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

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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.

Credit: NASA
Imagine NASA without Voyager …

Credit: NASA/JPL-Caltech

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 …
Imagine NASA without Cassini ...
Imagine NASA with ...LUVOIR
Imagine NASA astronomy with LUVOIR ...
Imagine solar system science with LUVOIR ...

Jupiter from JUNO at ~ 30 km resolution
Comparable to LUVOIR 15-m (~ 24 km at opposition)

12 August 2019
Imagine seeing other solar systems...
COSMIC ORIGINS & THE ULTRA-FAINT UNIVERSE

EXOTIC WORLDS

THE SEARCH FOR LIFE

OUR DYNAMIC SOLAR SYSTEM
Motivations for …Improving on NASA’s flagship cost and schedule performance
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GAO: NASA Programs Rack Up Delays, Cost Overruns
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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)

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Monday, March 25, 2019
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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

LUVOIR A Phasing
Mission PDR

<table>
<thead>
<tr>
<th>Mission</th>
<th>Segment</th>
<th>Element</th>
<th>Sub-System</th>
<th>Sub-System</th>
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<td>Observatory</td>
<td>Payload</td>
<td>OTA</td>
<td>ECLIPS</td>
<td>HDI</td>
<td>LUMOS</td>
<td>Pollux</td>
<td>PAS</td>
<td>Spacecraft</td>
<td>Sunshade</td>
</tr>
</tbody>
</table>

Currently Allowed Timeline to Develop Technologies to TRL6

Mission PDR 12 August 2019 August 2019 SPIE: Astronomical Optics and Instrumentation
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.

<table>
<thead>
<tr>
<th>Tech &amp; Arch. Development</th>
<th>Concept Development</th>
<th>Requirement Development, Design, and Analysis</th>
<th>Fabrication, Integration, and Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Phase A</td>
<td>Phase A</td>
<td>Phase B</td>
<td>Phase C</td>
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<tr>
<td>Technology Development</td>
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<tr>
<td>Pre-Phase A</td>
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<tr>
<td>Pre-Phase B</td>
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<td></td>
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<tr>
<td>Pre-Phase C</td>
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</tbody>
</table>

- **Conc Dev.**
  - High-Level Req. Dev.
  - Contract Review and Award
  - Formal Interface Agreements
  - Low-Level Req. Dev.
- **Assy. Design & Analysis**
  - Assy. Fab
  - Assy. I&T
- **Element I&T**
- **Sub-system I&T**
- **Segment I&T**

Requirements Complete
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

Contractor A

Product X

Contractor B

Product Y
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

- Contractor A
- Contractor B
- Product X
- Product Y

Challenge
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:


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 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:

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

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

<table>
<thead>
<tr>
<th>Pre-Phase A</th>
<th>Phase A</th>
<th>Phase B</th>
<th>Phases C &amp; D</th>
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<tr>
<td>Tech &amp; Arch. Development</td>
<td>Concept Development &amp; High-level Reqs. Development</td>
<td>RFP, Requirements Refinement, &amp; Formal Interface agreements</td>
<td>Cont’d Design, Analysis &amp; begin Fab &amp; Assy</td>
</tr>
<tr>
<td>Funding Installment 1</td>
<td>Concept Development</td>
<td>Formal Interface Agreements</td>
<td>Funding Installment 4</td>
</tr>
<tr>
<td>Funding Installment 2</td>
<td>High-Level Reqs. Dev.</td>
<td>Formal Interface Agreements</td>
<td>Funding Installment 5</td>
</tr>
<tr>
<td>Funding Installment 3</td>
<td>Contract Review and Award</td>
<td>Low-Level Reqs. Dev.</td>
<td>Funding Installment 6</td>
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<tr>
<td>Assembly I&amp;T</td>
<td>Subsystem, Element and Segment I&amp;T</td>
<td>Subsystem I&amp;T</td>
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12 August 2019
August 2019 SPIE: Astronomical Optics and Instrumentation
Advantages of Incremental Funding Blocks

• Fully fund each block of work up front to 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 runway 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

LUVOIR Pre-Phase A Project Office

Project Development Team

Project Manager

Dpty. Project Manager

Project Scientist

Lead Systems Engineer

Lead Concept Designer

Chief Technologist

Project Management

Science Definition

Architecture Development

Concept Development

Technology Development

Resource Analysts
Schedulers
Configuration Mgmt.
Administrative Asst.

Dpty. Project Scientist
Science Steering Cmte.
Science Analysis
Support

Systems Engineers
Discipline Engineers

Designers
Analysts

Dpty. Chief Technologist
Technology Dev. Teams
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

LUVOIR
https://asd.gsfc.nasa.gov/luvoir/
@luvoirtelescope
Backup
NASA Flagship Funding Lessons Learned References

- R41909, 2019, Multiyear Procurement (MYP) and Block Buy Contracting in Defense Acquisition: Background and Issues for Congress, https://fas.org/sgp/crs/natsec/R41909.pdf
A balanced astrophysics portfolio

Source: Paul Hertz