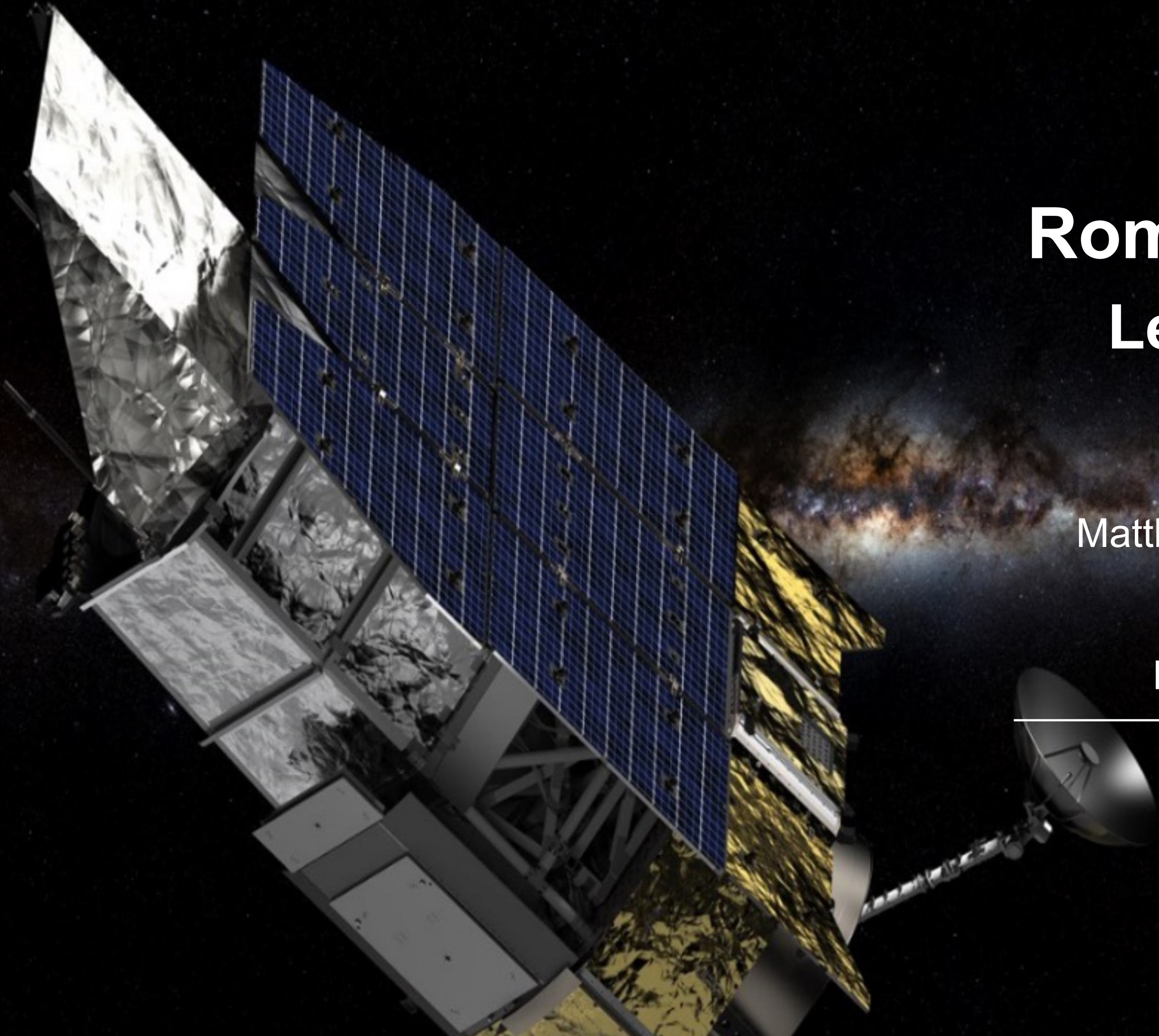
ROMAN SPACE TELESCOPE



Roman Space Telescope
Lessons for the Future

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On behalf of
Roman Space Telescope Project

Habitable Worlds Observatory
START/TAG Face-to-Face Meeting
Washington, DC
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In the following slides, the names have been changed to protect the innocent…

Introduction

- **While many individuals provided unique examples of lessons learned, they could generally be grouped under a set of common, high-level topics**
  - Further grouped topics by relevance to project phase (pre-/post-implementation; general)

- **Uniform consensus among team is that 15 minutes is *not* enough time to cover these lessons**
  - This presentation should be considered as an invitation to more in-depth engagement with project personnel on lessons, especially those of a more "sensitive" nature
  - Then again, many of these will sound familiar…

- **Recommend a workshop or working group to develop and document the *actionable* steps we will take to incorporate lessons learned**

Lessons Learned 101: "We'd like to stop making the same mistakes over and over again so we can start making all new ones."

Summary

- **Pre-Implementation:**
  - LL1: Build relationship with stakeholders / Engage the community
  - LL2: Invest in key enabling technologies to TRL 6 by PDR
  - *LL3: Be cautious of cost targets before PDR
  - LL4: Avoid requirements over-reach
  - LL5: Cost & schedule impacts due to desired operating temperature
  - LL6: Understand the impacts of hardware (Flight ***or*** GSE) and facility re-use
  - LL7: Start analysis & design early, ***including*** GSE and test configurations
  - *LL8: Include verification & validation ***details*** in early planning
- **Implementation:**
  - *LL9: Avoid requirements creep
  - LL10: Require forward-phased, consistent funding
  - LL11: Continuously reassess plans for work to go (“No plan survives contact with the enemy”)
- **General:**
  - LL12: NASA should lead Management, Systems, Modeling, and Integration
  - *LL13: Plan for differences in institutional culture and processes
  - *LL14: Have the right people in the right place at the right time
  - *LL15: Active control / compensation can reduce risk and increase robustness

*LL slides are provided for completeness, however will not be presented in detail in interest of time.

PRE-IMPLEMENTATION

LL1: Build Relationship with Stakeholders (1/2)

- **Stakeholder advocacy is critical when times are tough**
  - Want champions in the halls of HQ, Congress, science community, industry, and the public (see next slide)
- **A close partnership with HQ (SMD & APD) creates trust and facilitates communication that is crucial when issues arise**
  - The project needs to be able to openly & honestly communicate the cost and schedule risks associated with HQ- or externally-directed decisions
  - HQ needs to have enough insight into project to advocate on their behalf with Congress & public as well as hold project accountable
- **Make good use of reviews**
  - SRB* members are another set of advocates for the Project to HQ

*SRB: Standing Review Board

LL1: Community Engagement (2/2)

- **Broadest possible community needs to *be and feel* involved and have a vested interest in the mission's success**
  - Maximize the use of town halls and open meetings; leverage branding and social media early
- **Find balance in how the mission is "sold" to the community**
  - Webb & Hubble were capability driven; Roman is science driven (e.g., survey)
    - Require different approaches to advertising to the community ("How will I use this observatory?")
  - HWO is somewhere in between (exoplanet survey vs. general astro. capability)
    - Recognize the differing perspectives and balance the message to reach the whole community
    - Take action; create org structures to avoid stovepipes – we are one mission!
- **Foster interaction between science & engineering teams**
  - *Both* scientists and engineers need to understand
    - Science trades and how science drives technical and programmatic decisions
    - Where technical and programmatic "pain points" exist
    - Where investing time/budget matters, and when good enough is good enough
  - When issues arise, whole team needs to know to ask rather than assume, and know *who* to ask

LL2: Invest in Key Enabling Technologies to TRL 6 by PDR

- "Be rigorous and unflinchingly honest with yourselves about identifying key enabling technologies. Develop a robust plan to mature them – preferably gradually (alongside mission concepts), using modest annual investment over a long time. **Don't fudge this or believe the hype or assume disruptive breakthroughs."**

- "At this point (literally right now), **HWO no longer has time for mission concepts and technology development to evolve in their own separate sandboxes.** Every dollar and every brain needs to be assessing how to merge the two for the best achievable science reach in the 2030s."
  - Corollary: mission concept developers and technology developers need to be *directly involved* with technology funding decisions. No stovepipes!

*LL3: Be Cautious of Cost Targets before PDR

- **Cost targets established before PDR must strike a balance between committing to an acceptable cost and enabling the best possible science**
  - Done well, effective trades and timely off-ramps (or occasionally on-ramps) enable incredible science for a given price point
    - Combine with a commitment to forward phased, stable funding and executable program structure
  - Done poorly, appropriators and the science community are both disappointed – and the broader community objectives are compromised for a decade or more

- **We need to be careful about the language we use *right now* regarding the cost of the mission**
  - Up and out: message commitment to deliver best possible science for a negotiated development (*not lifecycle*) cost; inflate $RY in the 2030s when development will occur
  - Down and in: message team commitment to great science at negotiated cost
    - Use cost target to drive the tough, timely decisions and push creative thinking about technology maturation, off-ramps, and on-ramps (see LL4)

LL4: Avoid Requirements Overreach

- **“Decide early what science objectives will be and then set a very high bar for adding anything later”**
  - E.g., Roman’s Level 1 & 2 requirements have not substantially changed since start of Phase A
- **Pre-implementation *is* the place to take risks**
  - Need to use this time to maximize science/dollar
- ***But* time (and money) is limited**
  - Need to set a deadline and “ruthlessly” assess what will be ready by that deadline and drop anything that won’t
- **Have science margin**
  - Be able to fall back to a mission that is still worth doing if certain technology doesn’t pan out
  - Again, set deadlines for decisions and stick to them

LL5: Cost & schedule impacts due to operating temperature

- Across the team, there are differing thoughts on how "cold" (~265 K) operating temperature *fundamentally* impacted cost, schedule, and risk, yet consensus opinion is that it did so ***significantly***
  - Modifying inherited hardware to operate *modestly* colder-than originally designed
  - Designing all new aft-optics system to work at colder temperatures
  - Adapting "standard" processes for new cold development & test (e.g., new materials & process qualification for things as mundane as harness tie downs)
  - New thermal cycling and strength tests
  - Analysis and testing came with a heavy integrated modeling cost burden and substantial facility upgrades
- **"If science objectives can be achieved in other ways, room temperature optics have far less cost growth risk."**

LL6: Hardware (Flight *or* GSE) and Facility Re-use

- **If deciding to re-use hardware (Flight or GSE*), make every effort to use it exactly as originally intended (see LL5)**
  - Old hardware may not match the documentation that comes with it, especially GSE for which documentation requirements are less stringent
  - Conversely inherited / re-used hardware *can* have advantages as it collapses the trade space and focuses the team on a specific design

- **Facility upgrades carry large cost and schedule risk**
  - Identify and start on them ***as early as possible***
  - "Ground tests are extremely complicated and best designed-for-purpose"; simply showing you fit in the chamber ***is not enough***
    - Roman TVAC tests have gone through numerous iterations right up to early this year
  - Pay attention to the mundane infrastructure (transportation, cranes, dollies, test flats, hexapods, etc.)
    - Can become critical path drivers very quickly ("My kingdom for a hexapod!")

- **Don't neglect IT infrastructure!**
  - Especially if tests will be performed in secure facilities – how do you get the data out?
  - Re-using old IT equipment and legacy software will require costly hardware ***and*** software upgrades

*GSE: Ground Support Equipment

LL7: Start analysis & design early, *including* GSE and test configurations

- **Develop Flight and GSE interfaces concurrently**
  - Late discoveries of GSE-to-Flight hardware interference and GSE compatibility led to some significant test configuration changes (see LL6)

- **Early investment in integrated modeling (IM) will more than pay for itself over the long run**
  - Like JWST & Roman, HWO will be very dependent on analysis
  - Budget for an extensive IM effort with an engaged review board, and potentially even independent teams
  - Early investment in high-fidelity IM, skilled practitioners, and a capable manager to create a flexible and robust modeling architecture buys down the technical and programmatic risk of growth across the board

- **Need a "deep bench"**
  - Analyses are niche, so losing a single person during course of mission can have a big impact

- **Don't forget stray light!**
  - It's hard to model, next to impossible to test for, and almost certainly the thing you're going to get wrong

*LL8: Include verification & validation *details* in early planning

- **Simply saying a requirement will be verified by test, analysis, or both isn't enough**
  - Need a verification roadmap with more detail in verification description as early as possible as they can have big differences in cost and drive facility needs
- **Identify model validation tests early and protect them**
- **Requirements flow down, not up**
  - When writing Level *N* requirements, think about what you need at Level *N*+1 and make sure you write the appropriate parent. If there isn't an appropriate parent, then do you really need that requirement?
- **Every level of assembly should have documented, clear, traceable requirements flow down with associated verification approach**

IMPLEMENTATION

*LL9: Avoid requirements creep

- **In implementation, emphasis shifts to what is "good enough"**
  - NO new requirements or capability at this phase

- **Again – define, document, and plan to use offramps and descopes that can be executed when "better" starts driving cost & schedule (see LL11)**

LL10: Require forward-phased, consistent funding

- **Roman has received forward-phased funding per its plan every year**
  - Enables early, strategic investments that buy down risk later in development
  - Ensures steady, consistent progress and use of reserves to quickly mitigate challenges
  - Forward fund procurements and contracts to continue making progress throughout the year and mitigate impacts of “black swan” events (CRs, shutdowns, pandemics, etc.)

- **Effective management of reserves is key**
  - When early allocation of reserves is required, make sure it reduces risk of cost/schedule growth in the long term (see LL11) – *not* increasing baseline

LL11: Continuously reassess plans for work to go

- **"No plan survives contact with the enemy"**
  - Plans are essential, but cannot be blindly executed without reassessment
  - Programmatic and technical leadership needs to be constantly predicting long term performance and taking action to mitigate risks

- **Immediate investment *now* can often shrink long-term cost and schedule growth *later***
  - Project management/leadership team needs direct control of significant moving parts to change courses (see LL12)

- **"In Phase A, you're already out of time and money but just don't know it yet. Develop discipline early."**

ENTIRE LIFECYCLE

LL12: NASA as Lead

- **NASA should serve as Management, Systems, Modeling, and Integration Lead**
  - “This can’t be emphasized enough.”
  - “Early years of Webb, NPOESS epoch, lots of human flight programs are case studies of what happens when NASA follows the ‘smart buyer’ approach with even most capable industry partners.”
  - “Roman (will be) the first successful, cost-capped science flagship - use its example”
    - See also later years of JWST

- **This also enables many of the other lessons learned as the project holds the required authority and has access to near real-time data needed to anticipate problems and respond quickly to mitigate impacts**

*LL13: Plan for differences in institutional culture and processes

- **“Standard Rules” for processes and procedures (e.g., GOLD Rules, GEVS*) vary between government & industry, vendor to vendor, and even Center to Center**
  - Need to be clear on what we expect to receive as a product
    - EITHER let the vendor follow their own processes and document and communicate associated risks at the highest level
    - OR prescribe exactly what we expect them to do and include additional costs in the program up front
  - Have a strong leadership team in place early ***and for the long haul*** to ensure continuity and have long term vision to understand impacts of early decisions
    - Sometimes early decisions are made without sufficient documentation on rationale; when new team comes on later it can create a lot of churn to “re-litigate” those decisions

*GEVS: Goddard Environment Verification Standard; GOLD: Goddard Open Learning Design

*LL14: Have the right people in the right place at the right time

- **Rely on experience whenever possible and strong mentorship when it's not**

- **Match strengths across team to the work that needs to be done**
  – Requires being brutally honest about local strengths & weaknesses
  – Understand the cultural and process differences between partners (see LL13)

- **Balance oversight with need to let partners work**
  – Encourage direct engineer-to-engineer interaction rather than funneling through a PoC
  – Oversight team needs complementary skillsets across disciplines
  – Have an on-site oversight person/team for time critical interactions

*LL15: Active control / compensation can reduce risk

- Roman OTA has shown good ability to place optics with traditional methods, but ability to use actuators to adjust for offsets/errors/changes in environment has been critical and significantly reduced risk/increased robustness

- *But* actuators are difficult to manufacture and drive electronics are expensive

- **“A compensator would likely pay for itself IF it can save a handful of days on the project critical path. For example, an actuated optic may enable the project to reduce the complexity of a top-level optical test.”**

QUESTIONS?