National Aeronautics and
Space Administration

NASA earth

Venture = a risky or daring journey or undertaking. Is NASA's Earth Venture Class of missions taking a risky journey to create low-cost missions focused on innovative research?

Justin Hornback, Mark Jacobs, Shawn Hayes

Earth System Science Pathfinder Program (ESSP)

ESSP Overview

The goal is to stimulate new scientific understanding of the global Earth system by:

- developing and operating remote-sensing missions
- conducting investigations using data from these missions
- addressing unique, specific, highly focused requirements in Earth science research

Projects in the ESSP portfolio are:

- Science-driven
- PI-led investigations
- Competitively selected, one step Ao
- Orbital or sub-orbital
- Implemented within cost- and schedule-constraints

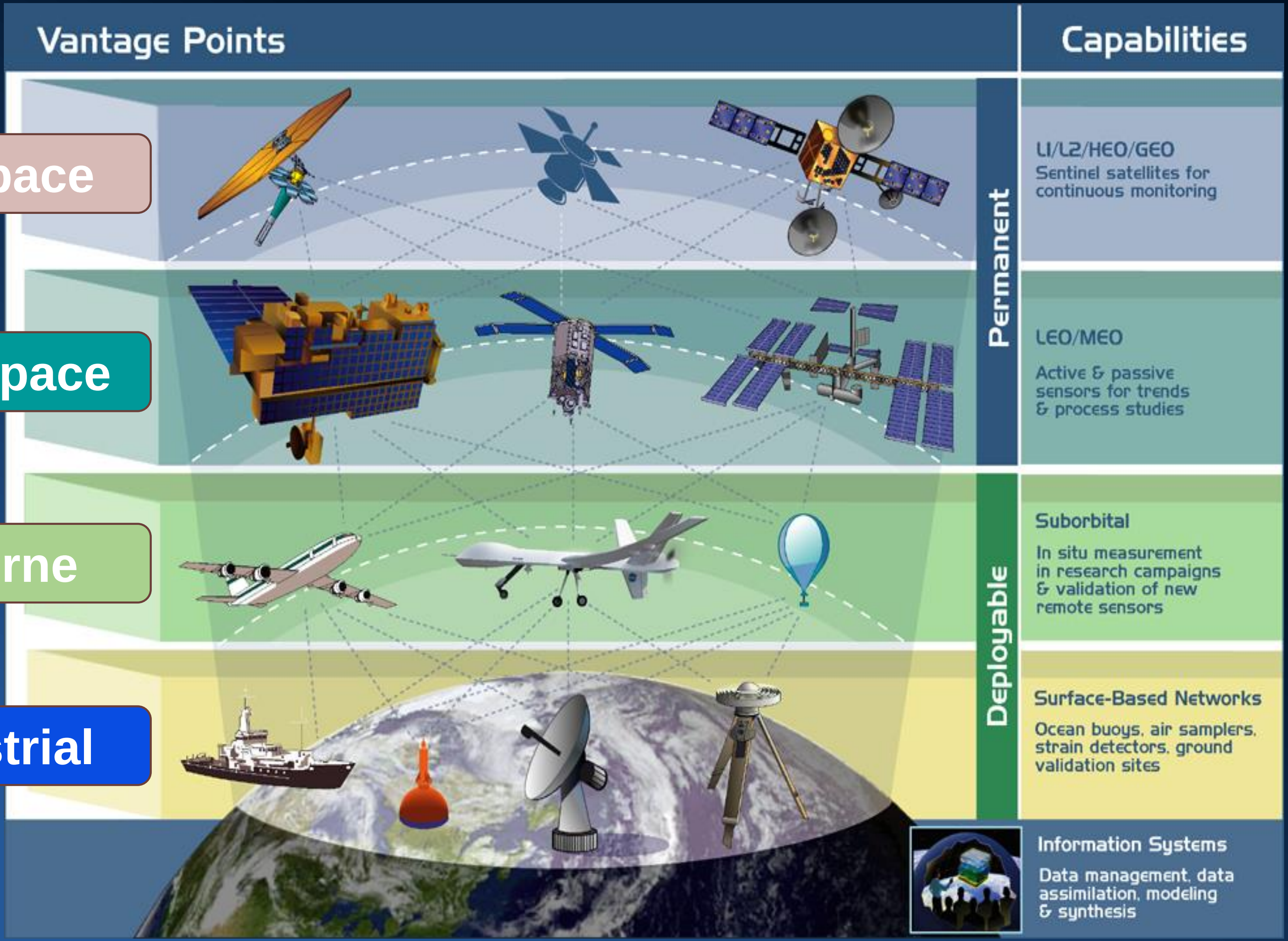
ESSP Earth Observing Vantage Points

Far-Space

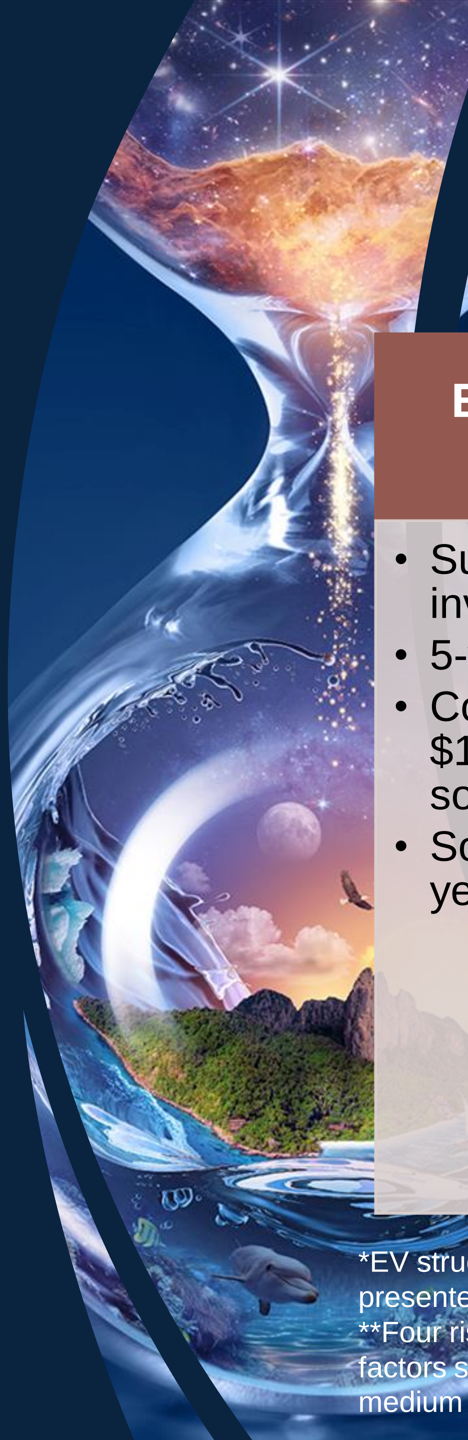
Near-Space

Airborne

Terrestrial



Measurement Domains for ESSP Projects



NASA’s Earth Venture Class

– The ESSP portfolio Earth Venture Class element currently* has 4 strands:

EV Suborbital (EVS)	EV Mission (EVM)	EV Instrument (EVI)	EV Continuity (EVC)
• Suborbital/airborne investigations • 5-year duration • Cost caped at $150M per solicitation • Solicited every ~4 years	• Small complete missions • 5 years to launch • Class-D** allowable • Small-sat or stand-alone payload as par of larger missions • Cost caped at $180M • Solicited every ~4 years	• Spaceborne instruments for flight on Missions of Opportunity (MoO) • ≤5years for development • Class-C** or Class-D* allowable • $30M-$100M total cost for development and operations • Solicited every ~3 years	• Spaceborne instrument or missions • Cost caped at $150M per solicitation • Solicited every ~3 years • specifically seeks to lower the cost for long-term acquisition of key “continuity” observations, rewarding innovation in mission-to-mission cost reduction through technology infusion, programmatic efficiency, and/or other means

*EV structure as of the date for this study. The NASA Earth Science Division recently announced changes to the EV structure. Additional details were presented at the March 13, 2024, ESD Community Forum (https://science.nasa.gov/earth-science/esd-community-forum/).
**Four risk levels or classifications (A, B, C and D) have been characterized in the NPR 8705.4 Risk Classification for NASA Payloads by considering factors such as criticality to the Agency Strategic Plan, national significance, complexity, mission lifetime, cost and other relevant factors. Class C is medium priority, medium national significance, medium to low complexity and cost while Class D is considered low in all these aspects.

Earth Venture (EV)

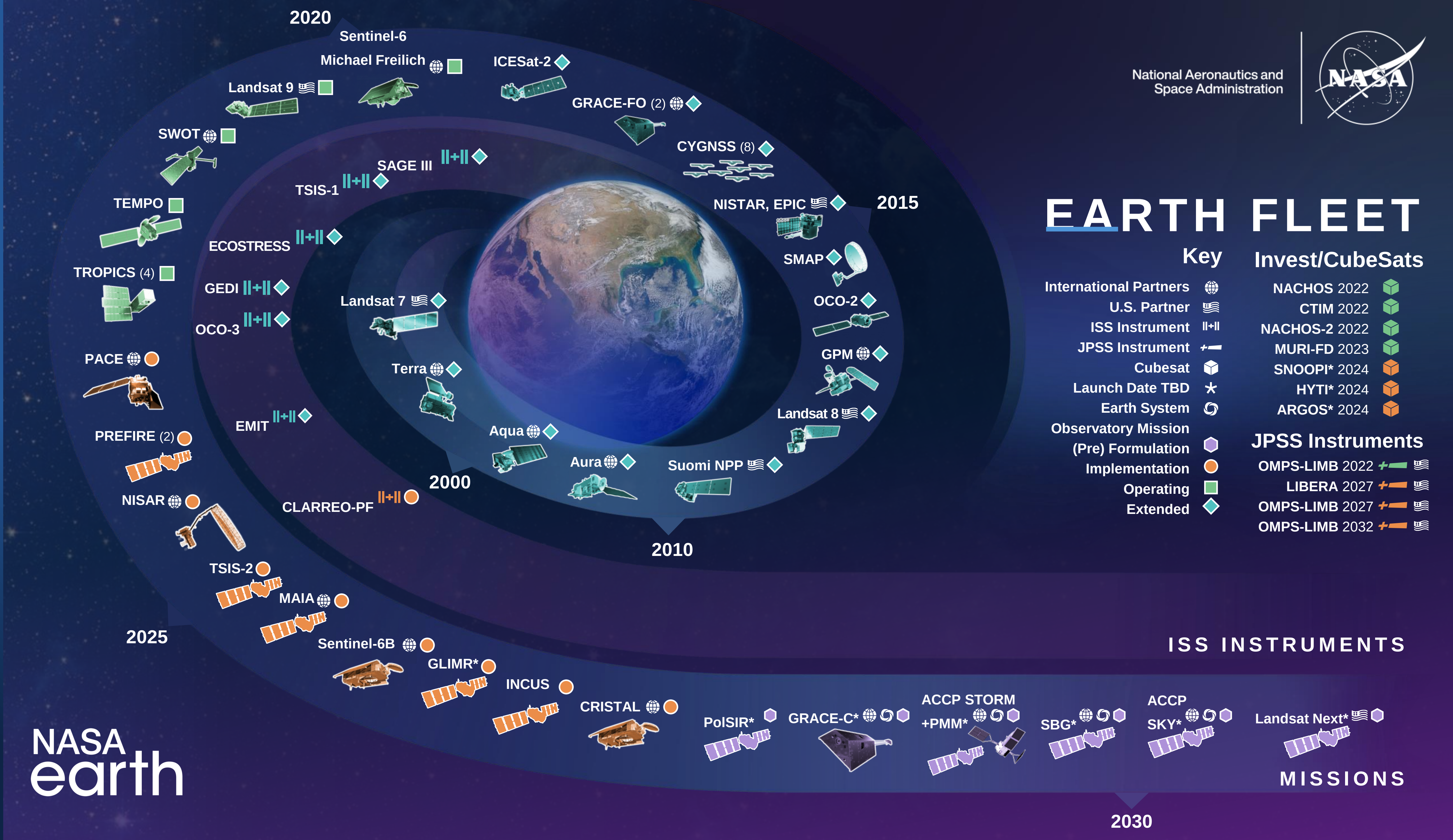
Principal Investigator Managed Cost Cap (PIMMC)

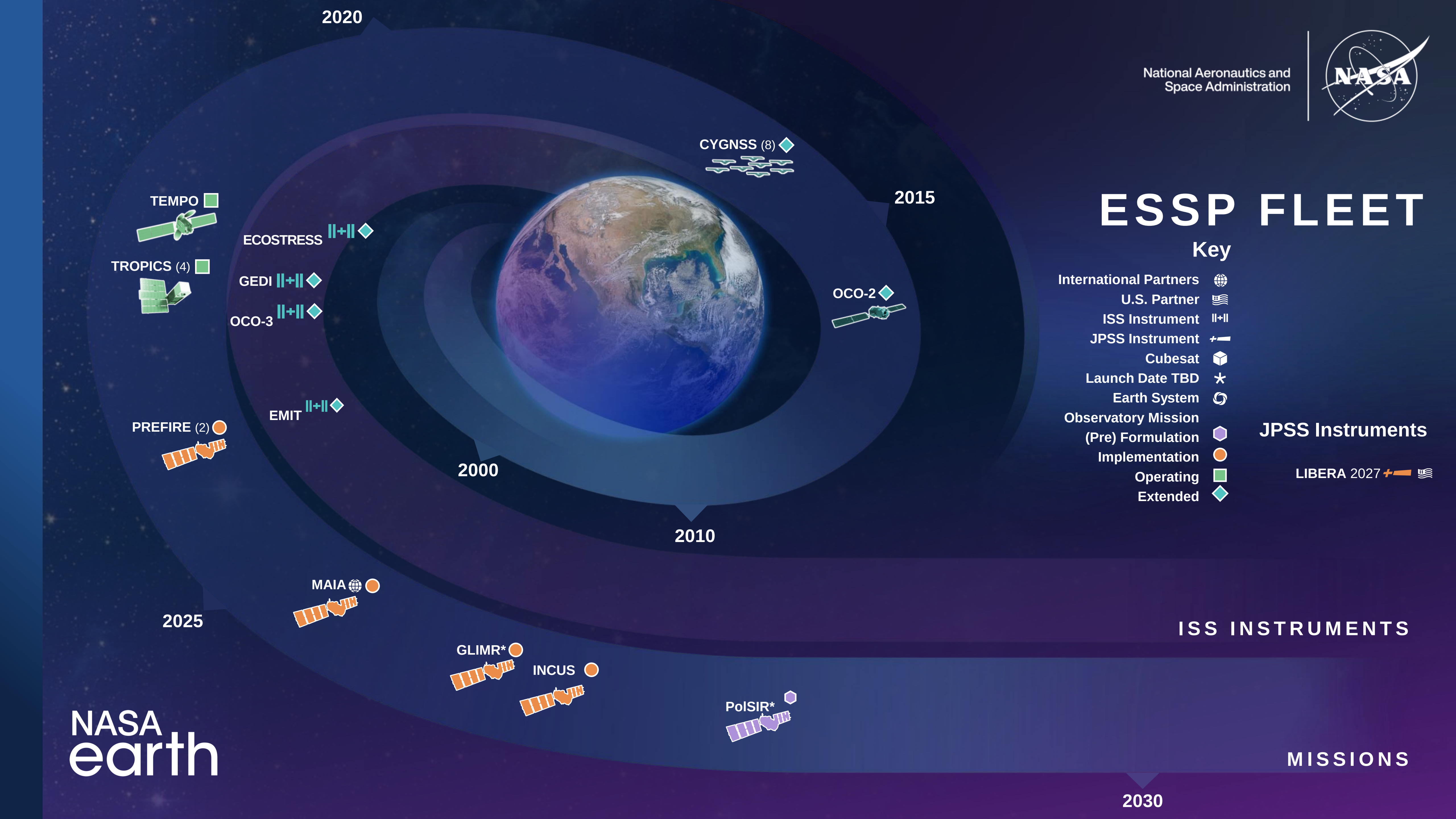
Outside PIMMC = Accommodations

- Access to Space (Spacecraft, Launch Vehicle, Interfaces, Storage, Hosting)
- Integration and Test to Selected Platforms

Table 2: List of portions of an Instrument Investigation cost that are within and outside the PIMMC.

Portion of the Investigation	Within PIMMC	Outside PIMMC
Phase A	X	
Phase B	X	
Phase C	X	
Investigation Costs during a potential gap between completion of instrument and start of integration (planning budget up to four years, on a per-year basis)		X
Science Team activity within Phase D	X	
Key management and engineering staff during Phase D (Project Manager, Instrument Manager, Systems Engineer, etc.) assuming a two-year Phase D	X	
Integration and test to selected platform (within Phase D) (planning budget nominally two years)		X
Cal/Val planning (all phases)	X	
Post-launch instrument commissioning activity (within Phase D)	X	
Phase E	X	
Phase F	X	
Cost for access to space		X
Communication Program (optional)	X	X - ESSP PO activities
Student Collaboration (SC) (optional)	X – any SC cost above 1% of the PIMMC	X - Up to 1% of the PIMMC
Science Enhancement Option (SEO) (optional)		X – only for Tailored Class D instrument and CubeSat investigations


National Aeronautics and Space Administration
NASA
EARTH FLEET
Key
International Partners
U.S. Partner
ISS Instrument
JPSS Instrument
Cubesat
Launch Date TBD
Earth System
Observatory Mission
(Pre) Formulation
Implementation
Operating
Extended
Invest/CubeSats
NACHOS 2022
CTIM 2022
NACHOS-2 2022
MURI-FD 2023
SNOOPI* 2024
HYTI* 2024
ARGOS* 2024
JPSS Instruments
OMPS-LIMB 2022
LIBERA 2027
OMPS-LIMB 2027
OMPS-LIMB 2032
2020
Sentinel-6
Michael Freilich
ICESat-2
Landsat 9
GRACE-FO (2)
SWOT
CYGNSS (8)
SAGE III
TSIS-1
NISTAR, EPIC
2015
TEMPO
ECOSTRESS
SMAP
TROPICS (4)
GEDI
Landsat 7
OCO-2
OCO-3
GPM
PACE
Terra
EMIT
Landsat 8
PREFIRE (2)
Aqua
Aura
Suomi NPP
2000
NISAR
CLARREO-PF
2010
TSIS-2
MAIA
2025
Sentinel-6B
GLIMR*
INCUS
CRISTAL
ISS INSTRUMENTS
PolSIR*
GRACE-C*
ACCP STORM +PMM*
SBG*
ACCP SKY*
Landsat Next*
MISSIONS
2030
NASA earth


National Aeronautics and Space Administration
ESSP FLEET
Key
International Partners
U.S. Partner
ISS Instrument
JPSS Instrument
Cubesat
Launch Date TBD
Earth System Observatory Mission
(Pre) Formulation
Implementation
Operating
Extended
JPSS Instruments
LIBERA 2027
ISS INSTRUMENTS
MISSIONS
2000
2010
2015
2020
2025
2030
CYGNSS (8)
OCO-2
TEMPO
TROPICS (4)
ECOSTRESS
GEDI
OCO-3
EMIT
PREFIRE (2)
MAIA
GLIMR*
INCUS
PolSIR*
NASA earth

Earth Ventures Cost/Schedule Performance Study
Study Approach

EV and ESD Project Selection → **Collect Cost, Schedule, and Technical Data** → **Analyze Data & Develop Findings**

- Initially started with 20 Projects w/ 10 EV & 10 ESD
- 4 Projects dropped
  - EV: GLIMR (too far from LRD) and GeoCarb (cancelled)
  - ESD: TIMED & GOES-P dropped due to difficulty obtaining starting point data
- Data set for this study includes 16 Projects (8 EV + 8 ESD)
  - Selected missions have adequate available technical and programmatic data from SRR & Launch

- A database with ~130 fields per Project has been completed covering all 16 Projects
- Technical (kg/W), Schedule, and Cost data collected from SRR and Launch (or latest)
  - SRR appeared to be the most consistent starting point
  - Exceptions: MAIA & PREFIRE delivered but not launched (EV) and PDR used as starting point for GPM and OCO-2 (ESD)

- Numerous comparisons of cost, technical, and schedule performance between EV projects and other ESD missions were developed
- These comparisons support a set of 9 findings covering Technical, Cost, Schedule, and Launch Vehicle (LV)

Earth Ventures Cost/Schedule Performance Study
Study Assumptions

All costs and % growth is based on Real Year (RY) dollars

EV Project development costs (Phases BCD) have been collected for the Project and ESSP-supported Accommodations

- EV costs related to Launch Services (or Access to Space) have been removed
- ESD Launch Vehicle costs are also not included

Technical (kg/W), Schedule, and Cost data collected from Systems Requirement Review (SRR) and Launch (or latest)

- SRR appeared to be the most consistent starting point
- Exceptions: MAIA & PREFIRE delivered but not launched (EV) and PDR used as starting point for GPM and OCO-2 (ESD)

Earth Ventures Cost/Schedule Performance Study
EV & ESD Project Data

- **Reasonable Start/End Point data has been collected covering 16 of the 20 initial project candidates**
  - 8 EV projects + 8 Other ESD projects
  - Dropped EV projects: GLIMR (too early) & GeoCarb (cancelled)
  - Dropped Other ESD projects: TIMED & GOES-P (ATP data unavailable)

Pgm	Start Point	End Point		Mission/Project
EV	SRR	ORR	3	**EMIT**
EV	SRR	L	4	**TEMPO**
EV	SRR	CDR	5	**MAIA**
EV	SRR	CDR	6	**PREFIRE**
EV	SRR	L	7	**TROPICS**
EV	SRR	L	8	**ECOSTRESS**
EV	SRR	L	9	**GEDI**
EV	SRR	L	10	**CYGNSS**
ESD	SRR	L	12	**CLOUDSAT**
ESD	SRR	L	13	**OCO**
ESD	SRR	L	15	**Glory**
ESD	PDR	L	16	**GPM**
ESD	CDR	L	17	**OCO-2**
ESD	SRR	L	18	**SMAP**
ESD	SDR	L	19	**GOES-R**
ESD	SRR	L	20	**JPSS-1**

Earth Ventures Cost/Schedule Performance Study Findings

COST

Finding 1: Average cost per project is significantly less for EV projects than other ESD projects

Finding 2: Development cost growth is lower for EV projects than other ESD projects

Finding 3: PM/SE/MA (WBS 1/2/3) is a higher % of hardware for EV projects

SCHEDULE

Finding 4: EV projects have shorter SRR-Launch schedules than other ESD projects

Finding 5: EV projects experience shorter launch slips than other ESD projects

Finding 6: Unclear relationship between cost and schedule growth

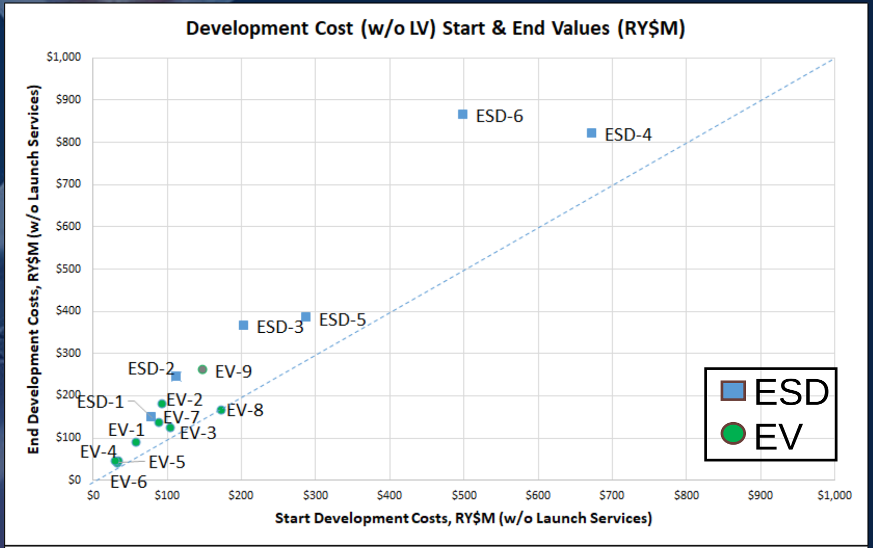
TECHNICAL

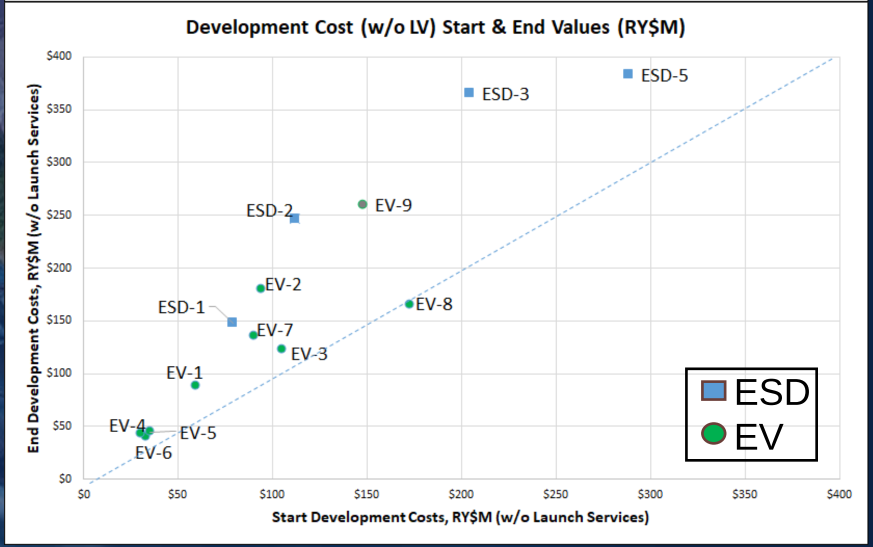
Finding 7: Development $/kg is similar between EV and other ESD projects

Finding 8: Mass growth for EV projects is greater than for other ESD projects

Earth Ventures Cost/Schedule Performance Study
Finding 1: Average cost per project is significantly less for EV projects than other ESD projects

- **The average Phase BCD cost (w/o LV) for the ESD projects studied is more than 10x higher than EV projects**
  - Average EV development = $96M
  - Average Other ESD development = $1,362M
  - Content of the ESD projects is far greater than the focused content of most EV projects

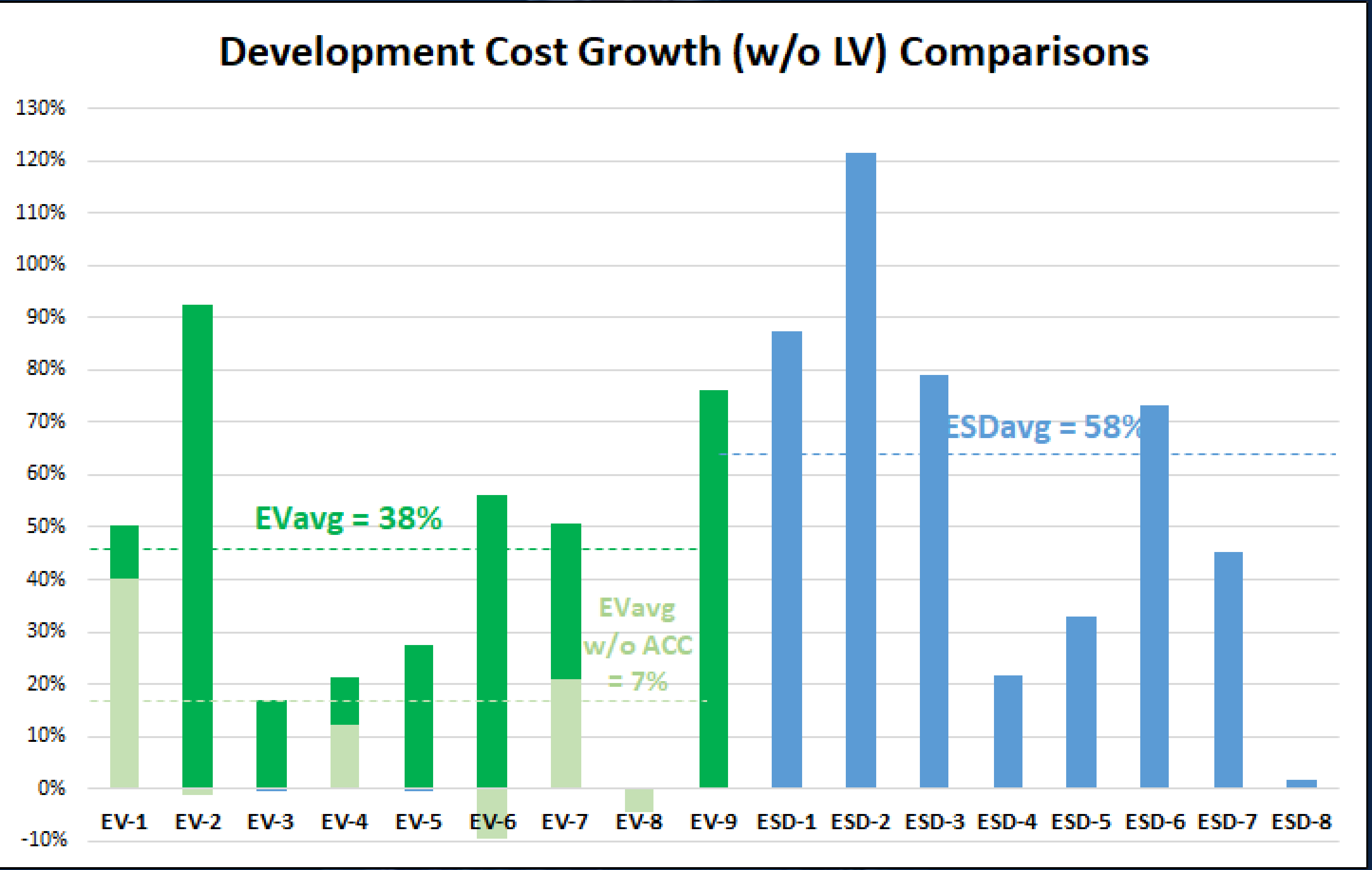




Note: GeoCarb is shown but not included in this study's statistics

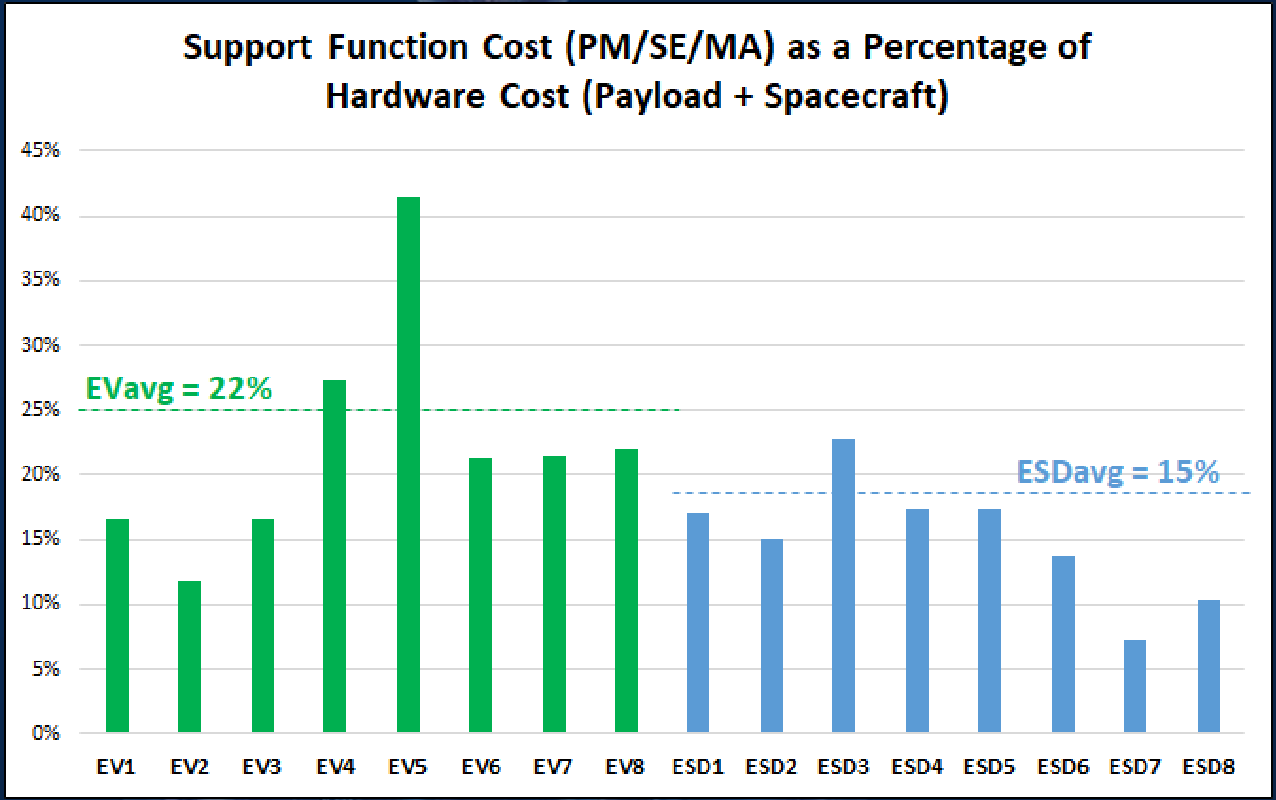
Earth Ventures Cost/Schedule Performance Study
Finding 2: Development cost growth is lower for EV projects than other ESD projects

- **Average development cost growth (w/o LV) from ATP to Launch (or Latest) for EV projects (including ACC) is significantly less than for other Earth Science projects**
  - EV growth (with ACC) averages 38%; EV growth is mainly from TEMPO (91%), GEDI (51%), EMIT (50%), and ECOSTRESS (47%)
  - Other ESD missions average 58%; Other ESD growth is mainly from OCO (121%), CloudSat (87%), and SMAP (73%)
  - Note: EV growth w/o ACC is only 7%



Earth Ventures Cost/Schedule Performance Study
Finding 3: Support functions somewhat higher as a percentage of hardware for EV projects

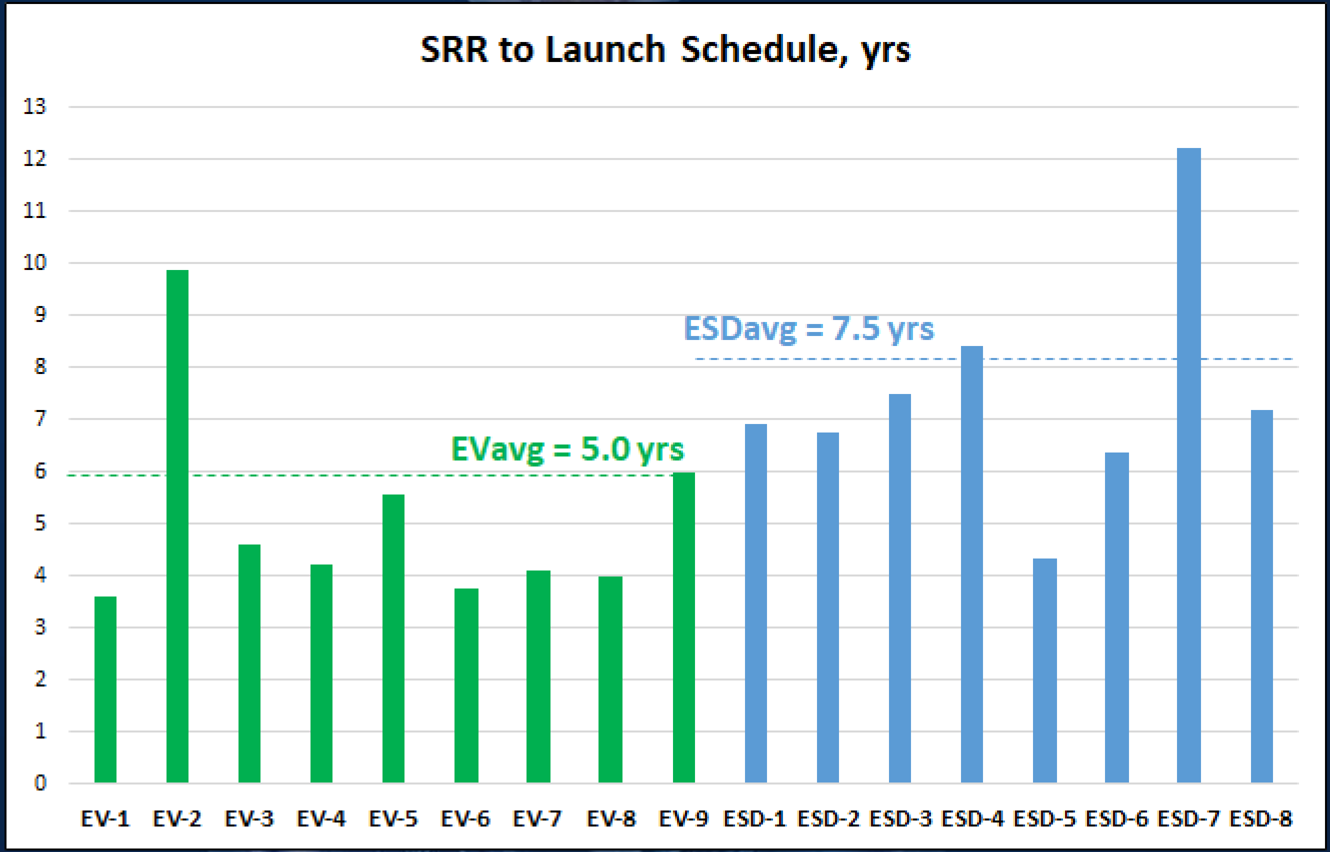
- **Although EV projects are significantly less expensive than other ESD projects, the cost of project support functions (program management, system engineering and mission assurance) expressed as a percentage of flight hardware (i.e., payload and spacecraft) cost is somewhat higher.**
  - EV projects average 22% compared to ESD which averages 15%
  - The slightly higher EV project percentage implies that there is a fix cost for some of these project support functions regardless of mission size/scope/cost



Earth Ventures Cost/Schedule Performance Study

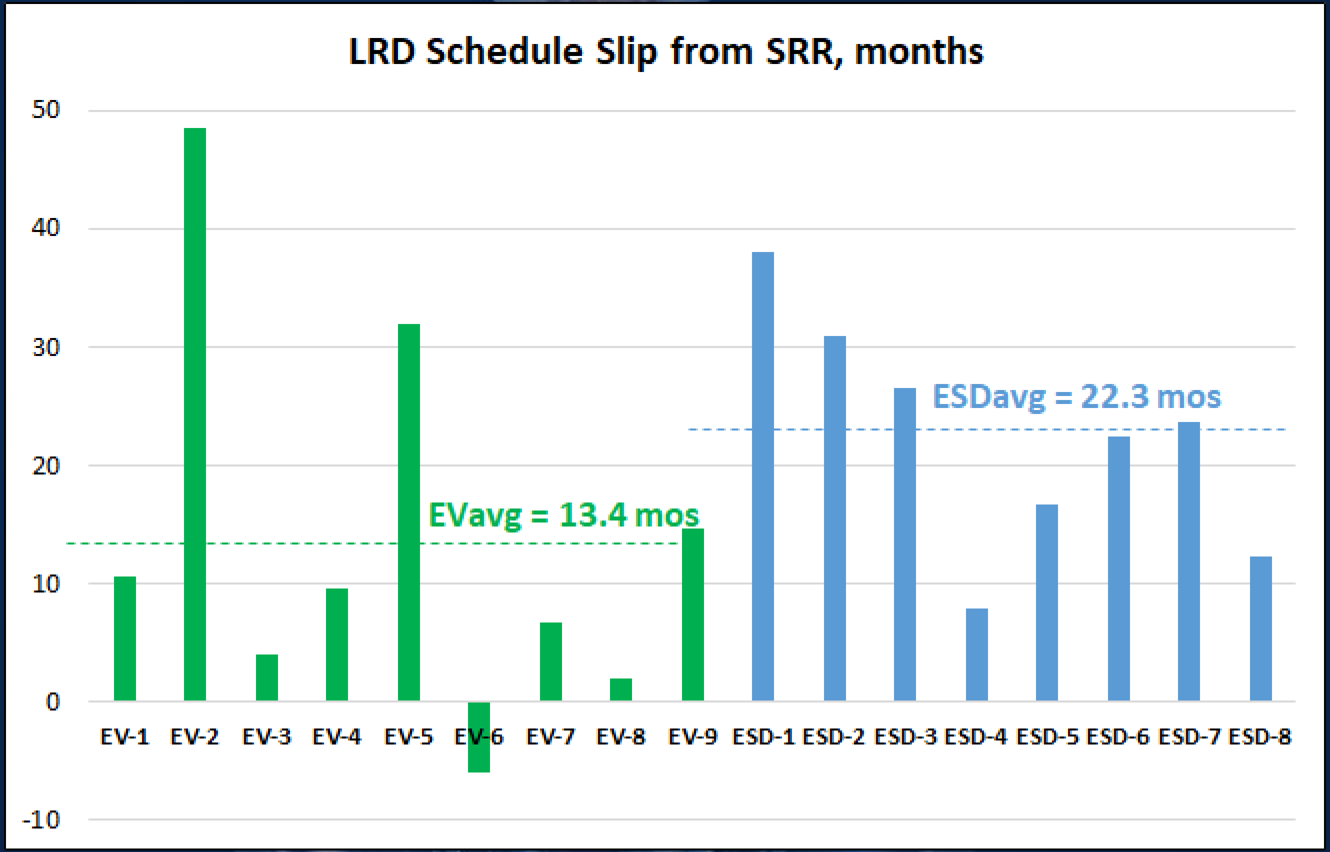
Finding 4: EV projects have shorter SRR-Launch schedules than other ESD projects

- **EV projects appear to require less time from SRR to Launch**
  - Average EV SRR-Launch schedule = 5.0 years
  - Average Other ESD SRR-Launch schedule = 7.5 years



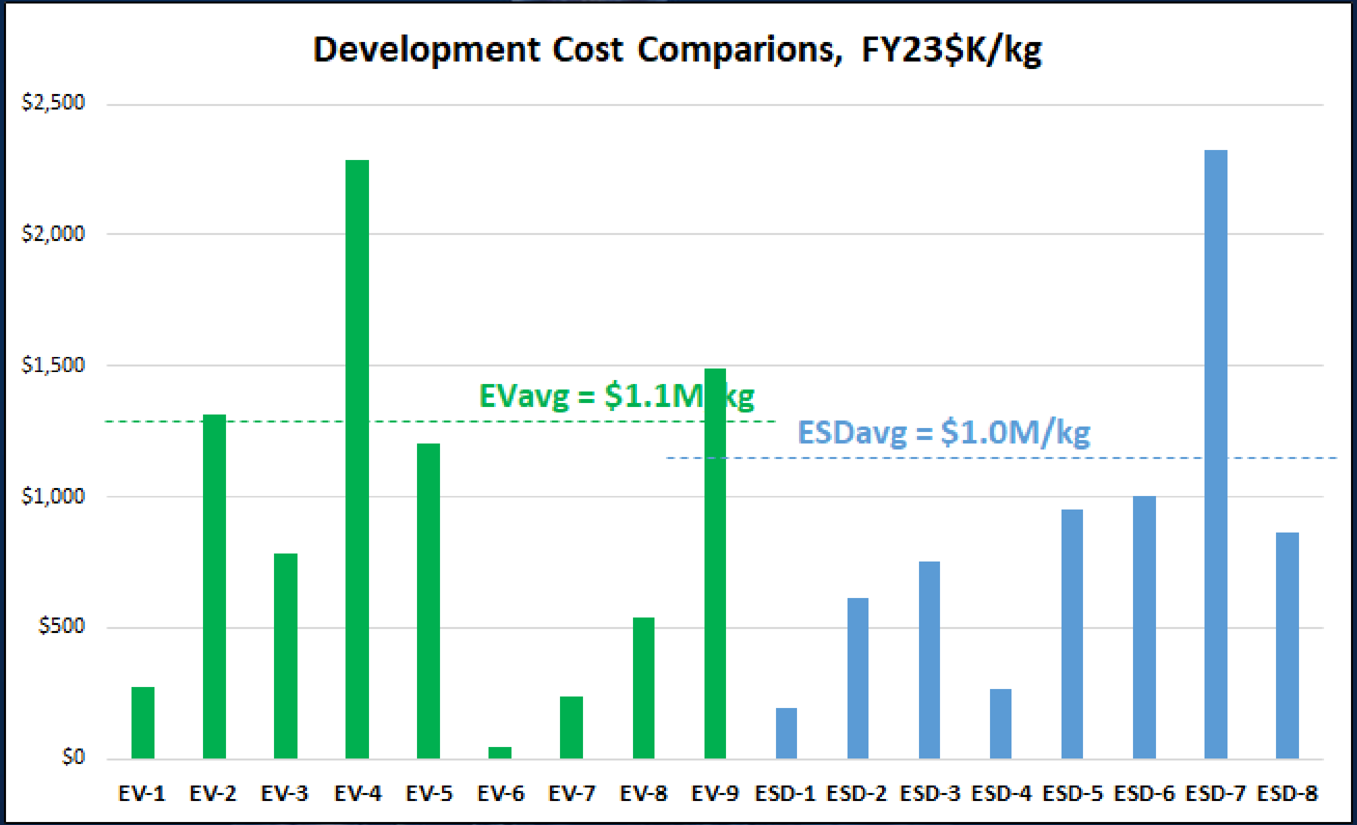
Earth Ventures Cost/Schedule Performance Study
Finding 5: EV Projects experience shorter launch slips than other ESD projects

- **EV projects have less schedule slips than other ESD projects**
  - EV project average LRD slip = 13.4mo
  - Other ESD project average LRD slip = 22.3mo



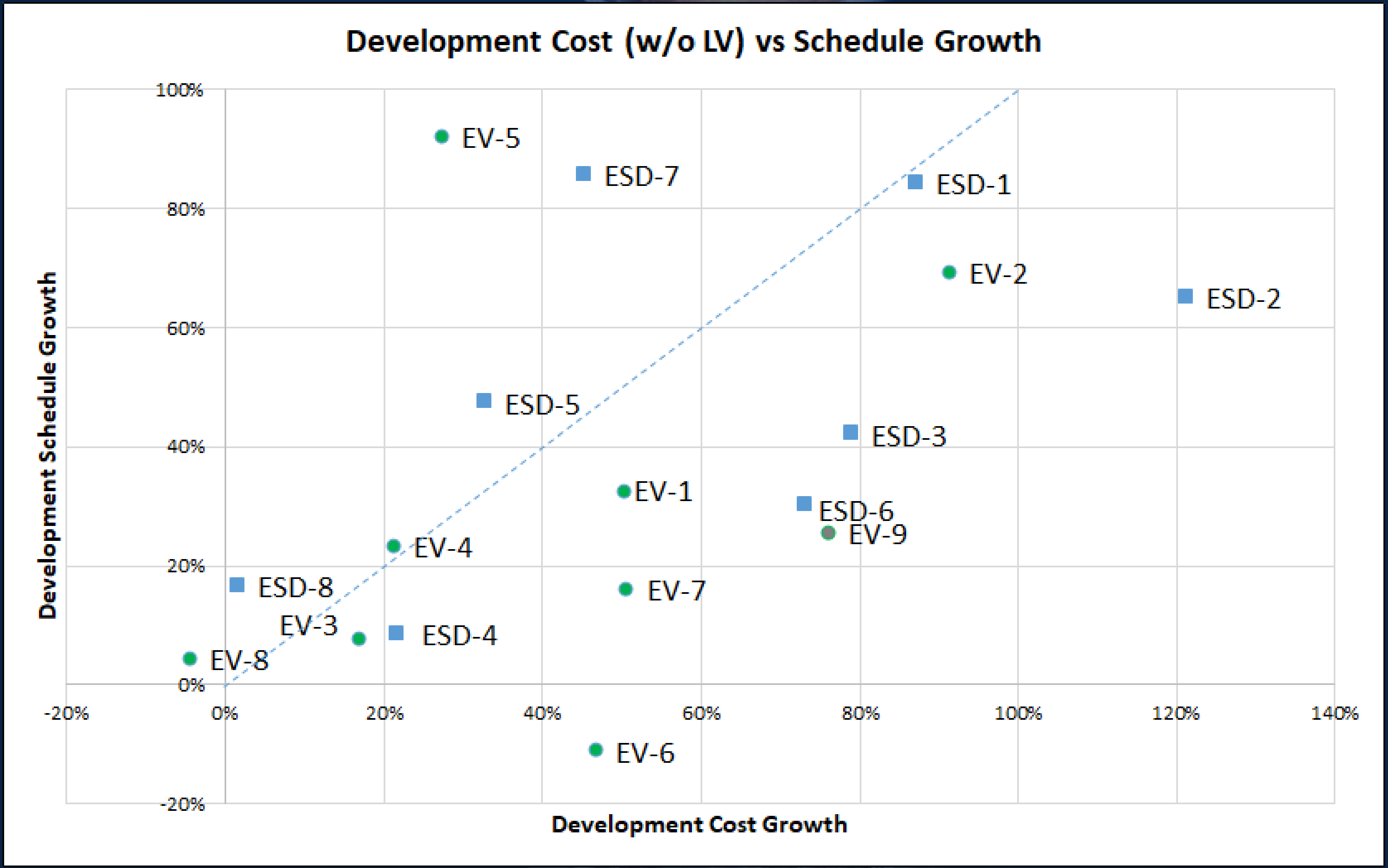
Earth Ventures Cost/Schedule Performance Study
Finding 6: Development $/kg is similar between EV and other ESD projects

- **Average development costs are close to $1M/kg for EV and Other ESD projects**
  - Higher than typical costs for PREFIRE and GOES-R; PREFIRE highlights higher $/kg for their low mass CubeSats; Higher $/kg for GOES-R due to non-recurring costs and high PM/SE/MA costs
  - Costs include all Phase BCD elements except Launch Services



Earth Ventures Cost/Schedule Performance Study
Finding 7: Unclear relationship between cost and schedule growth

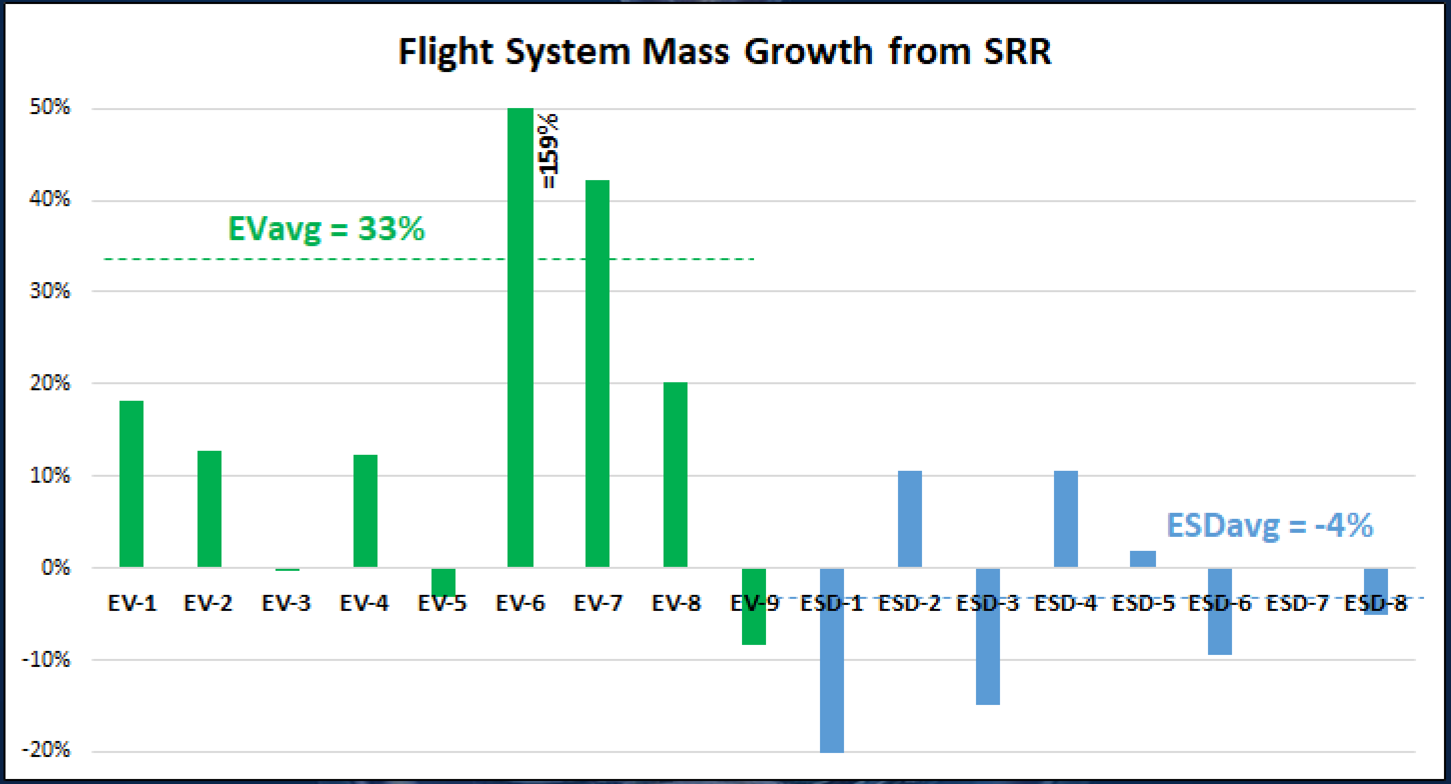
- **Cost and schedule growth do not appear well-correlated**
  - Although longer schedules can drive cost increases, many cost increases are from procurements, labor rates, inflation, and other non-schedule factors



Note: GeoCarb is shown but not included in this study's statistics

Earth Ventures Cost/Schedule Performance Study
Finding 8: Mass growth for EV projects is greater than for other ESD projects

- **Although mass growth for EV projects is greater than for other ESD projects, this is misleading due to differences in scope**
  - Significant scope differences between instrument projects and full missions
  - Mass reductions are typically associated with project descopes (often driven by cost increases)



Earth Ventures Cost/Schedule Performance Study
Findings

COST

Finding 1: Average cost per project is significantly less for EV projects than other ESD projects

Finding 2: Development cost growth is lower for EV projects than other ESD projects

Finding 3: PM/SE/MA (WBS 1/2/3) is a higher % of hardware for EV projects

SCHEDULE

Finding 4: EV projects have shorter SRR-Launch schedules than other ESD projects

Finding 5: EV projects experience shorter launch slips than other ESD projects

Finding 6: Unclear relationship between cost and schedule growth

TECHNICAL

Finding 7: Development $/kg is similar between EV and other ESD projects

Finding 8: Mass growth for EV projects is greater than for other ESD projects

Earth Ventures Cost/Schedule Performance Study
Summary of Key Findings

- **Average cost per project is significantly less for EV projects than other ESD projects [F1]**
  - Average EV development = $96M
  - Average Other ESD development = $1,362M
- **Average development cost growth (w/o LV) from ATP to Launch (or Latest) for EV Projects (including ACC) is significantly less than for other Earth Science Projects [F2]**
  - EV growth (with ACC) averages 38%; EV growth is mainly from TEMPO (91%), GEDI (51%), EMIT (50%), and ECOSTRESS (47%)
  - Other ESD missions average 58%; ESD growth is mainly from OCO (121%), CloudSat (87%), & SMAP (73%)
  - Note: EV growth w/o ACC is only 7%
- **Costs for EV project support functions (PM/SE/MA) expressed as a percentage of flight hardware (i.e., payload and spacecraft) cost is higher than other ESD projects [F3]**
  - EV projects average 22% compared to ESD which averages 15%
- **EV projects appear to require less time from ATP-Launch and have less schedule slips than other ESD projects [F4, F5]**
  - Average EV ATP-Launch schedule = 5.0 years with 13.4 months average LRD slip
  - Average Other ESD ATP-Launch schedule = 7.5 years with 22.3 months average LRD slip

Earth Ventures Cost/Schedule Performance Study
Qualitative Thoughts from the Presenter

EV missions are not considered too big to fail - Category 3, Class C (1/3) or D (2/3)

EV missions often consist of one or at most two instrument payloads

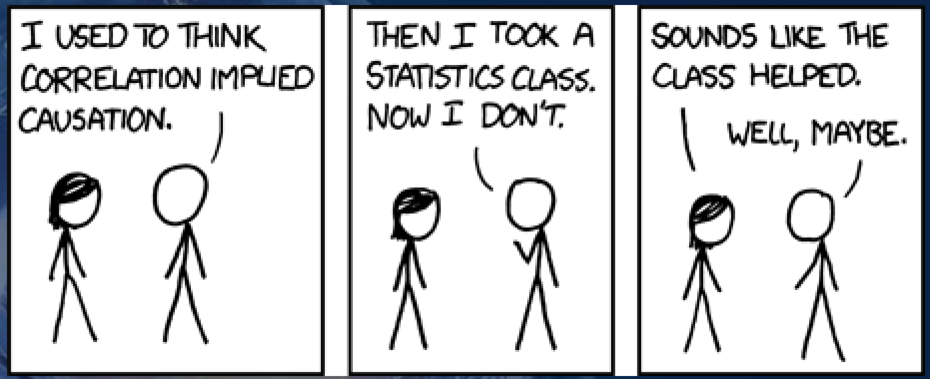
EV missions are competed through a one-step Ao evaluation process

EV missions maintain descopes through all phases of development

Many EV missions have benefitted from the International Space Station Hosting Environment. Launch, mature hosting requirements, amble resources (data/power)

Decision authority resides primarily at the Mission Directorate or Division level. Significant project management insight and oversight by Program Office.

Recent SMD Large Sat/Small Sat conference March 2024 - *Smaller, Class D, Ao missions create a steady pipeline of opportunity for industry, both science and aerospace. This pipeline provides funding and training to help better enable more complex larger missions. Without the regular and frequent smaller Ao opportunities the industry will propose more and more unrealistic larger missions to increase the likelihood of them obtaining some work.*



https://xkcd.com/552

Earth Science Strategy for Flight Opportunities (FY25)

Mission	Mission Type	Release	Selection	Major Milestone
EVS-1 (EV-1) (AirMoss, ATTREX, CARVE, DISCOVER-AQ, HS3)	5 Suborbital Airborne Campaigns	2009	2010	Completed KDP-F
EVM-1 (CYGNSS)	Class D SmallSat Constellation	2011	2012	Launched December 2016
EVI-1 (TEMPO)	Class C Geostationary Hosted Instrument	2012	2012	Launched April 2023
EVI-2 (ECOSTRESS & GEDI)	Class C & Class D ISS-hosted Instruments	2013	2014	Launched June & December 2018
EVS-2 (ACT-America, ATOM, NAAMES, ORACLES, OMG, CORAL)	6 Suborbital Airborne Campaigns	2013	2014	Completed KDP-F
EVI-3 (MAIA & TROPICS)	Class C LEO Hosted Instrument & Class D CubeSat Constellation	2015	2016	MAIA Delivery 2022; TROPICS Launched in May 2023
EVM-2 (GeoCarb)	Class D Geostationary Hosted Instrument	2015	2016	Cancelled
EVI-4 (EMIT & PREFIRE)	Class C ISS-hosted Instrument & Class D Twin CubeSats	2016	2018	EMIT launched to ISS July 2022; PREFIRE delivery NLT 2023
EVS-3 (ACTIVATE, DCOTSS, IMPACTS, Delta-X, SMODE)	5 Suborbital Airborne Campaigns	2017	2018	All in post-deployment phase.
EVI-5 (GLIMR)	Class C Geostationary Hosted Instrument	2018	2019	Delivery NLT 2024
EVC-1 (Libera)	Class C JPSS-Hosted Radiation Budget Instrument	2018	2020	Delivery NLT 2025
EVM-3 (INCUS)	Class D SmallSats	2020	2021	Launch ~2027
EVI-6 (PolSIR)	Class D CubeSats	2022	2023	Delivery NLT 2027
ESE	Explorer Mission	2023	2025	Launch ~2030 & ~2032
EVS-4	Suborbital Airborne Campaigns	2023	2024	N/A
EVX*	Orbital instrument, mission, or continuity	2026	2027	Launch ~2032
EVS-5	Suborbital Airborne Campaigns	2027	2028	N/A
EVX*	Orbital instrument, mission, or continuity	2028	2029	Launch ~2034
ESE	Explorer Mission	2029	2031	Launch ~2037
EVX*	Orbital instrument, mission, or continuity	2030	2031	Launch ~2036

EVS
Sustained sub-orbital investigations
(~4 years)

EVX
Small-size orbital instruments and missions
(~2 years)

ESE
Medium-size orbital instruments and missions
(~3 years)

Open solicitation/In review

Completed solicitation

*EVX Mission type will be dictated by PoR needs when AO is released.

This fits into ESD strategy for portfolio flexibility and resilience

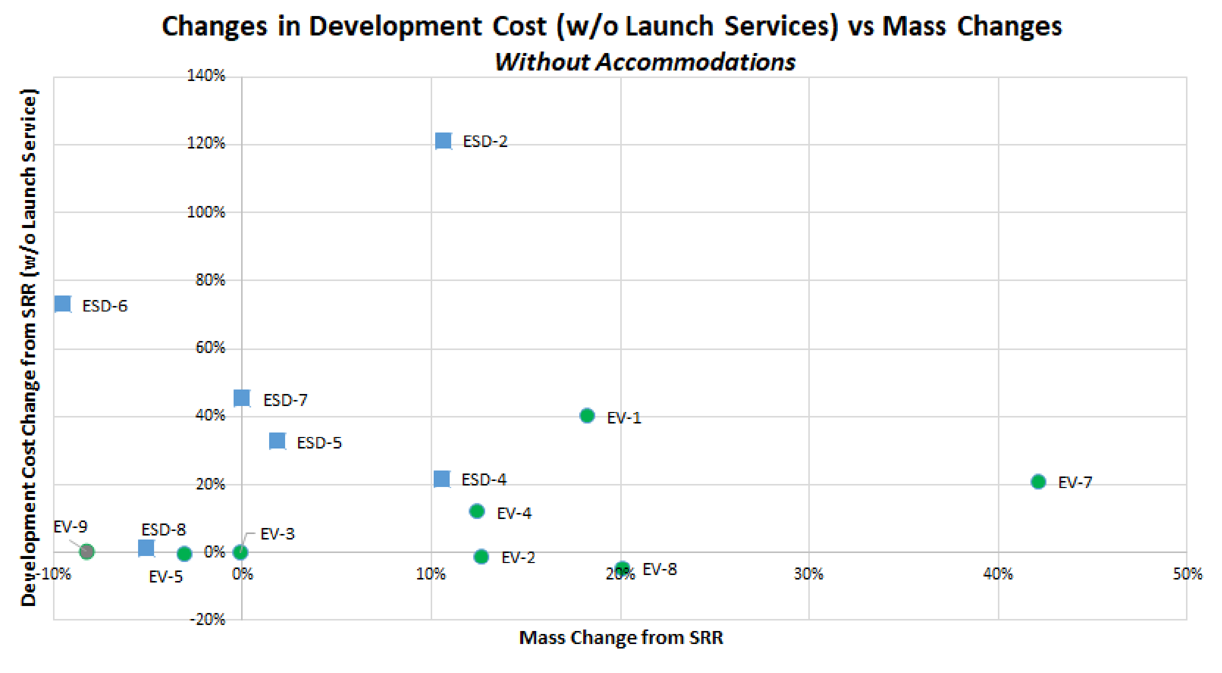
Backup

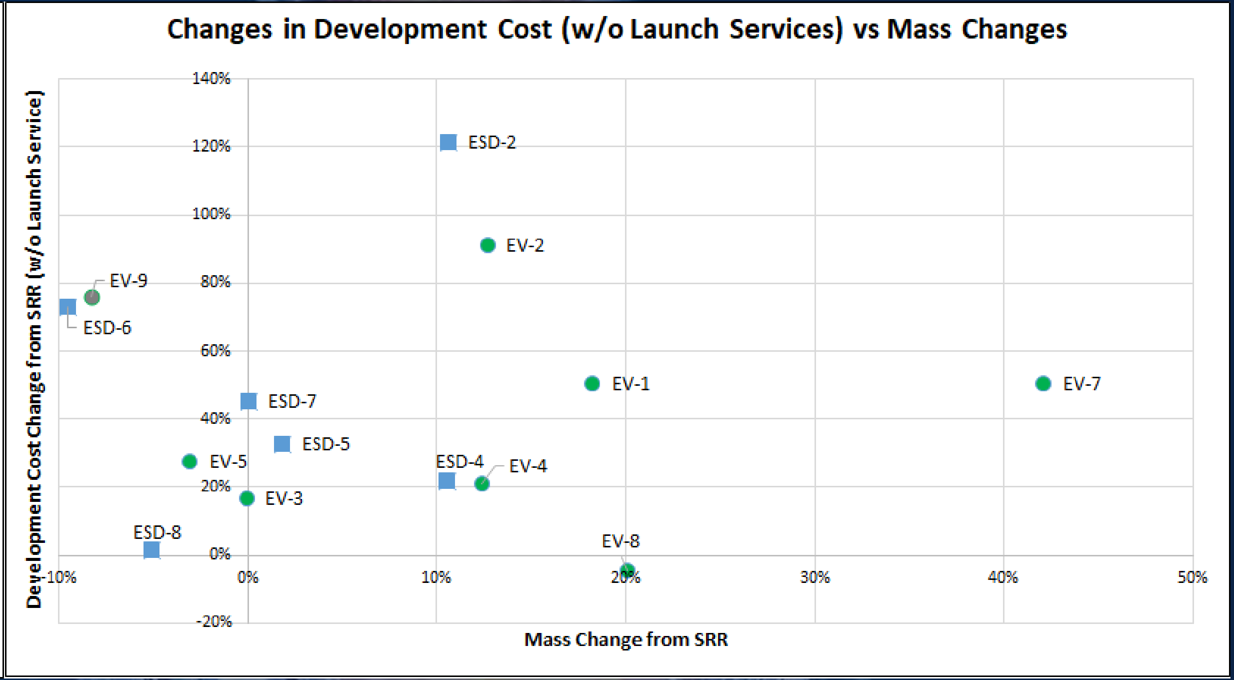
OIG Findings

"While the ESSP Program has controlled cost growth and met milestones for 18 of its 22 active projects, as of May 2023 the remaining four of seven unlaunched projects face cost and schedule challenges primarily related to subcontractor disruptions, access to space costs, and limited experience of PIs managing projects."

[Final Report - IG-23-018 - NASA's Earth System Science Pathfinder Program]

Earth Ventures Cost/Schedule Performance Study
BACKUP: Cost Growth vs Mass Growth

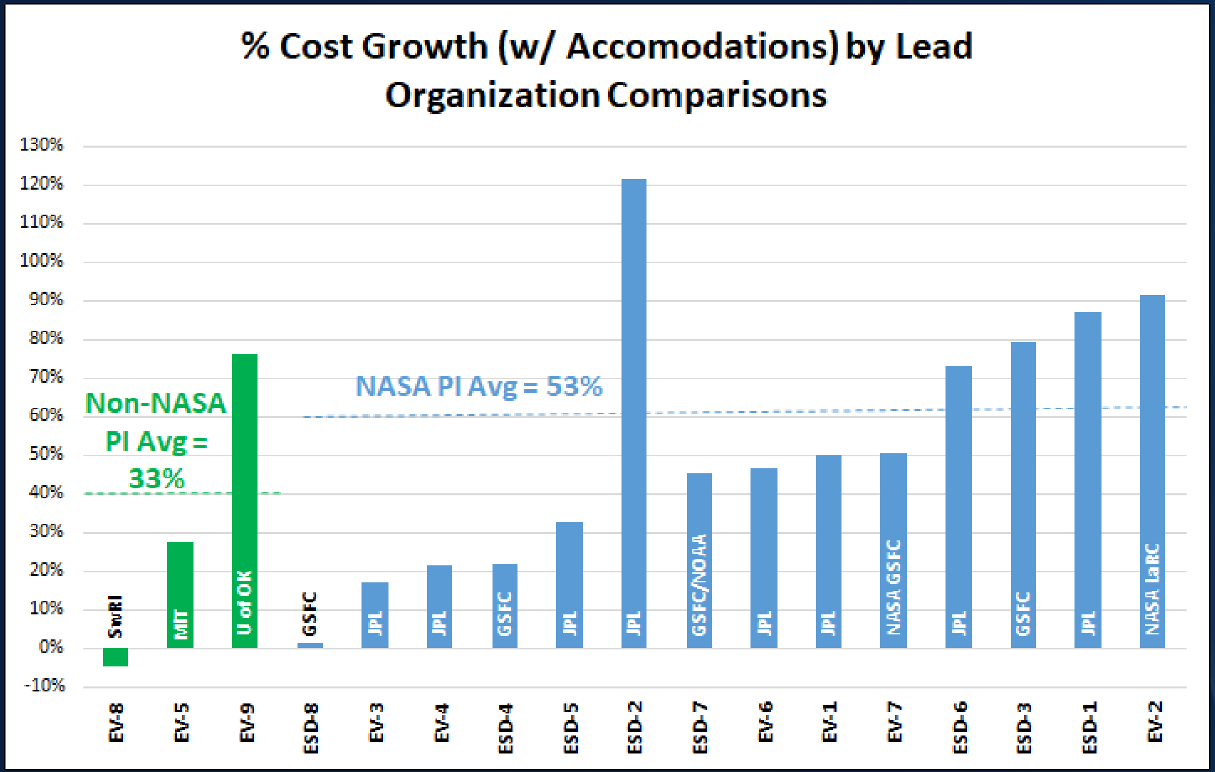




Note: GeoCarb is shown but not included in this study's statistics

- **Cost and mass growth do not seem well-correlated for any of these projects**
  - Cost growth experienced with or without mass growth
  - Some projects use mass reductions to maintain cost

Earth Ventures Cost/Schedule Performance Study
BACKUP: Cost Growth vs Project Lead Organization



- Although it appears as though non-NASA led missions have less cost growth when compared to NASA led missions, the small size of the non-NASA data set does not provide sufficient evidence to support the claim.
  - More non-NASA led missions will need to be completed before a conclusion can be made

NASA earth

science.nasa.gov/earth

Your Home. Our Mission.