Lessons for the Future

SMD Large Mission Study & LUVOIR

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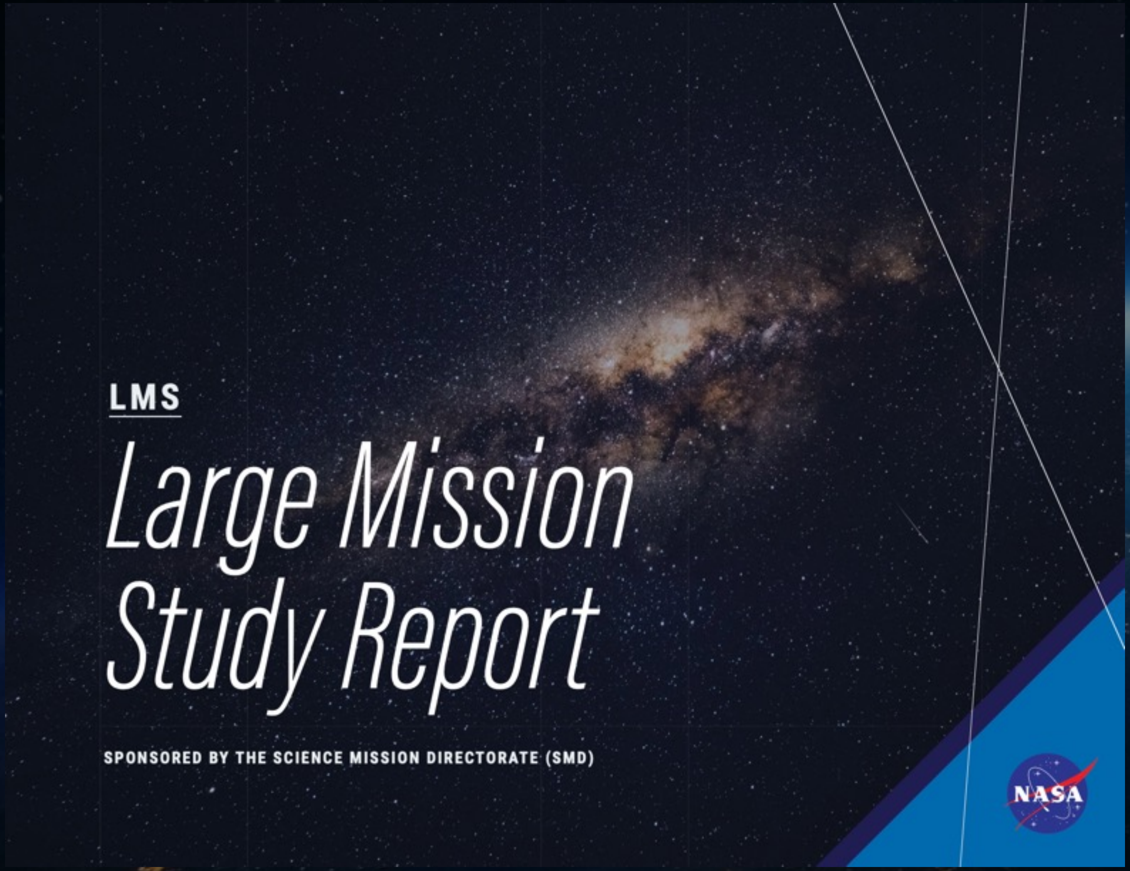
HABITABLE WORLDS OBSERVATORY

What was the SMD Large Mission Study?



12-month study to look at improving large mission development across all four NASA science divisions

- Limited set of impactful & actionable recommendations

Core team of 8, plus two Deep Dive Analysis Groups

Final Report released in 2021

Recommendation Topics

1. Pre-Phase A team composition
2. Pre-Phase A architecture trades and descope options
3. System maturity assessment
4. Technology integration into complex systems
5. Analytical tools
6. Cost and schedule estimation
7. Standing Review Boards
8. Instrument selection process
9. SMD capabilities
10. Center capabilities

Formalize the habits of successful large missions

1. Pre-Phase A team composition

Finding

Pre-formulation is critical for future mission success but is often under-prioritized and lacking some important expertise

"Design problems are baked into the cake at the start, and not uncovered until you have eaten half the cake."

Recommendation

- Include experts in late stages of mission development from the beginning
- Streamline team to promote collaboration across disciplines & rapid decision making
- Populate team with succession planning in mind

2. Pre-Phase A architecture trades & descope options

Finding

During Pre-Phase A, requirements development and architecture trades are often over-constrained

"For years the Europa mission was focused on a very expensive orbiter rather than the current multiple-flyby architecture."

Recommendation

- Conduct analyses and architecture trades that quantify science vs. cost
- Explore range of options that are faithful to science goals but might incur lower risk
- Maintain dialog with Academy committees to ensure intent of Decadal Survey is honored

3. System maturity assessment

Finding

Impact of complexity on technology transition, manufacturing, integration & test, and operations is often woefully underestimated

"Humans are bad at assessing complexity."

Recommendation

- Establish criteria for Concept Maturity Level (CML) and Manufacturing Readiness Level (MRL) to complement the existing Technology Readiness Level (TRL) system

4. Technology integration into complex missions

Finding

The current NASA standard for technology maturity, i.e., TRL-6 by PDR, is much too lenient for large missions

"Flagships can meet all the PDR success criteria but still not be ready for implementation."

Recommendation

- Move the current NASA TRL standard to the left for large missions
- Technologies should reach TRL 6 by Mission Definition Review (MDR; at end of Phase A) rather than the current standard of Preliminary Design Review (PDR; at end of Phase B)

5. Analytical tools

Finding

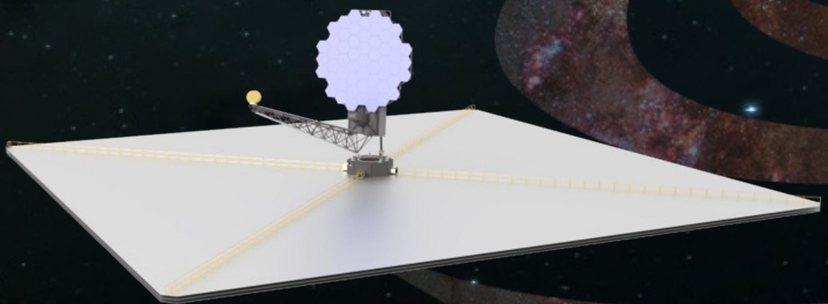
Integration of mechanical, thermal, and optical models has not been seamless, leading to long modeling cycles

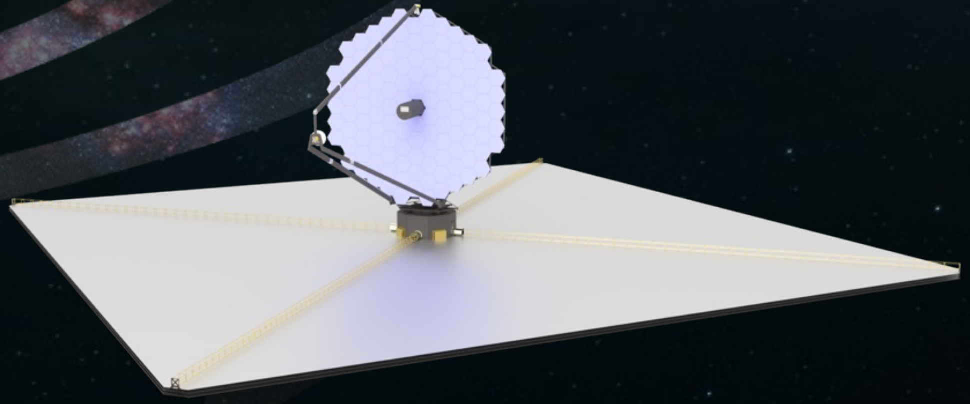
"Large and complex systems rely on smart management of performance margins and the use of modeling to verify system performance."

Recommendation

- Fund development of integrated modeling systems and other engineering tools to reduce analysis timelines
- Aki notes this should include integrated science modeling tools

LUVOIR Mission Concept Study
Lessons for the Future





Science Partnerships

We share our flagships more than some other NASA science areas

Astro flagships must serve a broad swath of the community

Can be hard to balance multiple science goals, but it is absolutely possible

An equal & harmonious partnership between exoplanets and astrophysics was achieved during the LUVOIR study

Partnership between different science areas takes realism, compromise, good will, & continual maintenance

Mission partnerships

Coordination and collaboration between HabEx & LUVOIR teams from the beginning

One joint STDT meeting per year

Teams helped each other on certain science & technical tasks

Common assumptions & analyses allowed apples-to-apples comparisons

HabEx, LUVOIR, Lynx, & Origins partnership led to New Great Observatories advocacy

Joint team dinner
New Haven, 2016

"Kumbaya" took effort but paid off at Astro2020

THE CONCEPT MATURITY LEVEL SYSTEM

Used during the pre-Decadal studies, with some initial skepticism

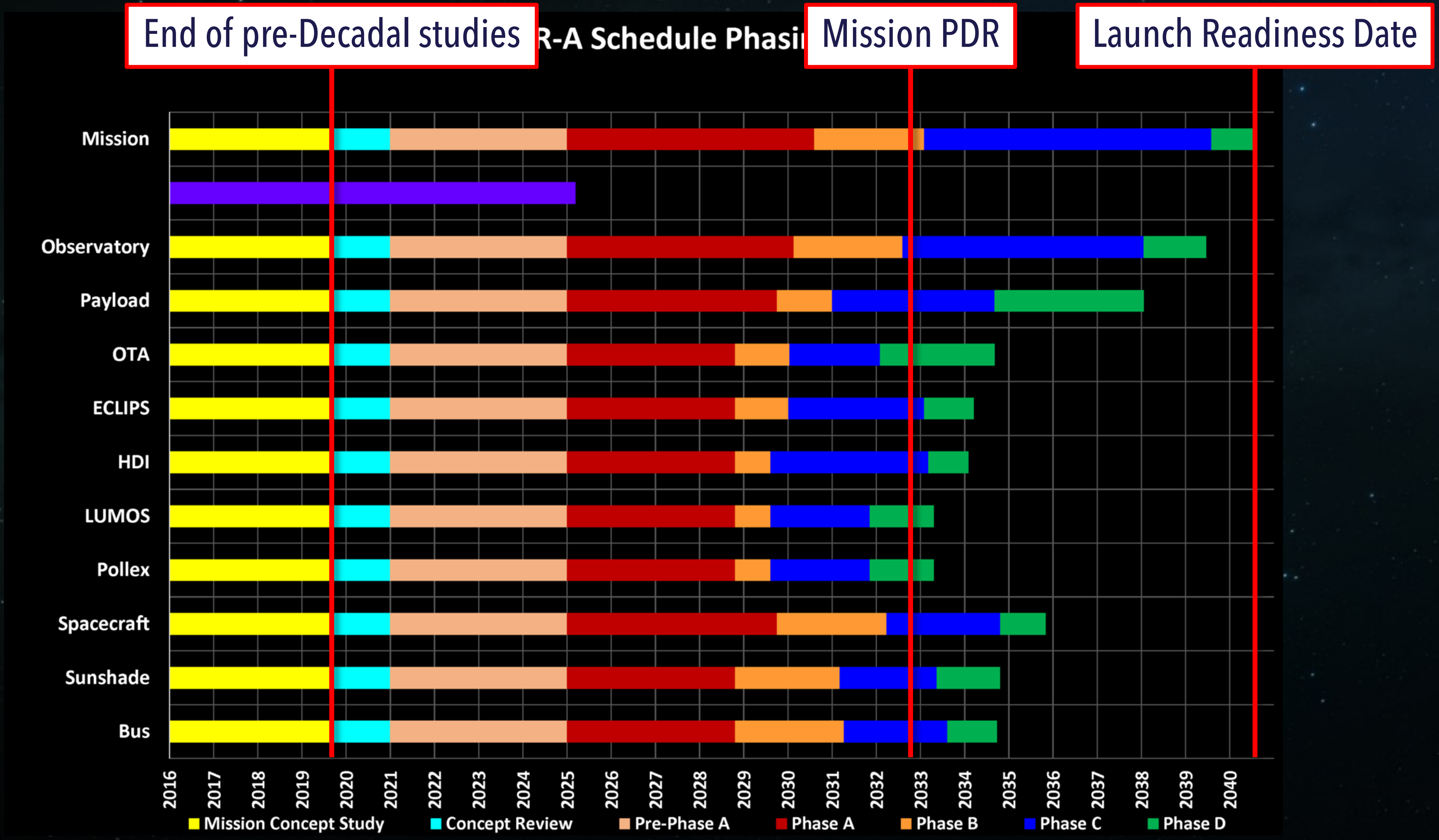
Forced us all to produce a complete package – science, design, schedule, cost, technology plan, integration & test, operations, etc.

Agree with LMS recommendation to adopt CML system SMD-wide

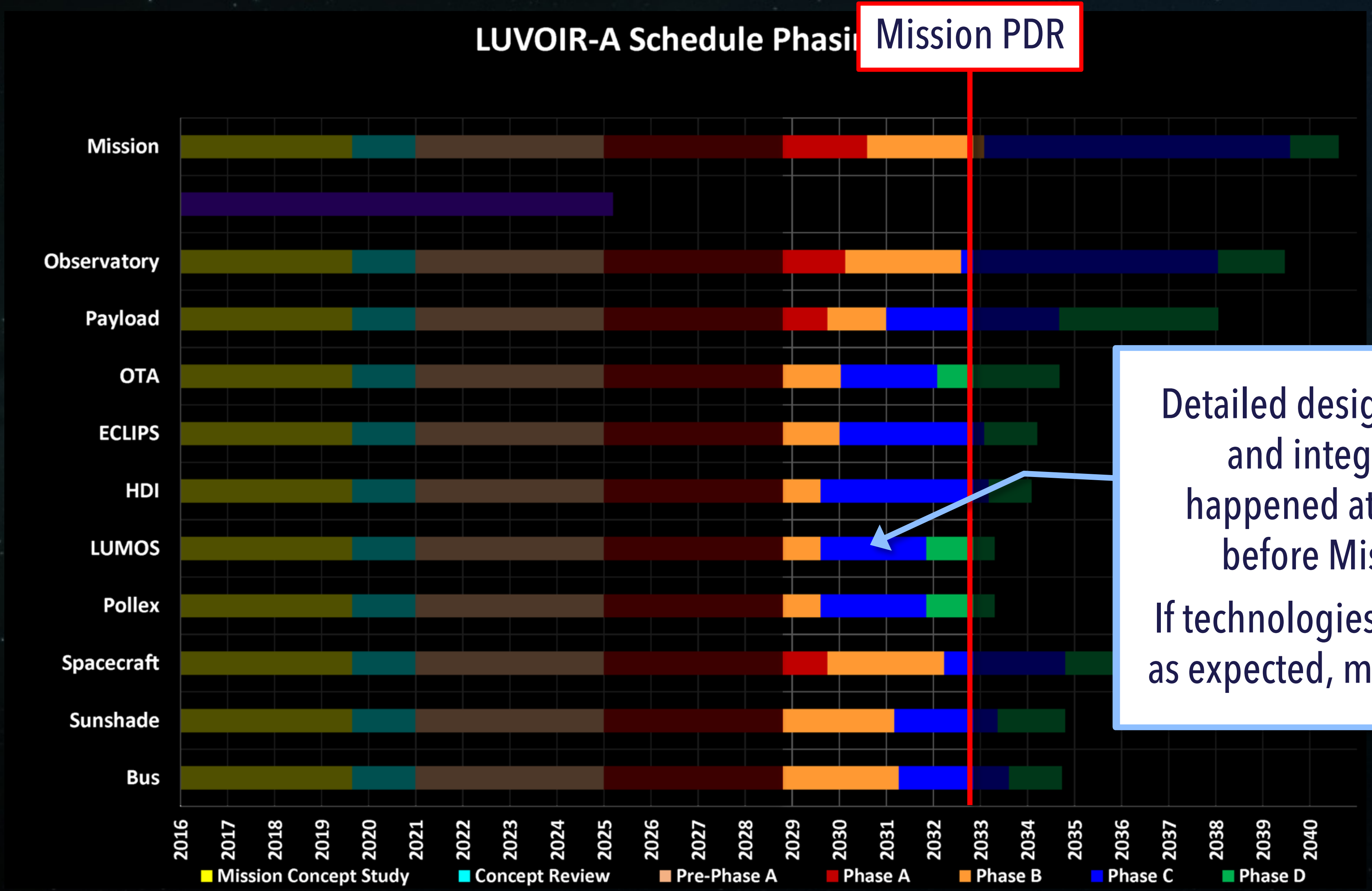
Think more about the whole mission lifecycle from the beginning

NASA Life-Cycle Phases	Approval for Formulation	FORMULATION		Approval for Implementation	IMPLEMENTATION			
Project Life-Cycle Phases	**Pre-A** Concept Studies	**A** Concept & Technology Development	**B** Preliminary Design & Technology Completion	**C** Final Design & Fabrication	**D** System Assembly, Integration & Test, Launch & Checkout	**E** Operations & Sustainment	**F** Closeout	

MISSION & TECHNOLOGY MATURATION



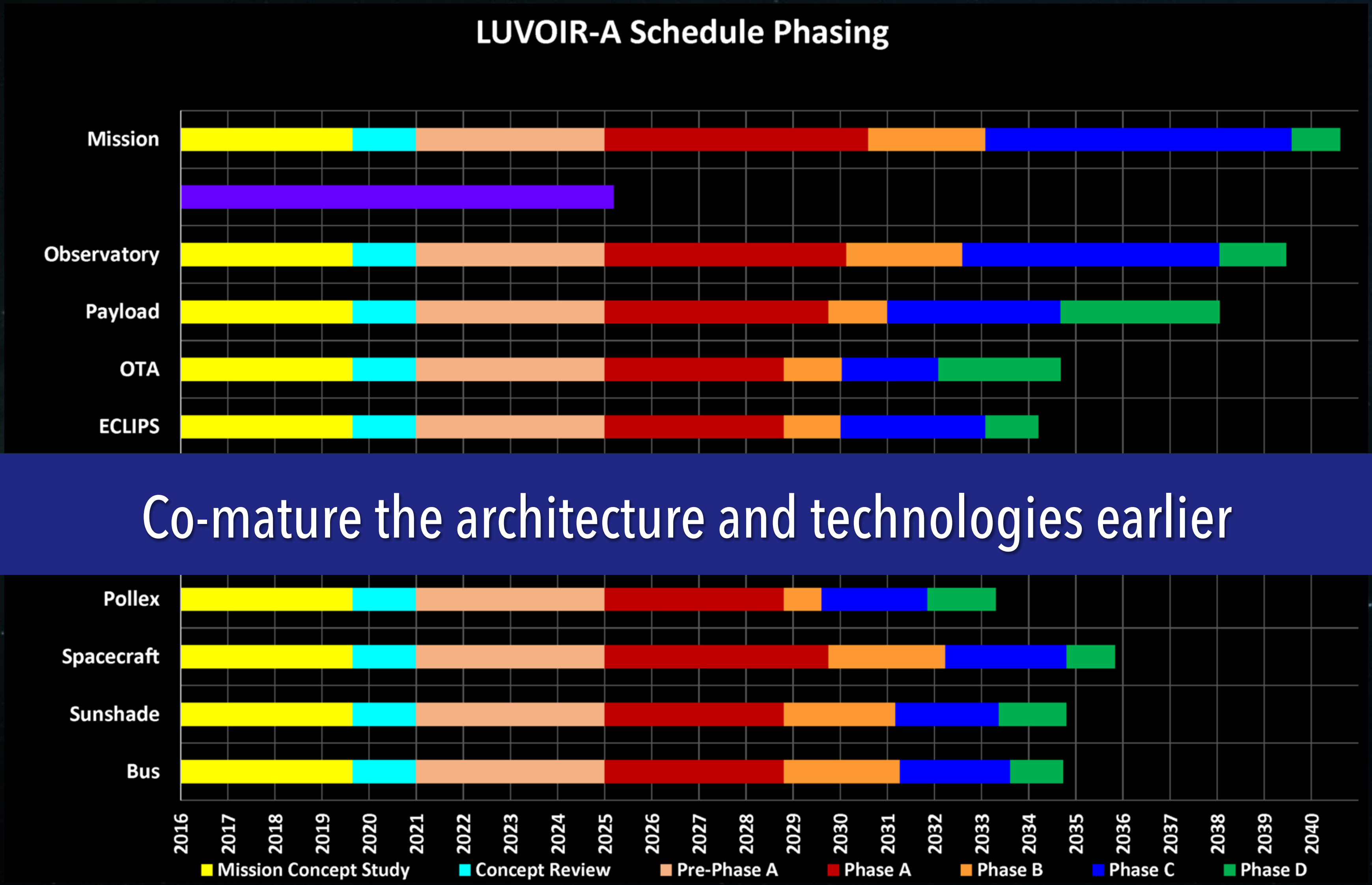
MISSION & TECHNOLOGY MATURATION



Detailed design, fabrication, and integration has happened at lower levels before Mission PDR.

If technologies don't develop as expected, must re-do work!

Mission & technology maturation



Co-mature the architecture and technologies earlier

HIGH-CONTRAST OBSERVATIONS OF EXOPLANETS

Direct observations of Earth-like planets is extremely challenging

The first LUVOIR-A design effort treated telescope & coronagraph as separate systems

Observatory was great for astrophysics, fell on its face for exoplanets

Had to re-design

Coronagraph & telescope must be designed together from the get-go to be an effective starlight suppression system

Teamwork part 1

Open call for STDT members produced a fantastic team

Having early-career scientists & engineers at the table really paid off

Better problem-solving with the combined insights of scientists, engineers, & technologists in the same room

Better decisions when scientists understand the technical challenges and engineers understand the science objectives

Inclusion improves the work. Let's do more.

TEAMWORK PART 2

Empower the team and do not micromanage

Defend work-life balance

Spread the load. No single-point failures in personnel if you can possibly avoid it

Appreciate all kinds of good work & diverse contributions

TEAMWORK PART 3


LUVOIR cake
2018


LUVOIR karaoke
2019

LEGO LUVOIR
2020

Make time for fun


Florence+the Machine concert
2019


Hawaii AAS
2020


HWO Science Conference
2023

AKI'S PARTING THOUGHTS

The unspoken "critical technology" for large missions is project management

There is more time and money to be saved by changing HOW we build big projects than in changing WHAT we build

Input from scientists is most necessary at the beginning and end of mission development