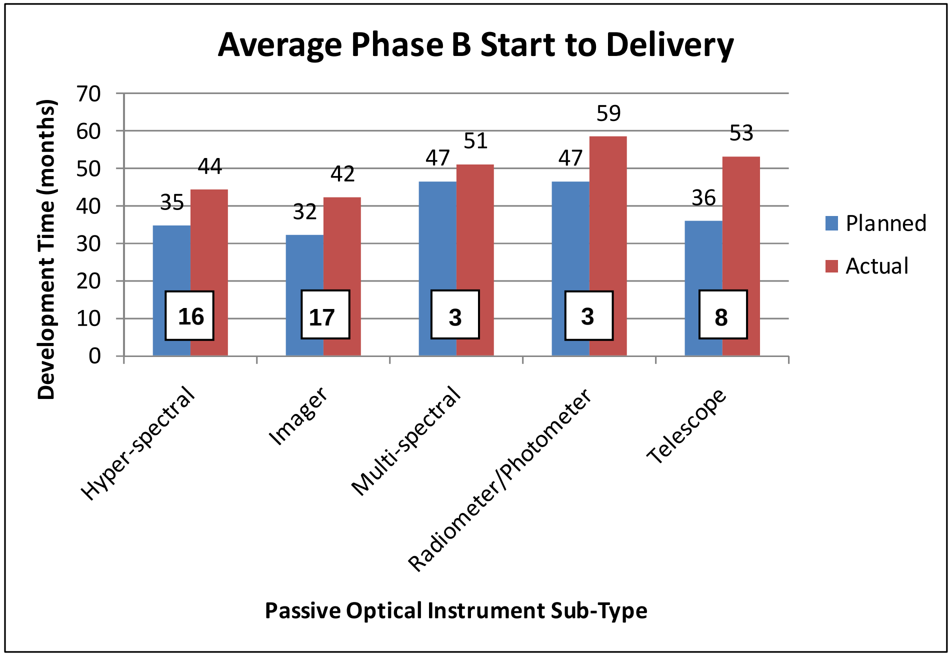
Instruments Binned by Secondary Type

Passive Optical Instruments





\# = number of instruments in each bin

For passive optical instruments, the largest schedule growth (percent and absolute) occurs from CDR to Delivery.
On average, passive optical instruments require 45.2 months from Phase B start to Delivery and experience 29% (10 months) schedule growth.

Telescopes experience the largest schedule growth (47%, 17 months) of all passive optical instruments. Radiometer/photometer instruments require the longest development time (59 months).

Passive optical instruments account for over 50% of the data set

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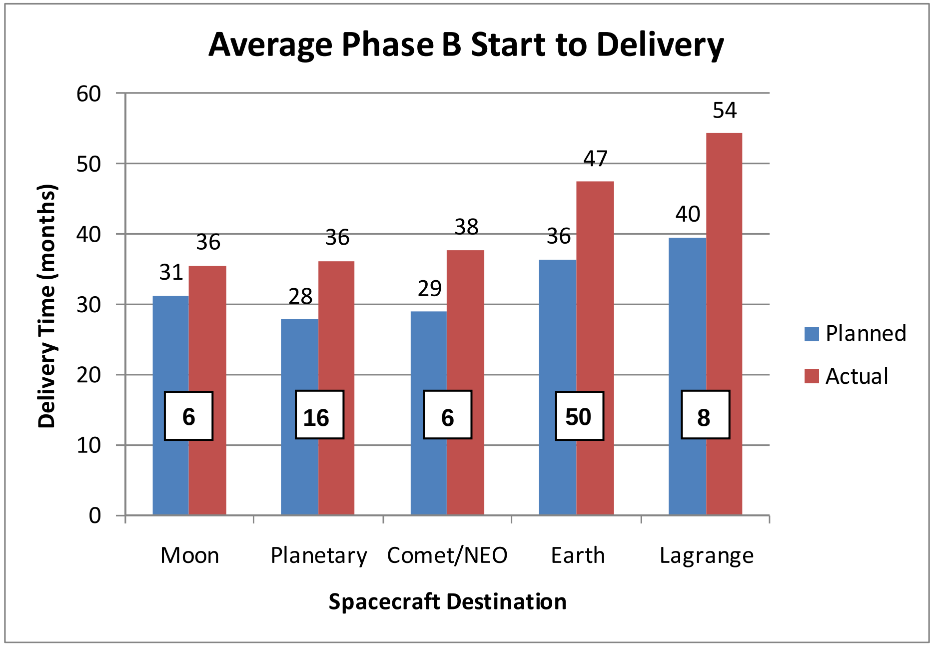
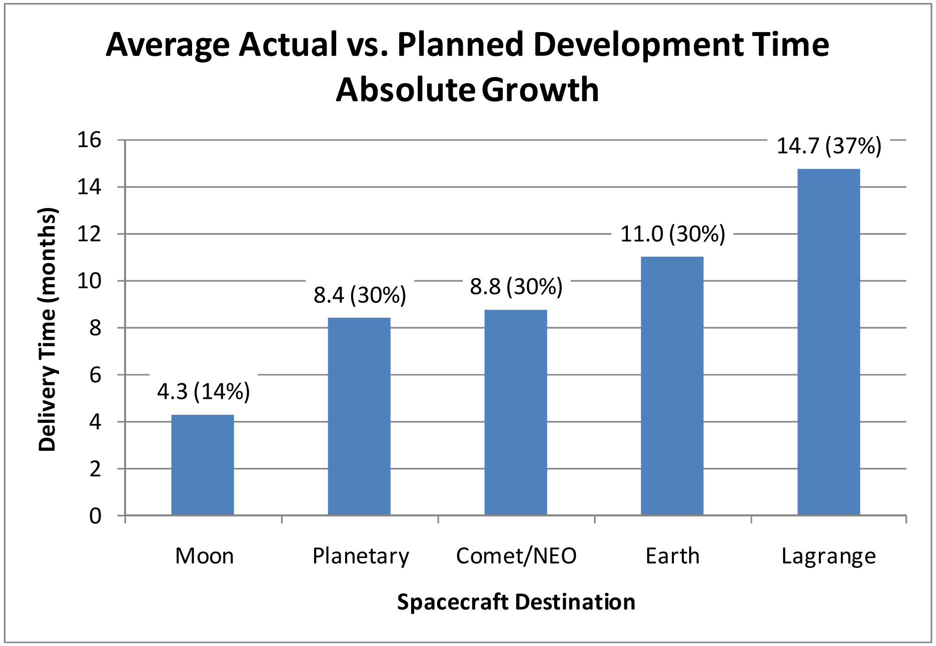
Instruments Binned by Spacecraft Destination





Missions with constrained launch windows (i.e., missions to planetary bodies or comets/asteroids) have shorter development times and less schedule growth.

= number of instruments in each bin

Results plot the average of all instruments on a given spacecraft

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Conclusions (1 of 3)

- Observed **trend**: Most schedule growth (percent and absolute) occurs from CDR to Delivery
- Observed **trend**: Larger mass and power instruments require longer schedule durations and experience larger absolute schedule growth
- Observed **trend**: Optical instruments require the longest schedule durations; active optical instruments experience the largest schedule growth
- Observed **trend**: Missions beyond the Earth (constrained launch windows) have shorter development times and experience less schedule growth than Earth-orbiting or Earth trailing/leading missions.

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Conclusions (2 of 3)

- More informed planning may help reduce schedule growth and hence possible reduce mission schedule and cost growth

- Previous study determined average instrument schedule growth across all instruments studied
  - ***Potential rule of thumb:*** *Planned instrument development schedules may warrant extra scrutiny if…*
    - Phase B Start to Delivery is less than 33 months
    - CDR to Instrument Delivery to Spacecraft is less than 15 months

- Certain types of instruments require longer than the typical schedule durations
  - ***Potential rule of thumb:*** *Planned instrument development schedules may warrant extra scrutiny if planned Phase B Start to Instrument Delivery is less than…*
    - 50 months for instruments with mass greater than 50 kg and power greater than 50 W
    - 58 months for active optical instruments
    - 46 months for passive optical instruments
    - 47 months for Earth-orbiting missions
    - 54 months for missions to Lagrange points or Earth-trailing/Earth-leading missions

Conclusions (3 of 3)

- Certain types of instruments require longer than the typical schedule durations
  - ***Potential rule of thumb:*** *Planned instrument development schedules may warrant extra scrutiny if planned CDR to Instrument Delivery is less than…*
    - 28 months for instruments with mass greater than 50 kg and power greater than 50 W
    - 30 months for active optical instruments
    - 25 months for passive optical instruments
    - 25 months for Earth-orbiting missions
    - 26 months for missions to Lagrange points or Earth-trailing/Earth-leading missions
- Rules of thumb are based on average durations for each instrument bin
  - *Because of large standard deviations in the data, rules of thumb should be used to determine if planned schedule warrants extra scrutiny based on previous experience*
  - *Rules of thumb are not hard caps on shortest achievable instrument schedules*

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Next Steps

- Compare study results with respect to current schedule reserve guidelines
  - *More informed planning may help reduce schedule growth and hence possibly reduce mission schedule and cost growth*

- Review monthly program reviews and schedules to potentially identify causal effects between instrument and mission schedule growth
  - *Current study establishes trends and correlations, not causation*

- Identify instrument development problem areas and reasons for instrument schedule growth
  - *Examine relationship between instrument schedule growth and instrument mass, power, and performance growth*

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Thank You