

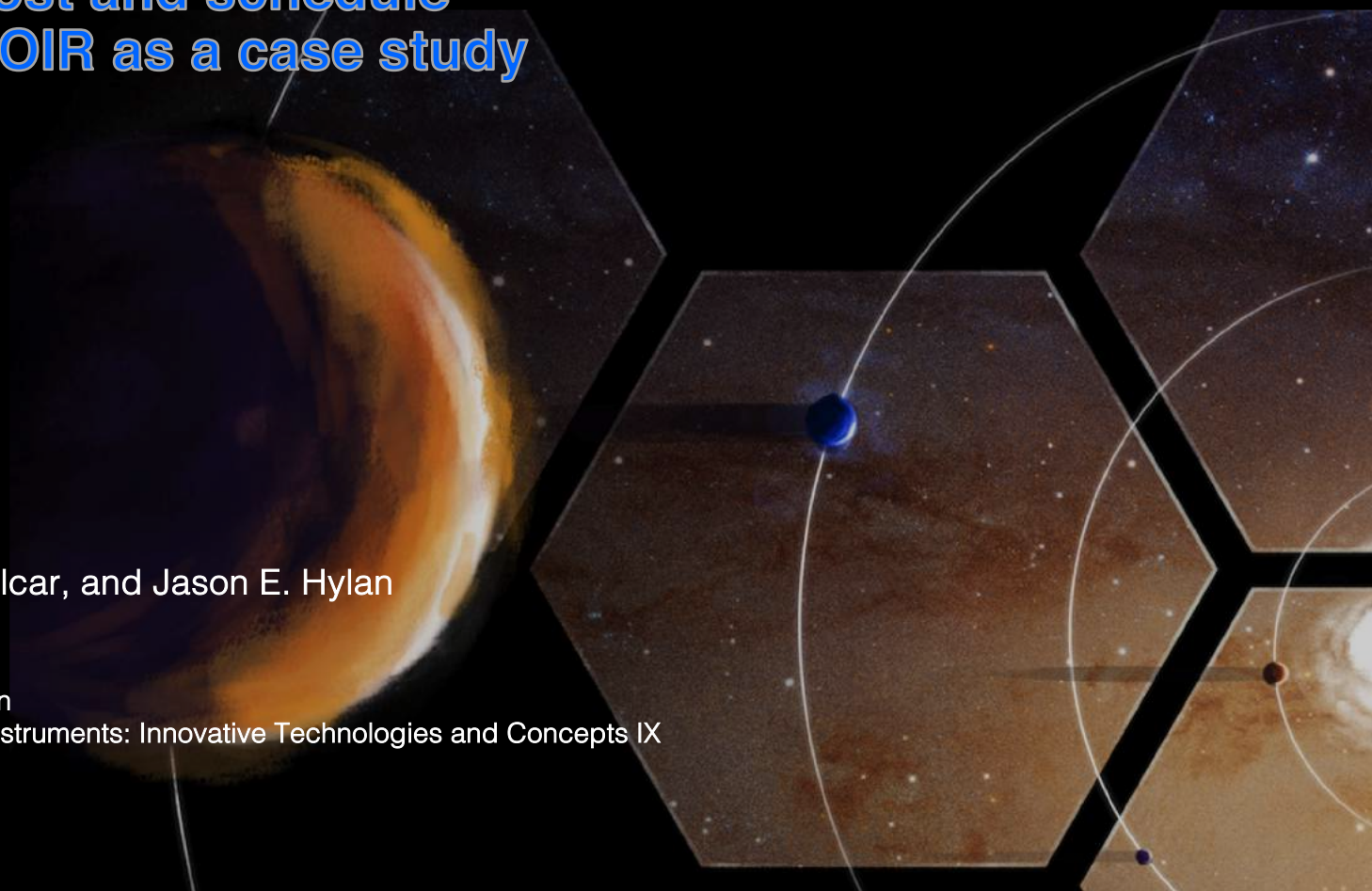
Evolving management strategies to improve NASA flagship's cost and schedule performance: LUVVOIR as a case study



Julie A. Crooke, Matthew R. Bolcar, and Jason E. Hylan

SPIE Optics and Photonics Meeting
Astronomical Optics and Instrumentation
UV/Optical/IR Space Telescopes and Instruments: Innovative Technologies and Concepts IX

12 August 2019





Motivations for ...NASA's flagships

Imagine NASA without the Apollo Program ...



OUT THERE

Apollo 8's Earthrise: The Shot Seen Round the World

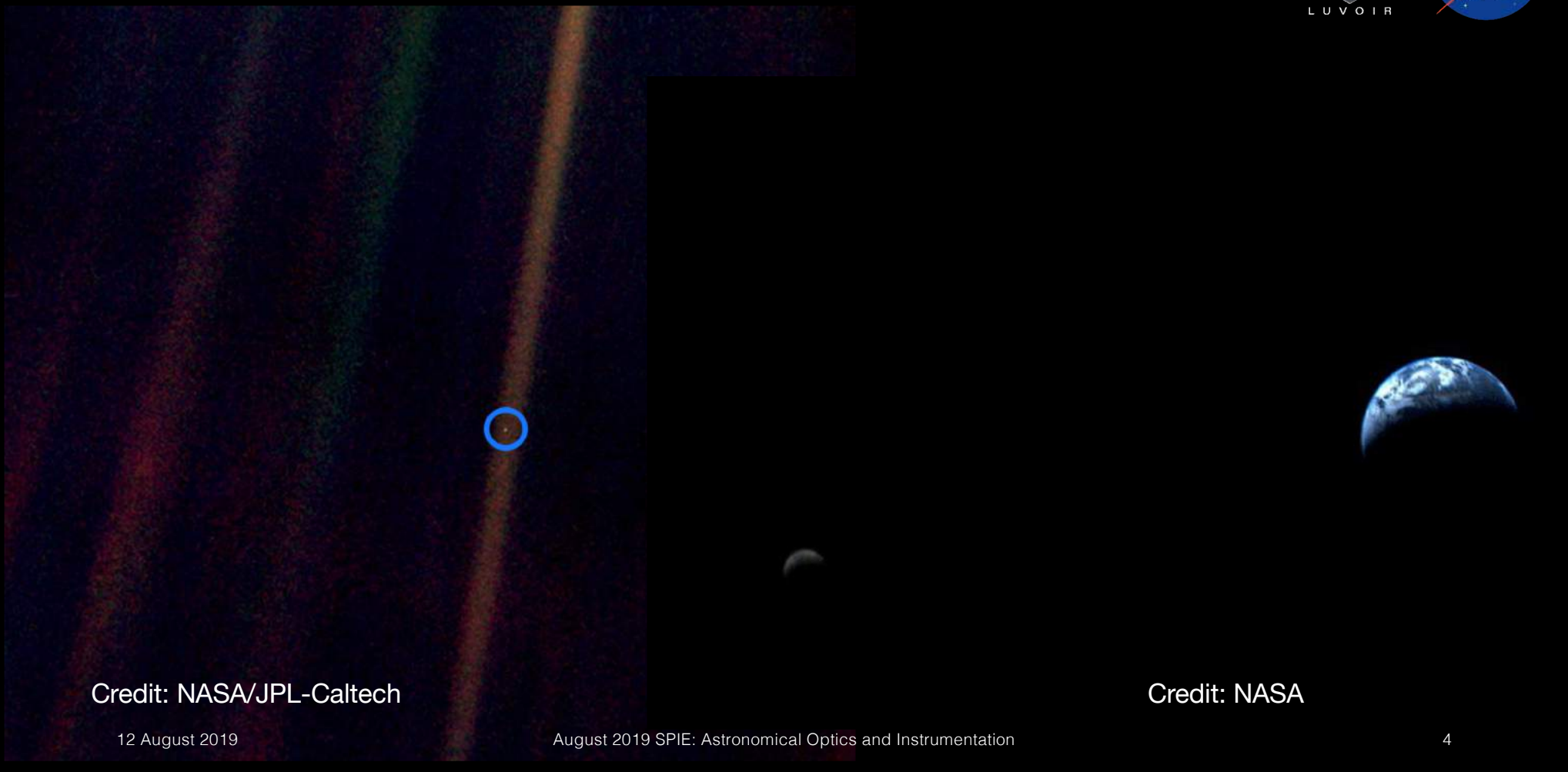
Half a century ago today, a photograph from the moon helped humans
rediscover Earth.

12 August 2019

August 2019 SPIE: Astronomical Optics and Instrumentation

Credit: NASA

Imagine NASA without Voyager ...



Credit: NASA/JPL-Caltech

Credit: NASA

12 August 2019

August 2019 SPIE: Astronomical Optics and Instrumentation

Imagine NASA without Hubble ...



Imagine NASA without Hubble ...

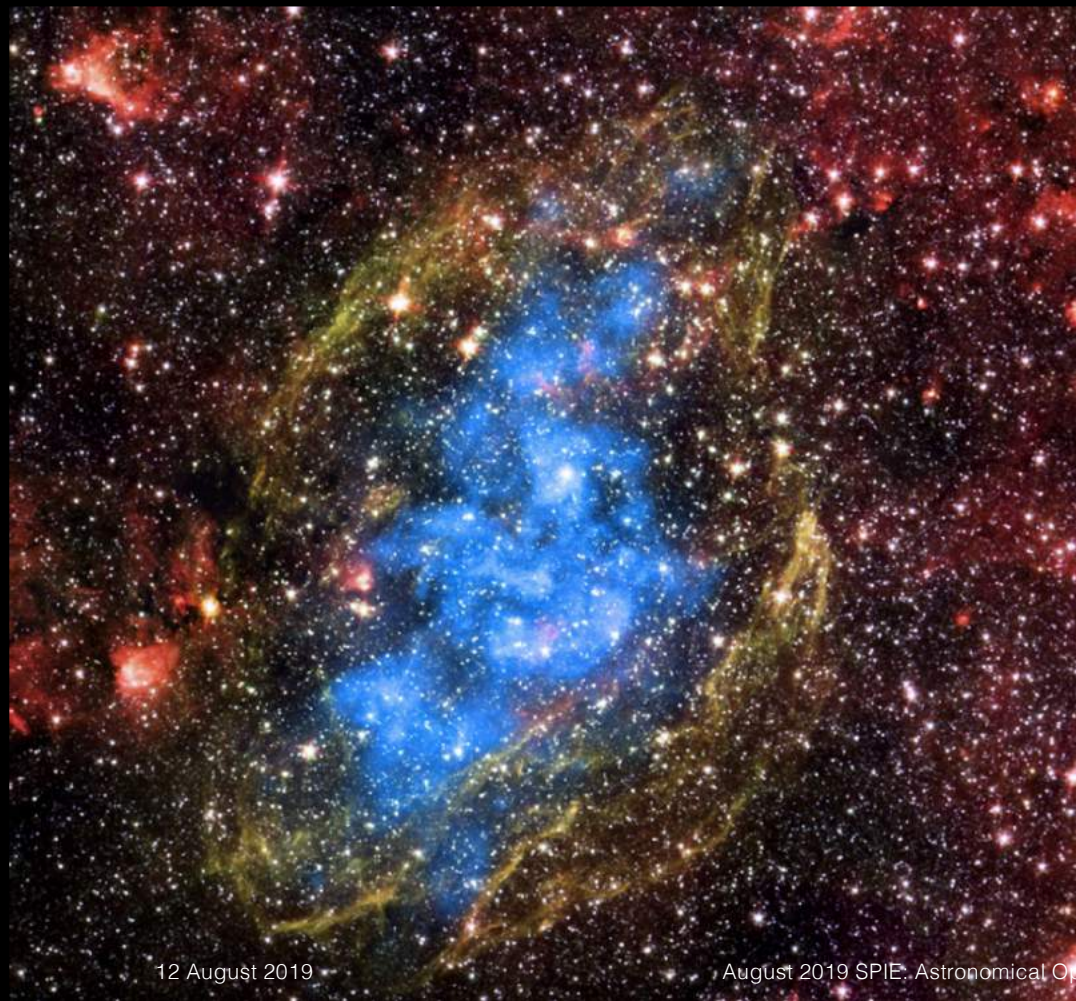


Eagle Nebula
(high resolution over wide field)

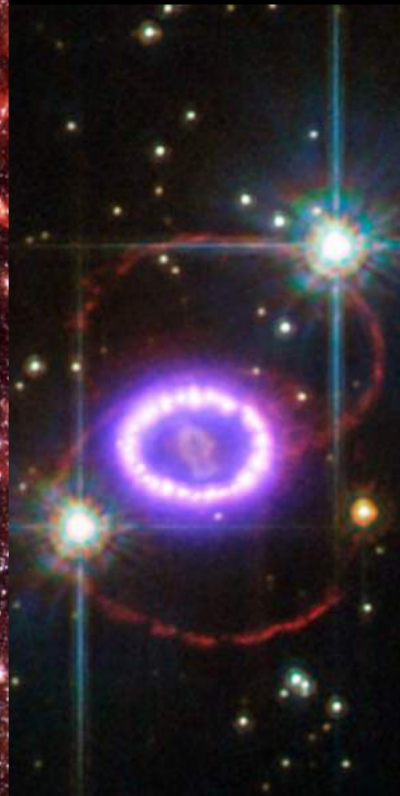
Jupiter's aurora
(UV, global monitoring)



Imagine NASA without Chandra ...



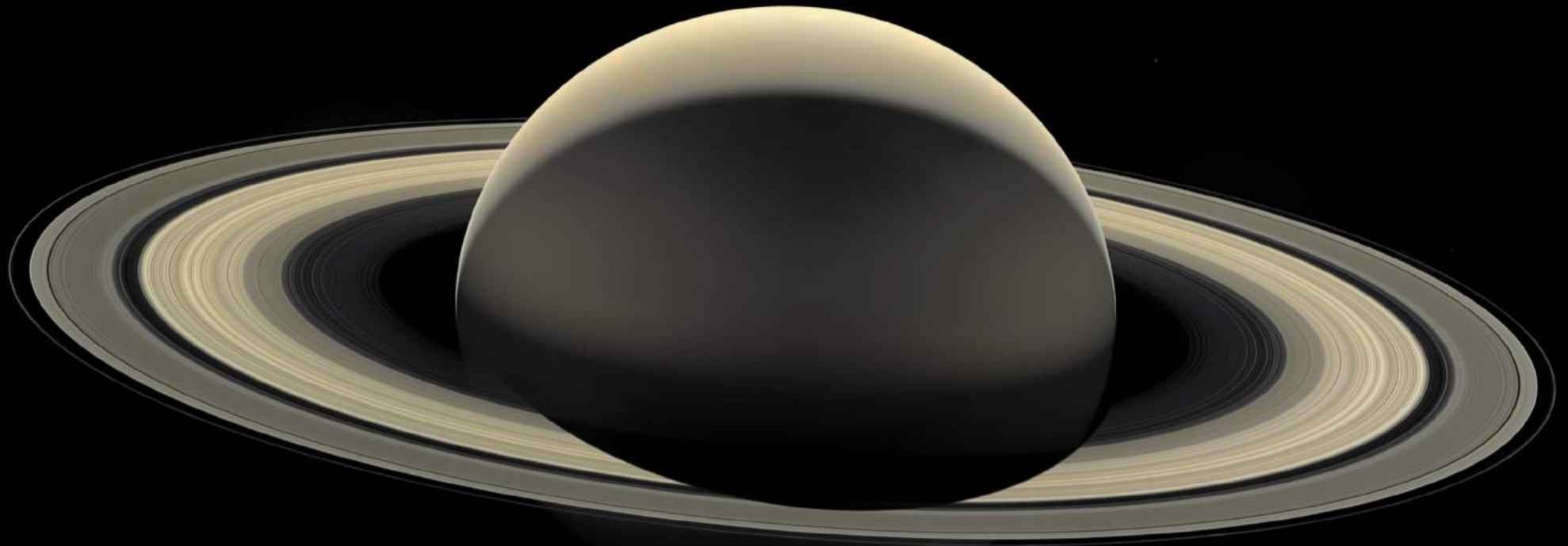
12 August 2019



August 2019 SPIE: Astronomical Optics and Instrumentation



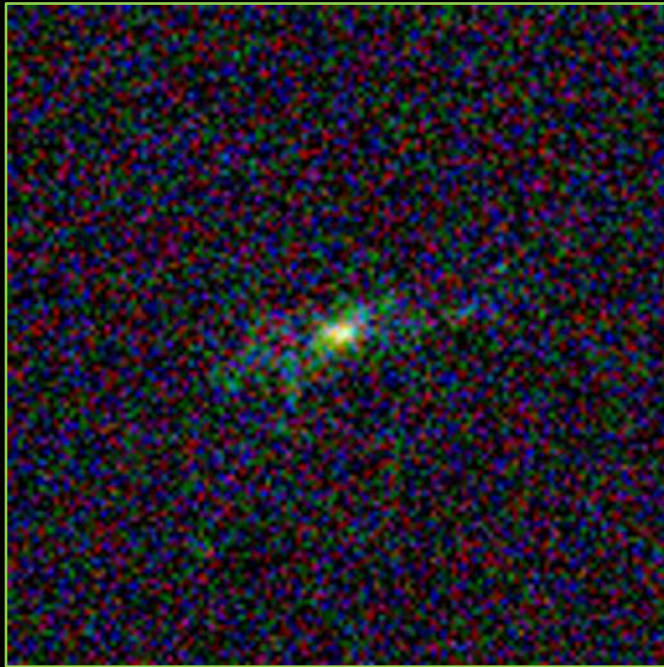
Imagine NASA without Cassini ...



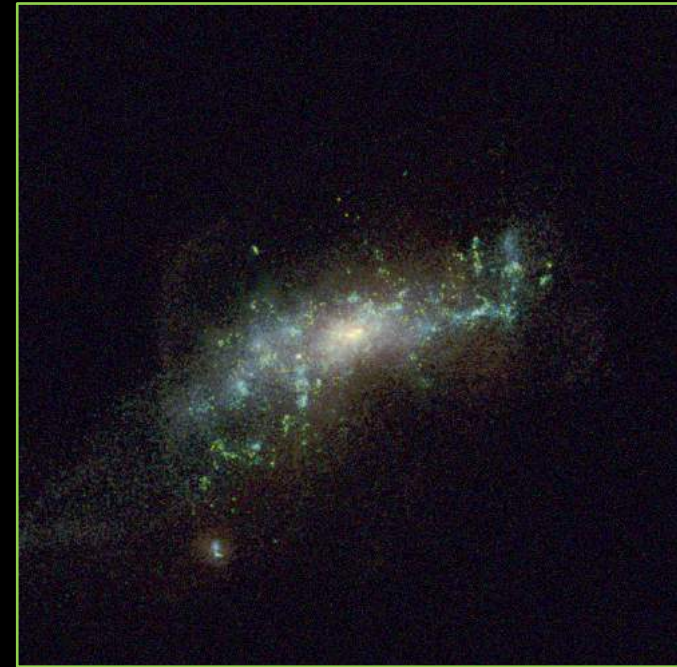


Imagine NASA with ...LUVOIR

Imagine NASA astronomy with LUVOIR ...



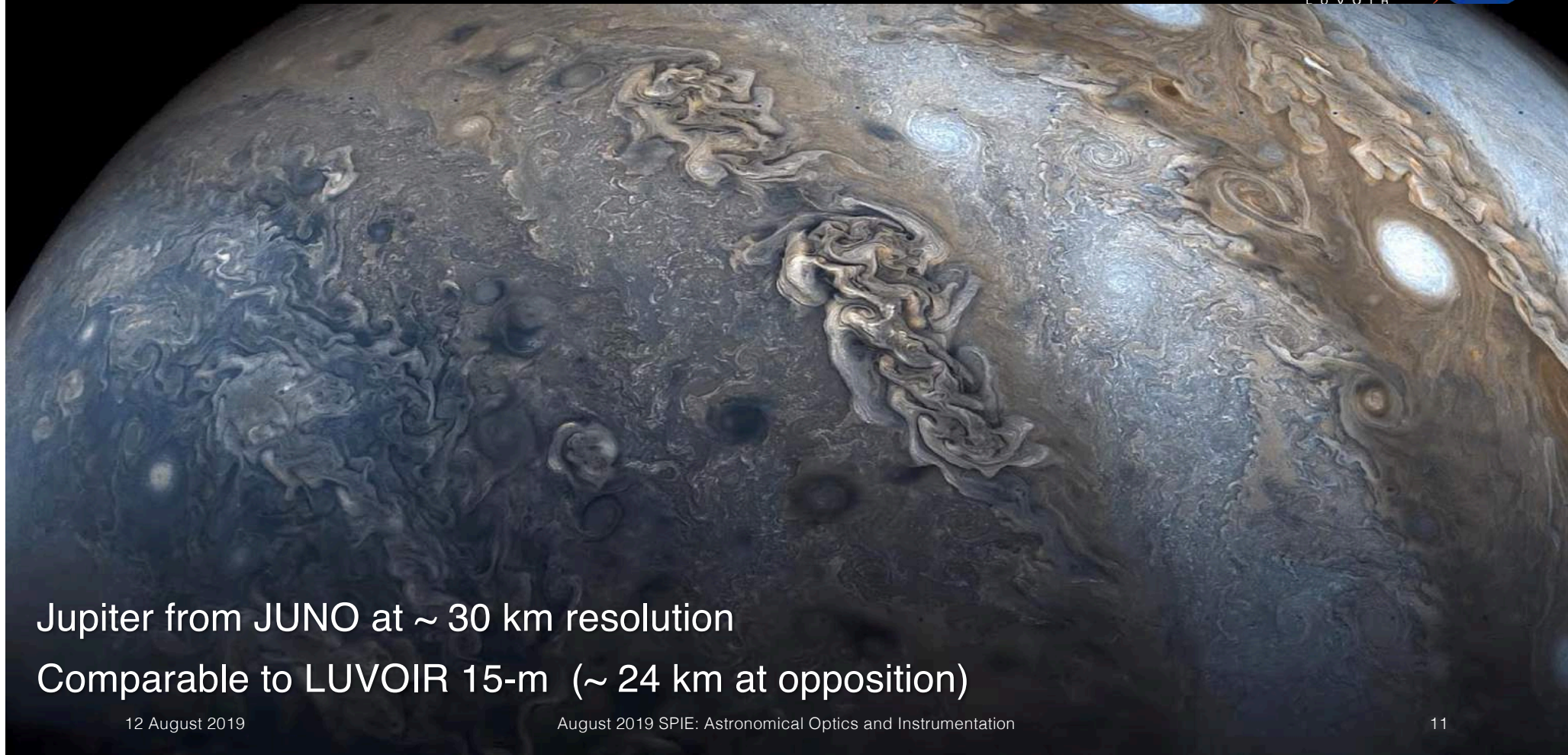
Low-mass galaxy at $z = 2$
with HST



Low-mass galaxy at $z = 2$
with 15-m LUVOIR

Credit: G. Snyder, M. Postman (STScI)

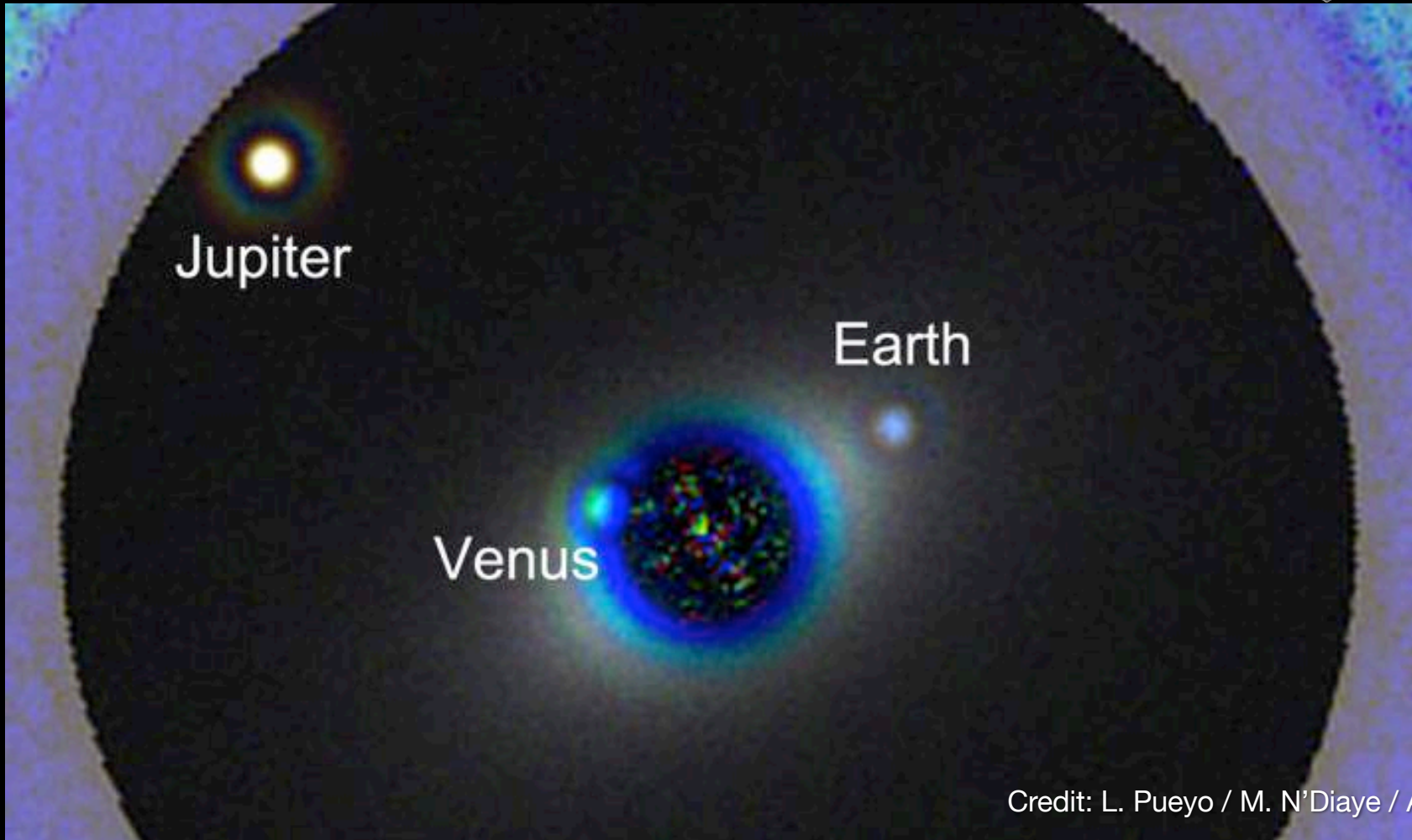
Imagine solar system science with LUVOIR ...



Jupiter from JUNO at ~ 30 km resolution

Comparable to LUVOIR 15-m (~ 24 km at opposition)

Imagine seeing other solar systems...



Credit: L. Pueyo / M. N'Diaye / A2Roberge



COSMIC ORIGINS
&
THE ULTRA-FAINT
UNIVERSE



EXOTIC WORLDS

THE SEARCH
FOR LIFE



OUR DYNAMIC
SOLAR SYSTEM



LUVOIR



Motivations for ...Improving on NASA's flagship cost and schedule performance

Motivations for ...Improving on NASA's flagship cost and schedule performance



GAO: NASA Programs Rack Up Delays, Cost Overruns

Motivations for ...Improving on NASA's flagship cost and schedule performance



GAO: NASA Programs Rack Up Delays, Cost Overruns

JWST EXCEEDS COST CAP, LAUNCH DELAYED TO 2021

JUNE 28TH, 2018

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Motivations for ...Improving on NASA's flagship cost and schedule performance



GAO: NASA Programs Rack Up Delays, Cost Overruns

JWST EXCEEDS COST CAP, LAUNCH DELAYED TO 2021

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NASA weighs delaying WFIRST to fund JWST overrun

by Jeff Foust — July 25, 2018



Motivations for ...Improving on NASA's flagship cost and schedule performance



GAO: NASA Programs Rack Up Delays, Cost Overruns

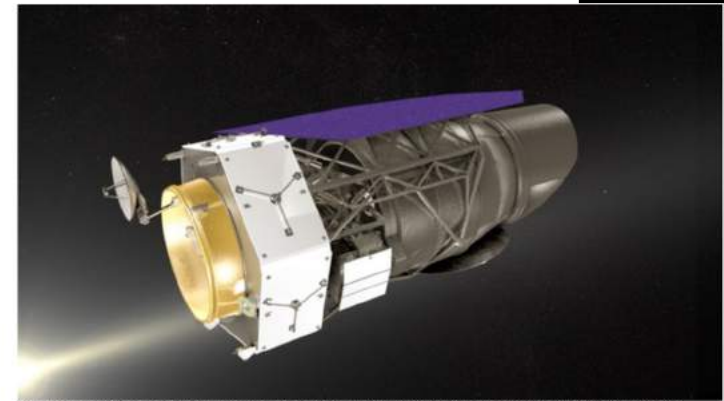
JWST EXCEEDS COST CAP, LAUNCH DELAYED TO 2021

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For the second year in a row, NASA's budget request proposes to cancel the WFIRST astrophysics flagship mission. (credit: NASA)

Cost challenges continue for NASA science missions

by Jeff Foust
Monday, March 25, 2019

Motivations for ...Improving on NASA's flagship cost and schedule performance



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NASA

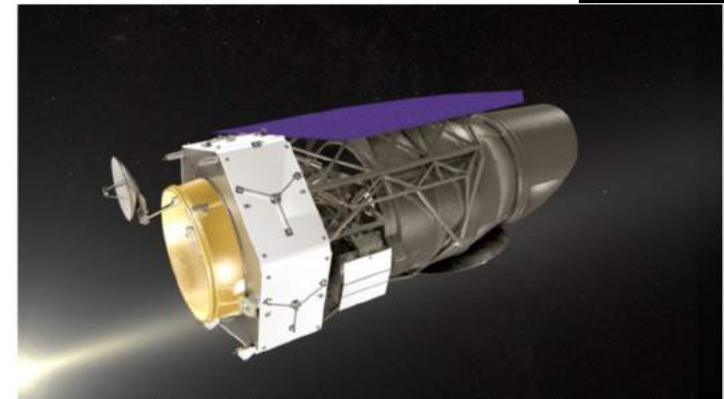
National Aeronautics and Space Administration

Office of Inspector General

Testimony before the House of Representatives
Subcommittee on Space, Committee on Science,
Space, and Technology

NASA COST AND SCHEDULE OVERRUNS: ACQUISITIONS AND PROGRAM MANAGEMENT CHALLENGES

Statement of Paul K. Martin
Inspector General
National Aeronautics and Space Administration



For the second year in a row, NASA's budget request proposes to cancel the WFIRST astrophysics flagship mission. (credit: NASA)

Cost challenges continue for NASA science missions

by Jeff Foust
Monday, March 25, 2019



**We need to acknowledging that flagships
have additional challenges, and therefore,
they need different management strategies...**

One-of-a-Kind, First-of-Its-Kind



Like any flagship-level mission, LUVOIR is a highly complex, nested, system-of-systems that has never been built before

Like any flagship-level mission, it will encounter challenges to the design and implementation

Must use *and adapt* what we have learned on past missions like Hubble, Cassini, JWST, WFIRST, MAVEN, OSIRIS-REx, Chandra, and others to overcome these challenges



Why we have to improve

- We love NASA's flagships....
- In order to keep them, we have to have better cost and schedule performance



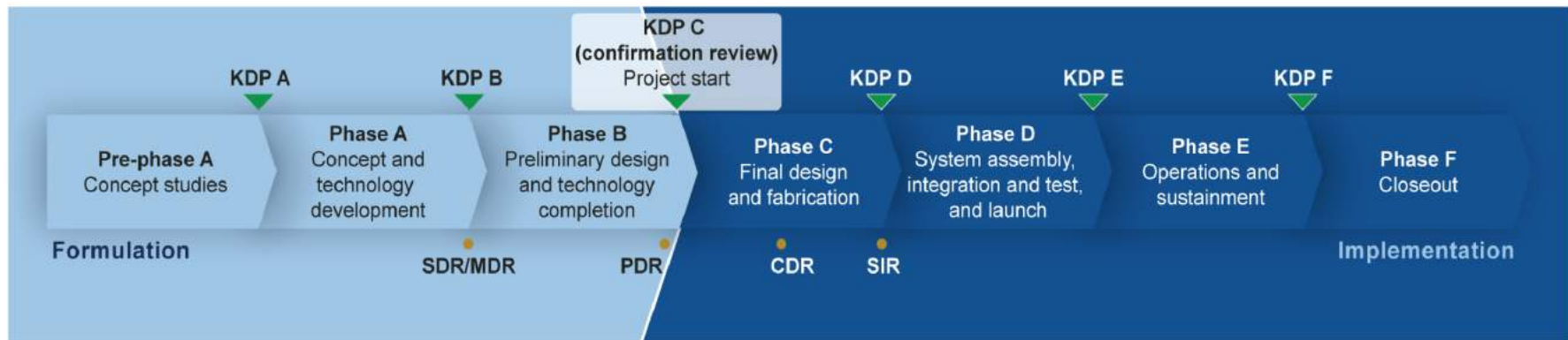
So, what should we do?

- We present our recommendations in the remaining slides
- They are split up into two groups:
 1. **Project-level recommendations**: A project can implement these recommendations within current NASA guidelines
 2. An additional recommendation is an aspect outside the control of any project. Only **NASA, the Agency, and Congress can execute this recommendation** on how to fund NASA's flagships.
- Before we give recommendations, here is information on the NASA lifecycle for developing projects



For reference: NASA's lifecycle development phases

Figure 1: NASA's Life Cycle for Space Flight Projects



Management decision reviews

▼ KDP = key decision point

Technical reviews

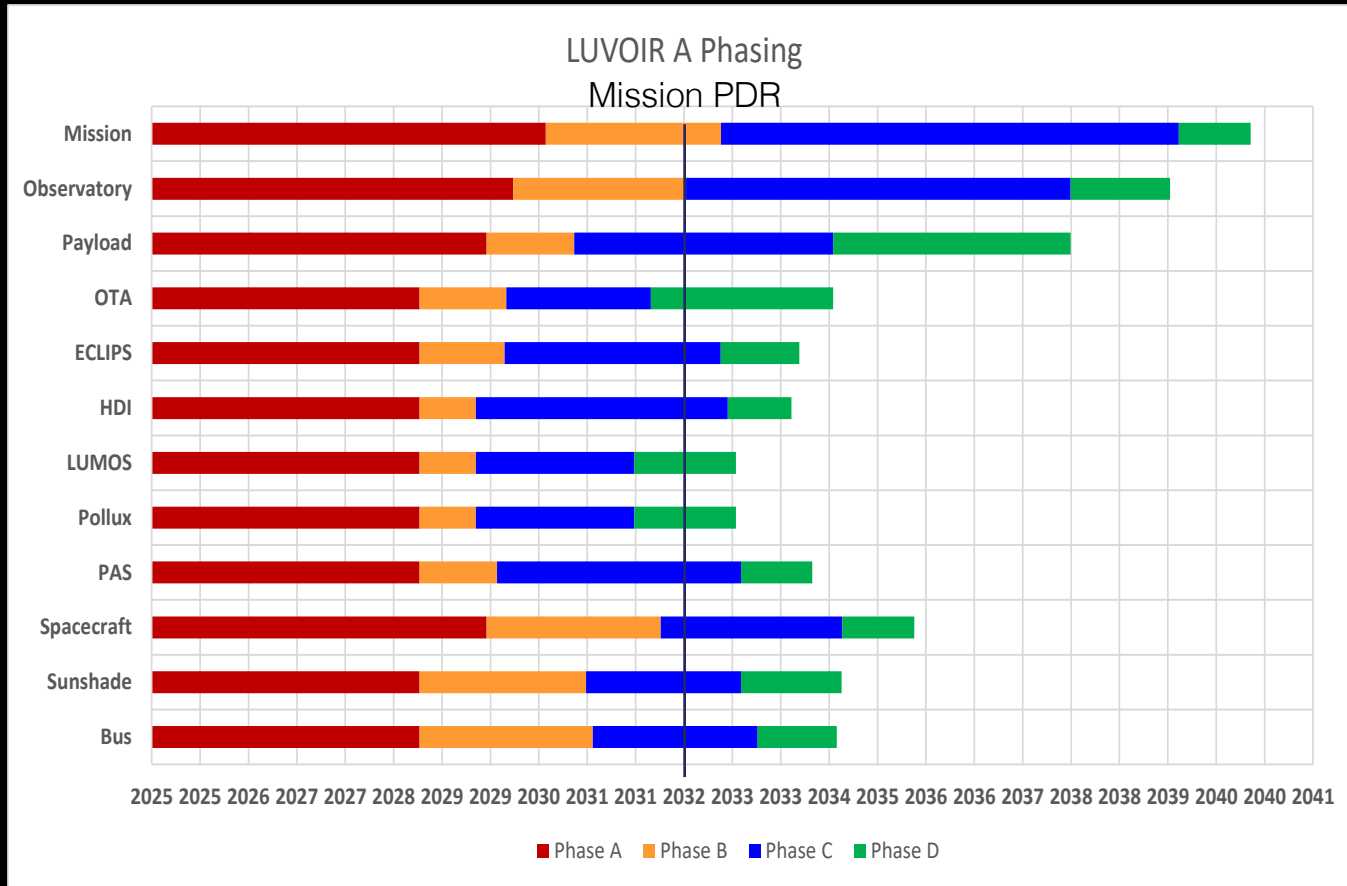
- SDR/MDR = system definition review/mission definition review
- PDR = preliminary design review
- CDR = critical design review
- SIR = system integration review

Source: GAO presentation of National Aeronautics and Space Administration information. | GAO-19-262SP

Currently Allowed Timeline to Develop Technologies to TRL6



- Mission
- Segment
- Element
- Sub-System
- Sub-System
- Sub-System
- Sub-System
- Sub-System
- Sub-System
- Sub-System
- Element
- Sub-System
- Sub-System

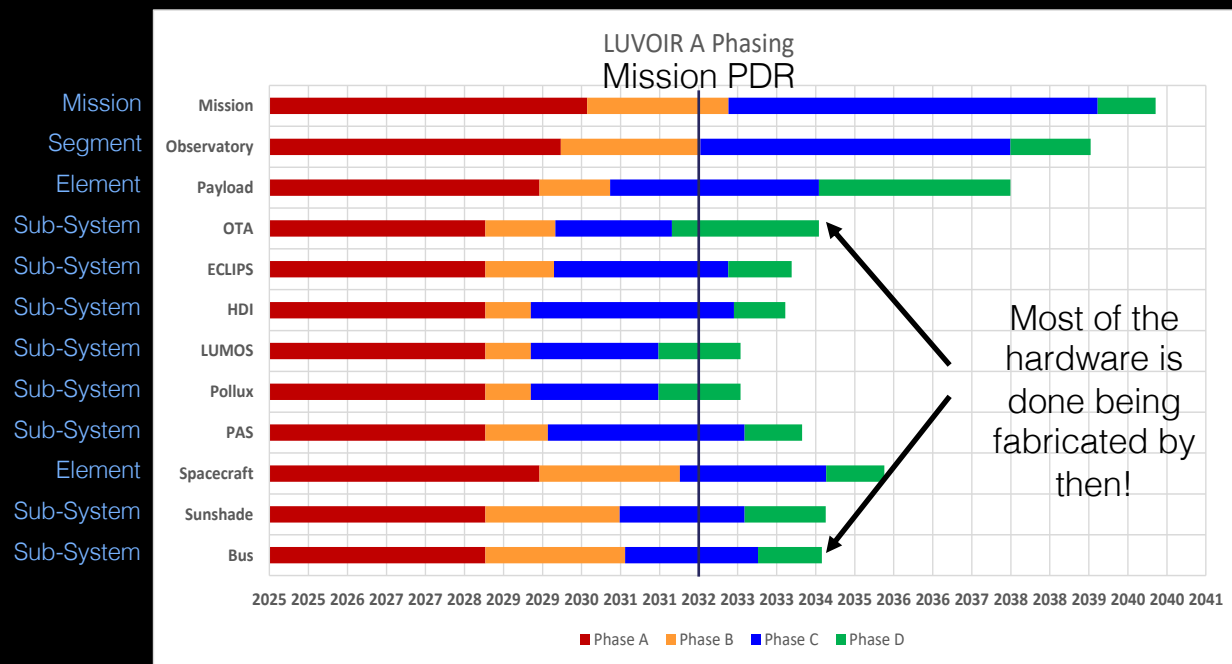


Recommended flagship project-level management strategies: #1: Early technology development



Technology development must be complete by the start of Mission Phase A, *not* Mission Preliminary Design Review (PDR), per current NASA guidance

- Broad Agency Announcements (BAAs) will be used to enable industry and academia to help mature technologies to TRL6 in Pre-Phase A

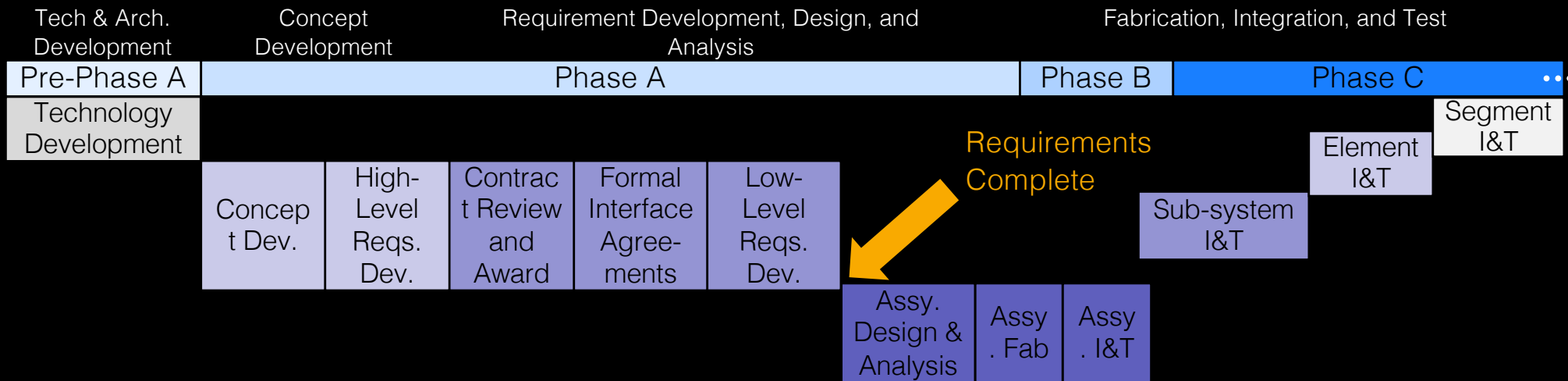


Recommended flagship project-level management strategies: #2: Managing complexity with earlier requirements definition



Full and clear requirements definition must be completed before standing up the full design team

Requirements are always subject to review and modification, but “TBRs” and “TBDs” should be closed before design begins



Recommended flagship project-level management strategies: #3: Managing complexity with pathfinders



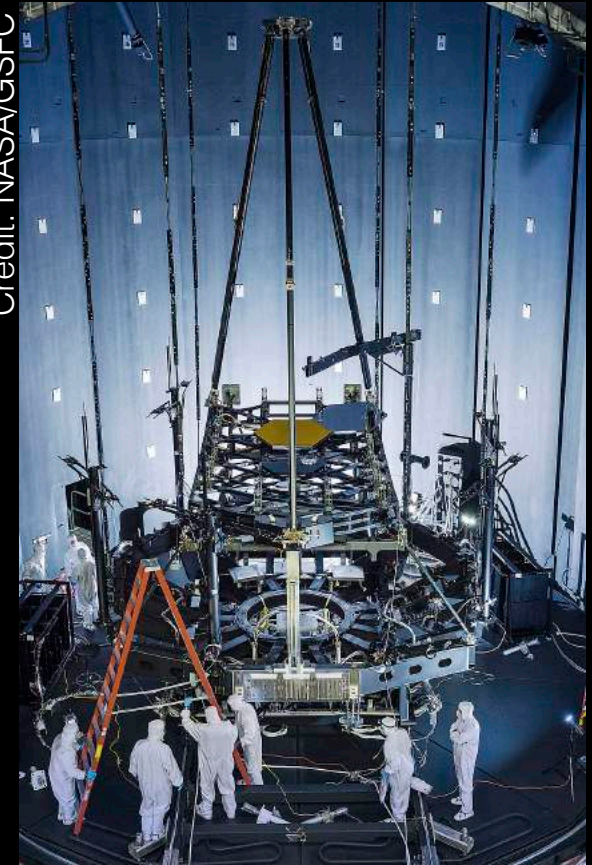
Strategically use pathfinders, ETUs, and EDUs to

1. Inform designs
2. Inform / practice testing processes and procedures

Example 1: Use some primary mirror wings to validate design modularity and de-integration / re-integration process

Example 2: Pathfinder structure to be used in thermal vacuum chamber to optimize testing sequence and troubleshoot bugs

Credit: NASA/GSFC

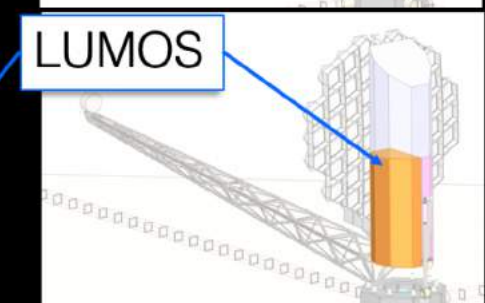
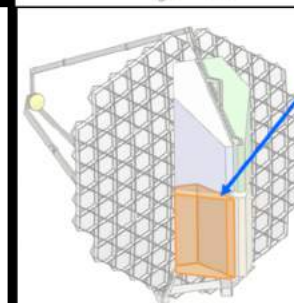
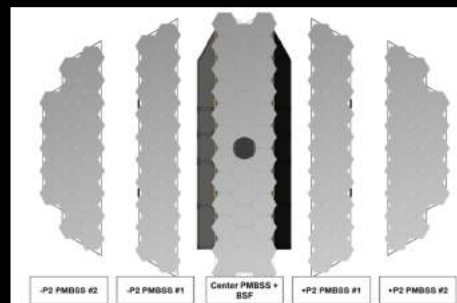
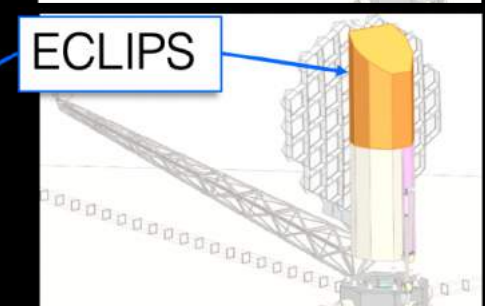
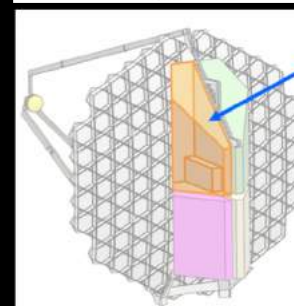
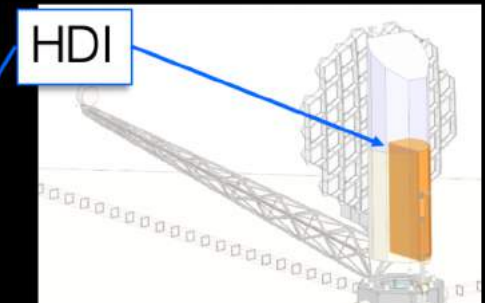
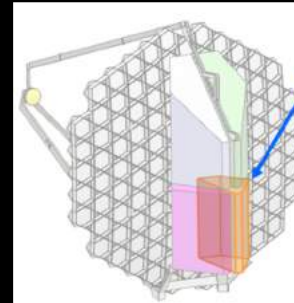


Recommended flagship project-level management strategies: #4: Managing complexity with modular design



Designing your mission to be modular enables:

- Servicing
- Ease of access to systems and subsystems during I&T
- Less complex I&T
- Ease of transportation considerations

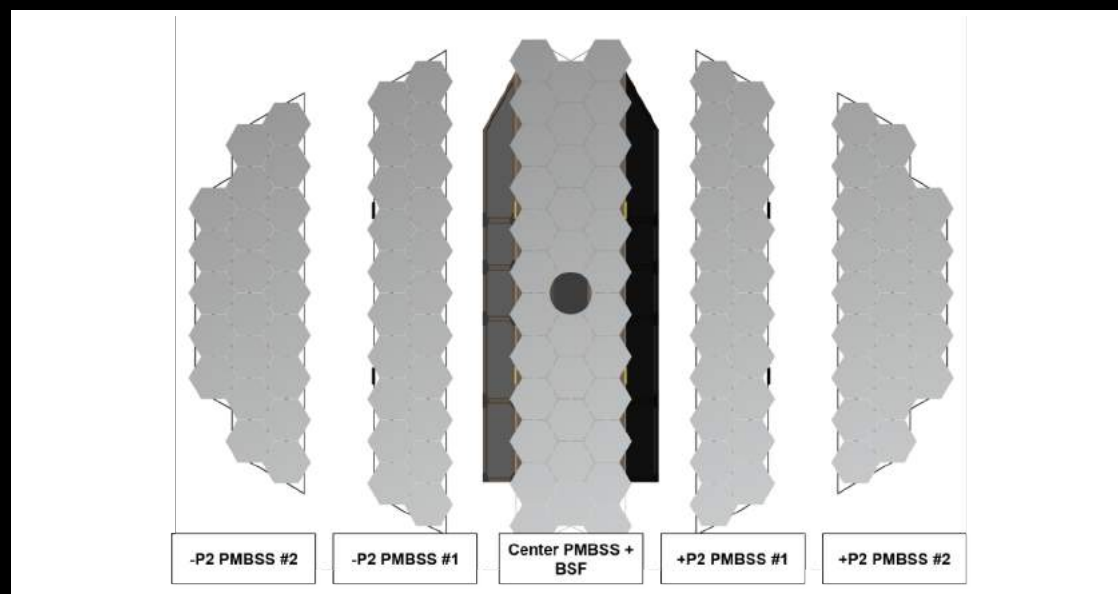


Recommended flagship project-level management strategies: #5: Enable parallel manufacturing, integration, I&T



More parallel operations lead to a more efficient schedule
e.g. Parallel integration of 120x nearly identical primary mirror segment assemblies

Modular design provides for ease of access to components, assemblies, and sub-systems
for efficient response to issues during system integration and test



Recommended flagship project-level management strategies:

#6: Distributed acquisition and partner strategy



Enable broad industry involvement and buy-in through multiple, smaller, open competitions – with requests for procurements (RFPs) - instead of a single winner-take-all prime” competition

Government acts as the “prime contractor”

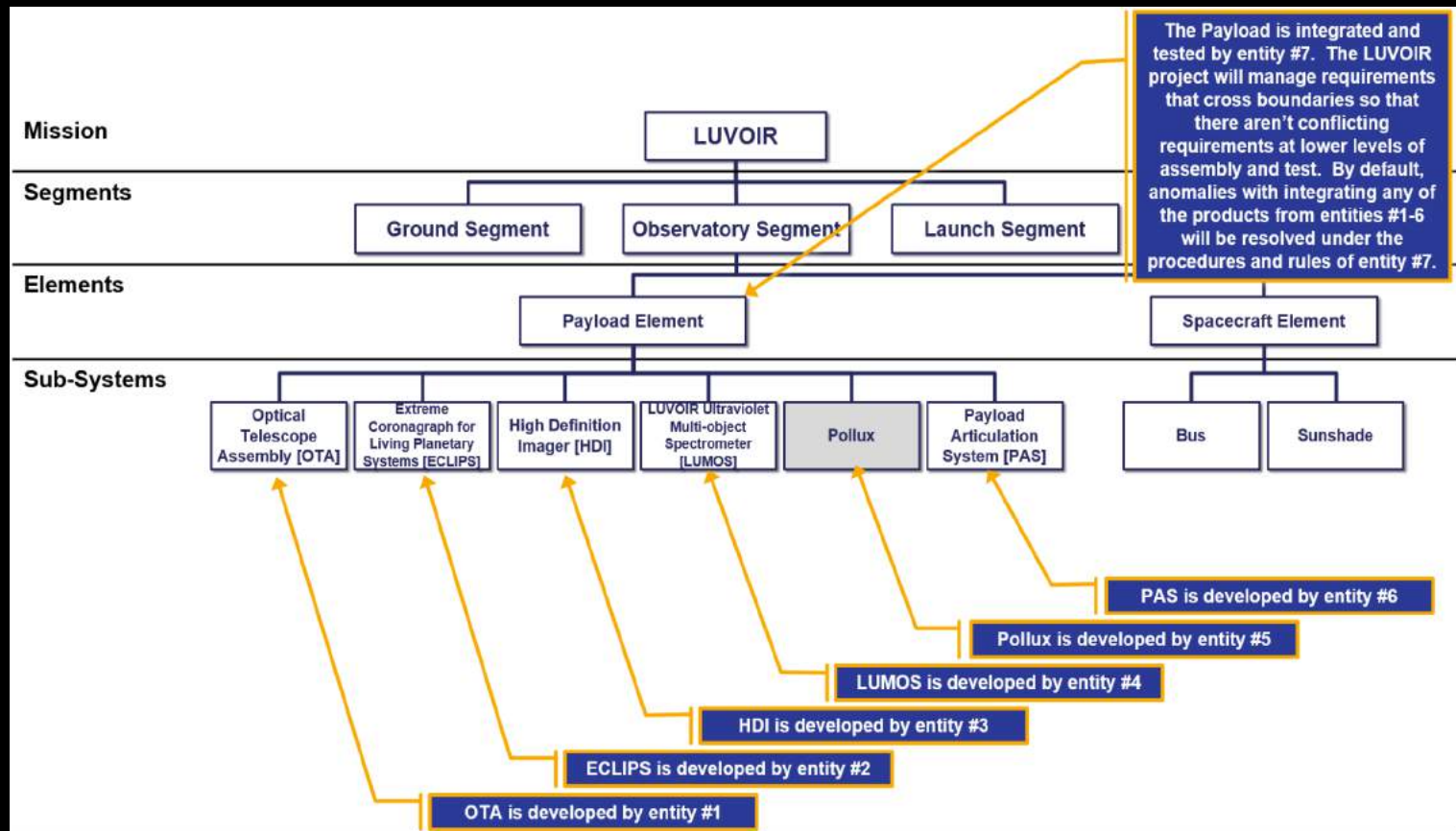
Eliminates significant industry investment in large, unsuccessful proposal efforts

Allows earlier involvement of and investment from industry partners

Recommended flagship project-level management strategies: #7: Managing institutional requirements



Understanding how institutional requirements governing one subsystem will apply and influence the development of products at higher levels of assembly will help minimize conflicts.

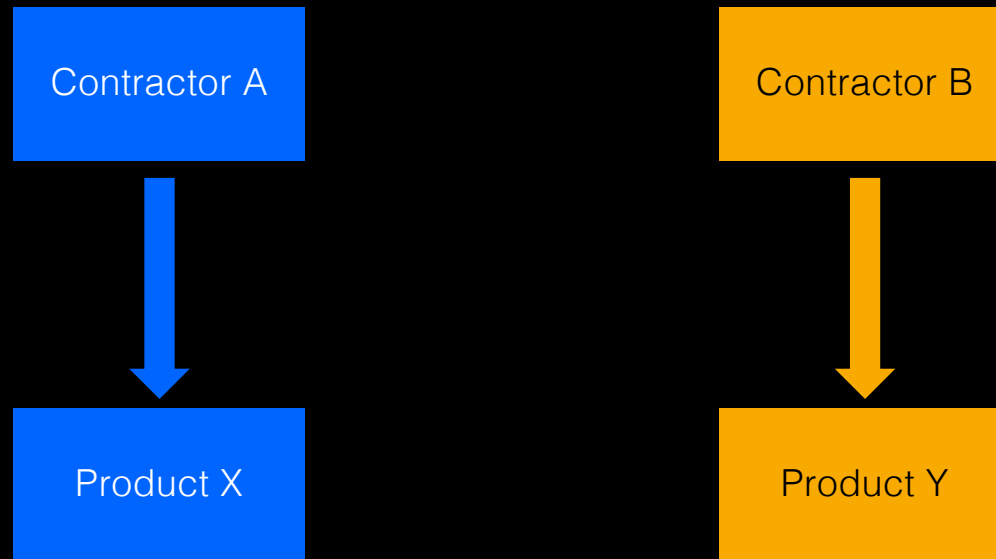


Recommended flagship project-level management strategies: #8: Integrated 'one-team' environment



Structure contracts and international agreements into a single, integrated team

Enables shared expertise and capability across assembly, sub-system, and system products

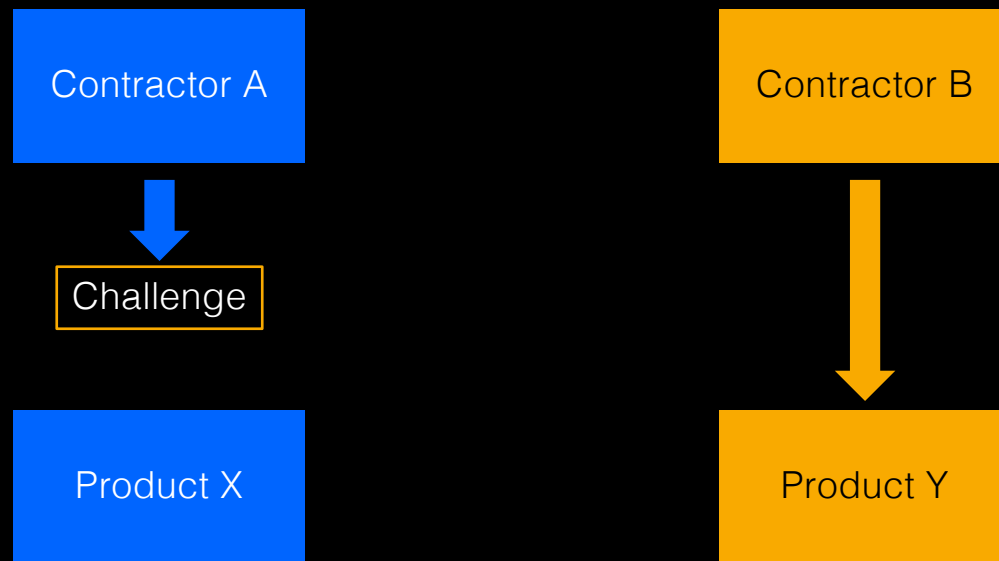


Recommended flagship project-level management strategies: #8: Integrated 'one-team' environment



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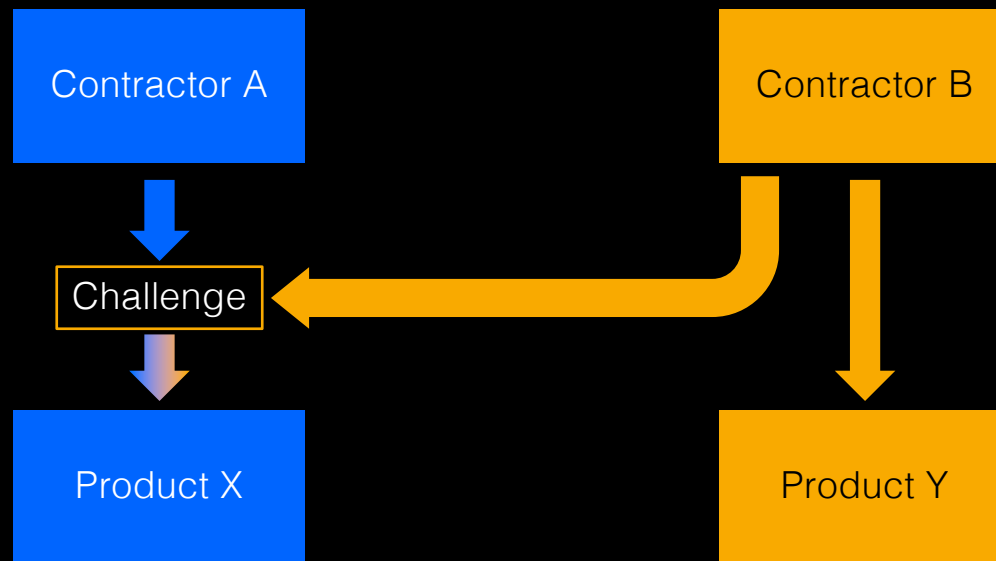


Recommended flagship project-level management strategies: #8: Integrated 'one-team' environment



Structure contracts and international agreements into a single, integrated team

Enables shared expertise and capability across assembly, sub-system, and system products



Recommended flagship project-level management strategies:

#9: Team, experience, depth



Must have leadership with relevant, hands-on space-flight mission development experience

For every product block in the system architecture, need – *at least* – two subject matter experts capable of leading that product development

Establish a decision-making command structure with clear lines of authority and accountability

Issue: NASA funding policy of annual appropriations does not enable execution of an optimized integrated master schedule (IMS)



Issue can't be solved at project-level:

- Funding instability forces work to be delayed, leading to cost and schedule overruns:
 - Funding profile: In the early years, flagships typically receive funding based on what's available, i.e., an "allowance" (a small wedge gradually increasing over time as the previous flagship nears launch). The appropriated funding is not necessarily based on what the project needs to execute its optimal schedule
 - Project forced to defer work
 - Continuing resolutions (CRs) require projects to be held at previous FY\$-level.
 - Congress has passed a NASA budget on-time only 7 times in the history of NASA. Thus, CRs are the norm for NASA.
 - Project forced to defer work

Recommended funding strategies for change



Recommended strategies for cost- and schedule-efficient project management based on research:

Bitten, R., et al., 2019, *Challenges and Potential Solutions to Develop and Fund NASA Flagship Missions*, IEEE, 978-1-5386-6854-2/19

Wiseman, J., 2015, *The Hubble Space Telescope at 25: Lessons Learned for Future Missions*, IAUGA 2258532W

Mitchell, D., 2015, *An Overview of NASA Project Management, MAVEN Magic, and Lessons Learned*

Martin, P., 2012, *NASA's Challenges to Meeting Cost, Schedule, and Performance Goals*, OIG Report IG-12-021

Feinberg, L., Arenberg, J., et al., 2018, *Breaking the Cost Curve: Applying Lessons Learned from the JWST Development to Build More Cost Effective Large Space Telescopes in the Future*, SPIE 10698-23

Arenberg, J., Matthews, G., et al., 2014, *Lessons We Learned Designing and Building the Chandra Telescope*, SPIE 9144-25

2004-2007, *Defense Procurement: Full Funding Policy – Background, Issues, and Options for Congress*, CRS Report for Congress, RL31404

O'Rourke, R., 2006, *Navy Ship Procurement: Alternative Funding Approaches – Background and Options for Congress*, CRS Report for Congress, RL32776

Crooke, J., Bolcar, M., Hylan, J., 2019, *Funding Strategy Impacts and Alternative Funding Approaches for NASA's Future Flagship Mission Developments*, Astro2020 White Paper.



Context: DoD available funding method options

Full-funding policy methods and options available to DoD large projects since the 1950s

- **No-year (zero-year) funding:** All funding is appropriated in a single lump sum before starting development.
- **Incremental funding:** All funding is appropriated in 2 or more year increments, ~2-5 years, in amounts that are not limiting. However, each year requires an appropriation bill to be passed by Congress.
- **Multiyear procurement (MYP):** A single contract requires congressional approval in the first year enabling stable funding for 2-5 years' worth of procurement without requiring Congressional annual renewal in the following years
- **Block Buy Contracting (BBC):** BBC it is more flexible for several reasons, namely:
 - a. BBC only needs to be approved in a single appropriations act.
 - b. There are no legal criteria required to qualify for a BBC
 - c. A BBC can cover more than five years of planned procurement.
- **Economic Order Quantity (EOQ) Authority:** This provides the authority to allow a few select "long-lead" items to be procured in the first or second year usually for "batch items".
- **Advance Procurement (AP) Funding:** This provides the authority to disburse funds one or two years prior to the procurement of the entire system usually for long lead items for that system.
- **Cost to Complete Procurement Funding**

Full-funding strategy would benefit NASA's flagships



Full-funding of NASA flagships with 'no-year' funding is not realistic

- DoD has the benefit of:
 - a. Better understanding of large DoD project "flagship" cost estimates
 - b. They build many of the same thing (aircraft carriers, submarines, fighter jets, helicopters, etc.)
 - c. They have been building these for ~70 with near-similar ones with technology upgrades each time
- NASA on the other hand:
 - a. NASA's flagships are one-offs, state-of-the-art, precision space observatories
 - b. Accurate final cost estimates and schedule estimates cannot be known at the time of the Decadal
 - c. Use incremental approach to cost estimating and full-funding methods to line up with product developments
 - d. This embodies a proactive, integrated, development and funding framework
 - e. There is precedence for NASA fully-funding two (2) programs: Apollo and Return to Flight after Challenger

Recommended flagship **Agency-level** management strategies:
#10: **NASA- DoD- Hybrid full-funding policy**



Rather than funding the entire mission upfront, instead:

- Recommend that project “work packages” be fully funded, regardless of fiscal-year alignment.

NASA- DoD- Hybrid Full-Funding Policy Recommendation



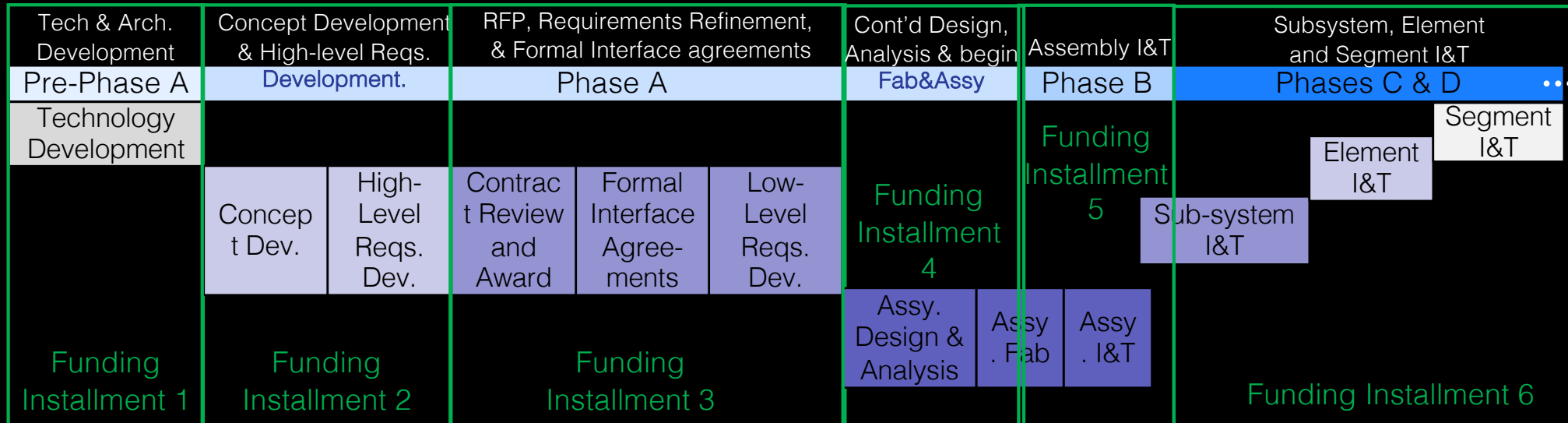
Fully-fund each of six (6) funding blocks (“work packages”) individually with criteria to pass through the next funding block:

Funding Block	Funding Decision Point	Decision Point Criteria
1	Start of Pre-Phase A	Decadal Prioritization. Agency decision to proceed with mission Pre-Phase A study.
2	Start of Phase A	All technologies demonstrated at system-level to TRL 6.
3	Issue Requests for Proposals (RFPs)	Requirements developed to sub-system level. Ready to issue RFPs for all industry, academic, and international partners.
4	Mission System Requirements Review (SRR)	All requirements developed to lowest level. Project successfully passes Mission SRR.
5	Key Decision Point (KDP) - B	Mission satisfies all criteria for completing Phase A.
6	KDP - C	Mission completes Preliminary Design Review and satisfies all criteria for completing Phase B.

Full Project Funding



Six (6) recommended “work packages” be fully funded at Funding Decision Points (FDPs) that align with products:



Advantages of Incremental Funding Blocks

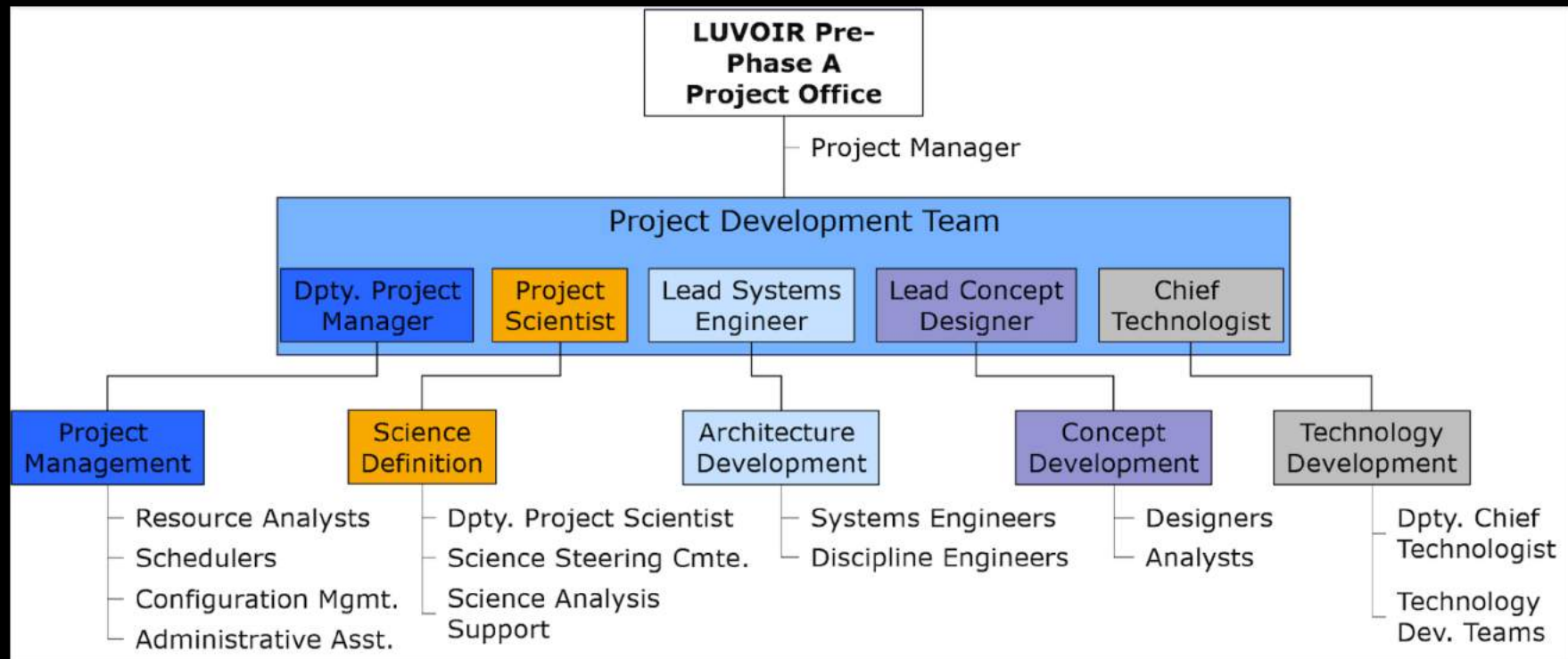


- Fully fund each block of work up front so that the project can execute the optimized master schedule
- As the mission matures through mission formulation (Pre-Phase A through Phase B):
 - a. Mission design becomes more detailed and complete
 - b. Cost and risk estimates become more accurate
 - c. Independent costing entity can signal runaway cost growth
- Congress and NASA only commit to funding the next block of work; not the full mission
- If progress is not successful, FDPs give stakeholders opportunity to cancel or delay
- This funding method gives the needed control for each product development effort and lowers the risk of cost and schedule overruns and gives stakeholders control as well.

Establish a Pre-Phase A project office



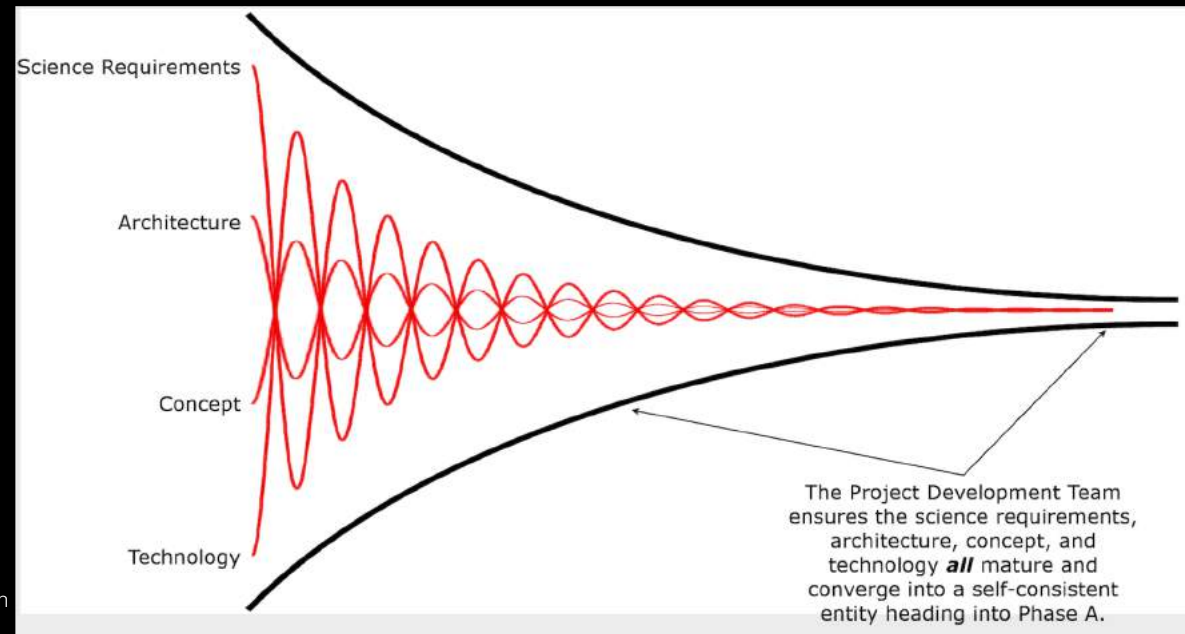
A key component to success is a strong Pre-Phase A



Funding Block 1: Pre-Phase A Activities



- Develop all technologies to TRL6 with broad agency announcements (BAAs) to leverage industry and academia (all hands on deck)
- Establish a funded Science Steering Committee, community-led, to:
 - a. Decompose science objectives into requirements to guide the architecture design, and technology development
 - b. Perform science analyses to validate architecture and design
 - c. Establish process to accept new science objectives
 - d. Support engineers to resolve TBRs and TBDs
- Architecture dev. & long-term planning:
 - a. Mature the architecture and concepts
 - b. Explore additional trade studies
 - c. Facility development planning
 - d. Pathfinder planning
 - e. Servicing approach studies
 - f. Verification and validation approach
 - g. Interface development
 - h. Develop integrated modeling tools



Summary

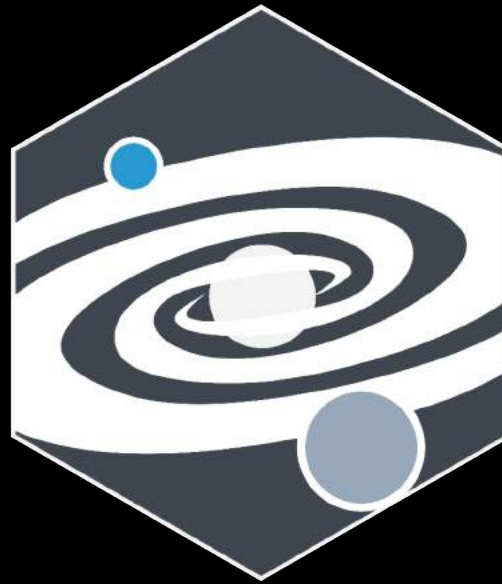


- NASA flagships are awesome! And, each one is a one-off
- We provided a number of project-level management strategies that will vastly improve their cost and schedule performance
- We recommended an improved funding strategy borrowing from NASA's past and the current way DoD large projects have been funded for ~70 years and continue today
- We recommend a strong Pre-Phase A
- NASA's flagships are equally high-caliber national assets that deserve a similar full-funding-policy as DoD large projects



Questions?

We use lessons from the past to enable the future



L U V O I R

<https://asd.gsfc.nasa.gov/luvoir/>
@luvoirt telescope



Backup



NASA Flagship Funding Lessons Learned References

- Crooke, et. al., *Evolving Management Strategies to Improve NASA Flagship's Cost and Schedule Performance: LUVOIR as a Case Study*' SPIE, 2019.
- Crooke, et. al., *Funding Strategy Impacts and Alternative Funding Approaches for NASA's Future Flagship Mission Developments* , NAS APC White Paper, 2019.
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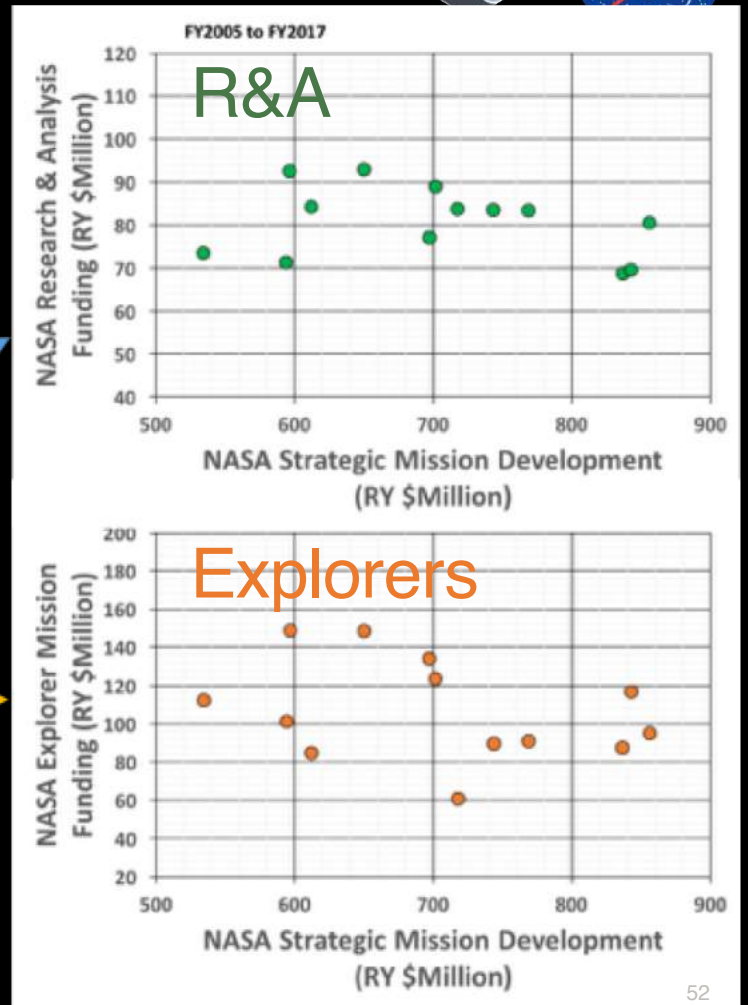
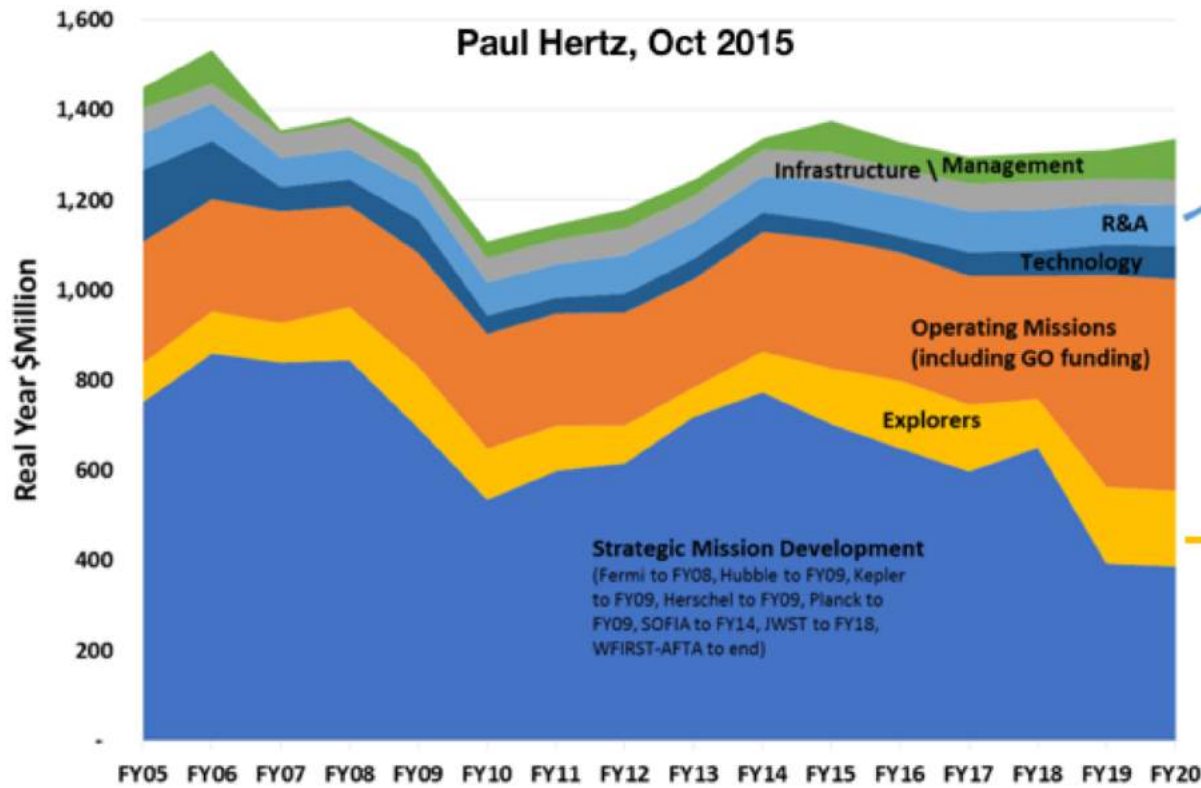
A balanced astrophysics portfolio



Source: Paul Hertz

Astrophysics Budget by Function
 FY05-FY14 Actual, FY15 Op Plan, FY16-FY20 Request

Paul Hertz, Oct 2015



NASA Annual expenditures for science missions in FY 2015 millions of dollars for 57 years (1969 - 2026)

