



De-risking the Next X-ray Flagship: A Dedicated Technology Development and Proto-Flight Strategy

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De-Risking the Next X-ray Flagship



Goal:

- Put forward an X-ray flagship concept that can win the support of NASA and Astro2030

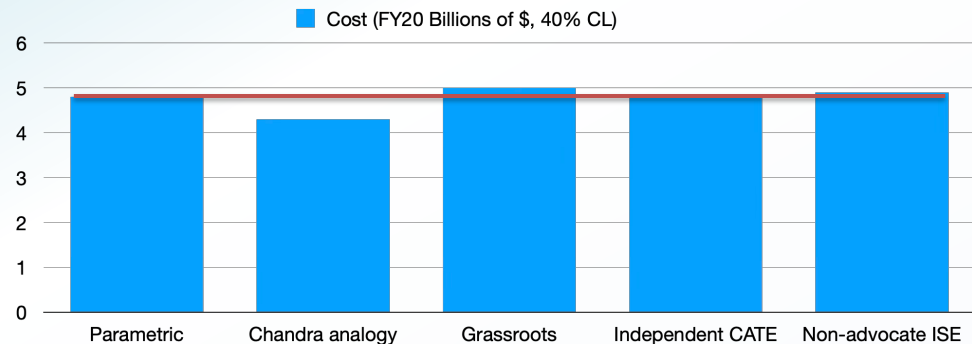
Take-away

- One of the biggest challenges to selection/implementation is cost risk
- Cost risk is primarily driven by potential delays in instrument delivery (marching army costs)
- We can potentially reduce risk through an EDU-First approach (Engineering Development Unit)
- The strategic X-ray mission Science/Technology Development Team (STDT) should study this

Cost Risk Sunk Lynx (And Here's Why)



The Lynx concept team's parametric cost was validated by independent estimates...



... but Astro2020's TRACE process estimated a much higher cost (only 70% confidence available)

Almost all of the cost growth comes from longer schedule and need for greater reserves: **cost risk!**

	Lynx Team	TRACE
Cost (FY20\$, 70% CL) [with 64% reserves]	\$6.2B	\$9.0B (+\$2.8B)
Tech Dev/Phase A	5 years	6.75 years
Phase B-D	10 years	11.5 years
Total	15 years	18.25 years
Total with \$ per year budget constraint		21.25+ years



Cost Risk Sunk Lynx (And Here's Why)

Increased TRACE cost vs. team parametric comes from three key elements based on *arguably* more realistic historical modeling

Area	Issue	Cost Delta (FY20\$B)
Technology Development, Mirror Assembly	Underestimated complexity of mirror assembly manufacturing, alignment, and integration	\$0.8B
Schedule Margin and Reserves	TRACE modeling estimates 18.25-19 years vs. team estimate of 15	\$1.5B
Overhead and Support	TRACE 19-year estimate requires more management, systems engineering, and mission assurance	\$0.5B
		\$2.8B total

The Point: If you think Lynx would take 19 instead of 15 years to build, it could cost almost \$3B more. Is Lynx compelling at the \$9B price point (cf. JWST, Roman)?



EDU-First: Front Load the Cost to Retire Risks

Let's embrace modern hardware iteration...

- Traditional flagship formulation requires large schedule margin, overhead
- Commercial aerospace methodology (e.g., SpaceX, Polaris) prioritizes early hardware testing: a test-heavy, iterative approach to definitively retire risk *before* triggering flagship implementation costs

... and pursue an EDU-First strategy

- **Cost:** ~\$600M over 8 years to construct EDUs (instead of a TRL-6 demo once TRL-5 is achieved)
 - Optics: \$300M (~\$40M/yr)
 - Detectors: \$200-\$300M
- **Strategic Delay:** Intentionally delay full mission-level implementation and reviews until these EDUs are proven successful, minimizing overall cost risk.
 - This approach costs a lot up front for something without certainty to fly.
 - But we won't be wasting money; reality is that an enormous amount can be saved!
- **The Math** of Strategic Delay: 4 years of a lean, EDU-only development team costs ~\$250M.
4 years of a fully-staffed Phase C/D mission team costs ~\$2.0B.



How EDU-First Saves Money

Formulation costs

- Validated EDUs definitively de-risk observatory before triggering flagship mission implementation costs

Bypass Engineering Model Phase with Mission Implementation

- Successful EDUs allow mission to quickly transition to proto-flight within the mission implementation phase
- EDU-First allows serious industrialization of X-ray mirror assembly (unique problem for X-ray missions)

Fixed-Price Contracts

- Mature hardware enables use of fixed-price contracts (e.g., for spacecraft and optics)
- EDU-First acknowledges contracting takes time

Sharper S-Curve

- Front-loading the investment dramatically reshapes cost profile
 - 70% confident cost becomes very similar to 40% confidence cost
 - Further ~ \$1B reduction in cost

Internal estimates suggest that the core mission cost *after* EDUs could be \$2.8B (FY20\$)

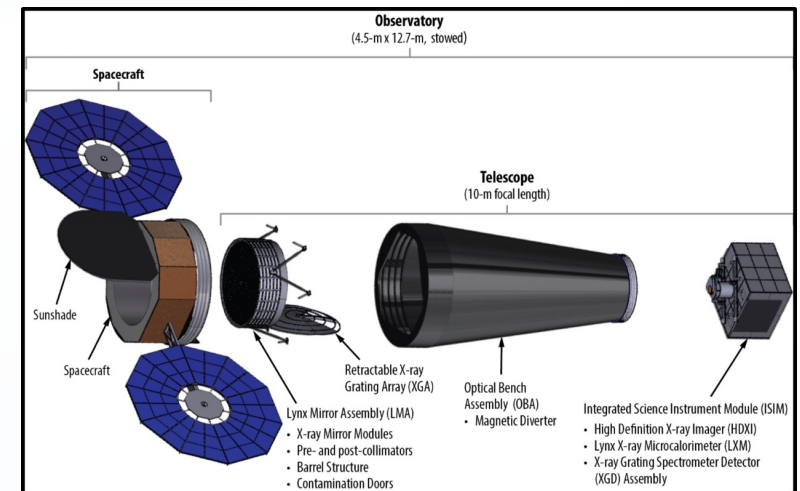
- Fits comfortably within \$3-\$4B cost cap
- (Includes lower spacecraft costs than Lynx)

A Stable X-ray Flagship Foundation Guarantees Return on Investment



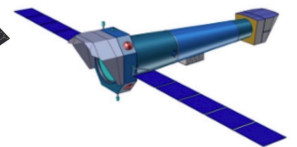
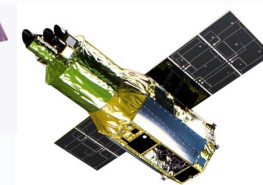
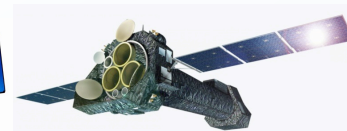
X-ray community is unique in having limited options for flagship mission architectures

- Arguably stable mirror requirements for
 - Focal length (bandpass)
 - Effective area (sensitivity)
 - Angular resolution (image quality, source identification)
- Mirror assembly is large, expensive, considered risky (Lynx, AXIS, STAR-X), and is a major cost driver
 - Lynx required fabrication and alignment of **37,492** segments / 611 modules
 - Early, serious industrialization is key to retiring risk, driving down cost



Lynx (2020) is a mature foundation

- We can bypass repetitive CML-3 paper studies





Trade-Offs & Challenges of the EDU-First Approach

1. Systems Engineering & Interface Risks

- **The Challenge:** Defining EDU requirements and interfaces is inherently riskier without a fully staffed, mission-level systems engineering team in place.
- **The Mitigation:** Risk is substantially lowered by leveraging senior engineering oversight and the strong architectural heritage from *Chandra*, *XRISM*, and *NewAthena*.

2. Non-Standard Review Lifecycle

- **The Challenge:** Forces a tailored review cadence. Independent SRR/PDR (iSRR/iPDR) processes must be modified, pushing formal Mission SRR and PDR unusually late in lifecycle.
- **The Mitigation:** Schedule and programmatic risks of this delayed cadence must be formally assessed early.

3. Procurement & Contracting Friction

- **The Challenge:** Traditional aerospace procurement bundles Engineering Models (EM) and Flight Units (FU) into a single process. Issuing two separate contracts creates unacceptable overhead and schedule drag.
- **Proposed Solutions (Modified Single-Contract):**
 - *Hybrid Approach:* "Cost-Plus" for complex EDU development phase, transitioning to "Firm-Fixed-Price" (FFP) for Flight Units.
 - *Gated FFP Approach:* Single Firm-Fixed-Price contract for both EDU and FU, but with hard contractual gate committing *only* to EDU at outset.

Bottom-Line Strategic Trade-Off:

- Upfront programmatic hurdles must be weighed against massive "**standing army**" **cost risk** avoided by maturing hardware *before* staffing full mission team.



Next Steps: A Call to Action for the STDT

- **Formal Investigation:** Upcoming Science and Technology Definition Team (STDT) should formally evaluate this alternative programmatic pathway.
- **Evaluate the Trade-offs:** Rigorously weigh the requirement of heavy upfront funding against the long-term savings and risk reduction.
- **Validate the Premise:** Confirm that our stable, pre-existing requirements safely enable early EDU development.
- **Develop the Cost Estimate:** Task the STDT with generating a detailed, rigorous cost estimate for this dedicated ~\$0.5-0.6 B technology and industrialization phase.

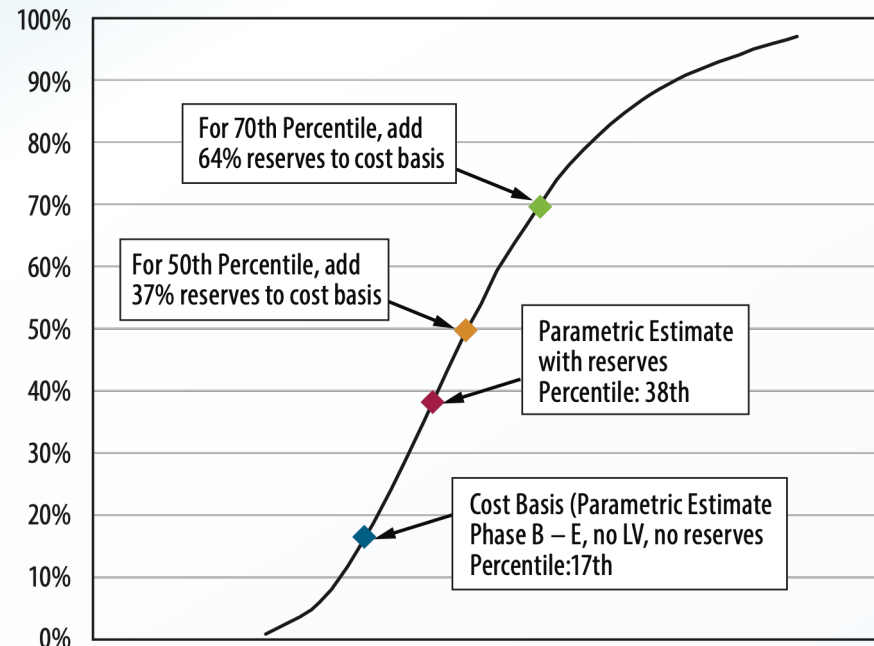


Backup

TRACE Analysis of the Lynx Proposal



- Conducted by Aerospace Corporation to evaluate Lynx project team's estimates.
- Lynx Project Team Estimate:**
 - Cost:** \$6.2 billion (FY2020)
 - Schedule:** 15 years total (5 years Tech Dev/Phase A; 10 years Phase B–D)
- TRACE Independent Estimate (at 70% Confidence):**
 - Cost:** \$9.0 billion (FY2020) — a 45% increase over the Lynx team estimate.
 - Schedule:** ~18.25 years total (6.75 years Tech Dev/Phase A; 11.5 years Phase B–D).



- Lynx parametric cost estimate with 30% reserves on Phase B–D (exclusive of LV) represents a 38% CL.
- For 70% CL, 64% reserves to be added.

Estimated cost of Lynx2020



- **Robust Cost Validation:** Lynx CSR baseline was rigorously cross-checked against four independent methodologies to prove credibility.

Estimating Process / Methodology	Cost at 40% Confidence	Fraction vs. 40% Baseline (\$4.8B)	Cost at 70% Confidence	Fraction vs. 70% Baseline (\$6.0B)
Project Parametric Estimate (Baseline)	\$4.8 Billion	--	\$6.0 Billion	--
Chandra Analogy (Point Estimate)	~\$4.27 Billion	-11%	N/A	N/A
Grassroots Estimate (Point Estimate)	~\$5.0 Billion	+4%	N/A	N/A
Independent CATE (MCR)	\$4.8 Billion	0%	\$5.1 Billion	-15%
Non-Advocate ICE (MSFC)	\$4.9 Billion	+2%	\$6.2 Billion	+3%
Decadal Survey:				
TRACE Analysis (Aerospace Corp.)	Not Provided	N/A	\$9.0 Billion	+50%

- Lynx Team Estimate (70%): \$6.0B
- TRACE Independent Estimate (70%): \$9.0B

All numbers above in Fiscal Year 2020 Dollars (FY\$20)

Takeaway: "How did the estimate grow by \$3B (50%)? Let's look at the breakdown."

Cost Estimate Variance: Lynx vs. TRACE (\$2.8B Delta)



Lynx Estimate: \$6.2B (11% conf. - TRACE) | TRACE Estimate: \$9.0B (70% confidence)

1. Tech Development & Mirrors (~\$800M Delta)

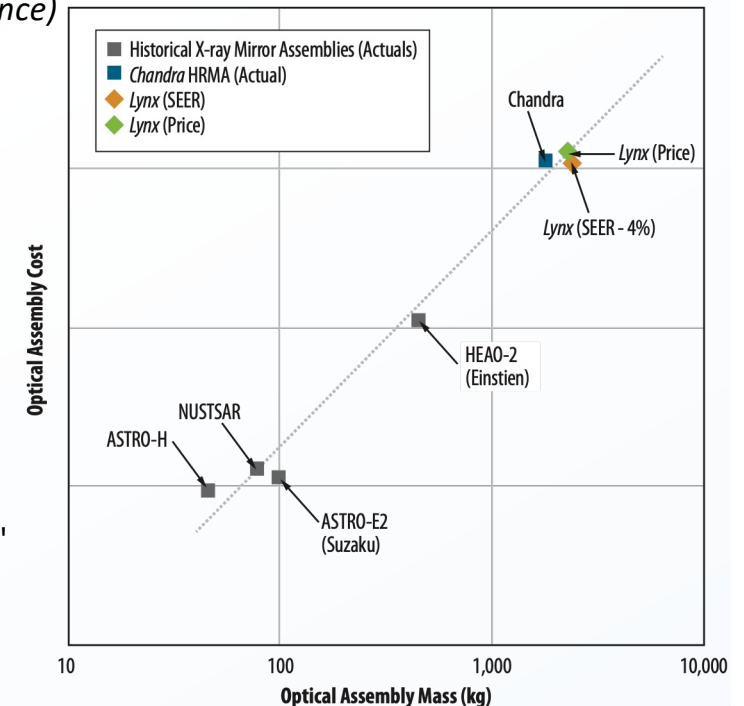
- **The Issue:** Underestimated complexity of Lynx Mirror Assembly (LMA) manufacturing, integration, and alignment.
- **Opportunity:** Early down-selection from three parallel mirror technologies could recover some of these costs.

2. Schedule Margin & Reserves (\$1.5B Delta)

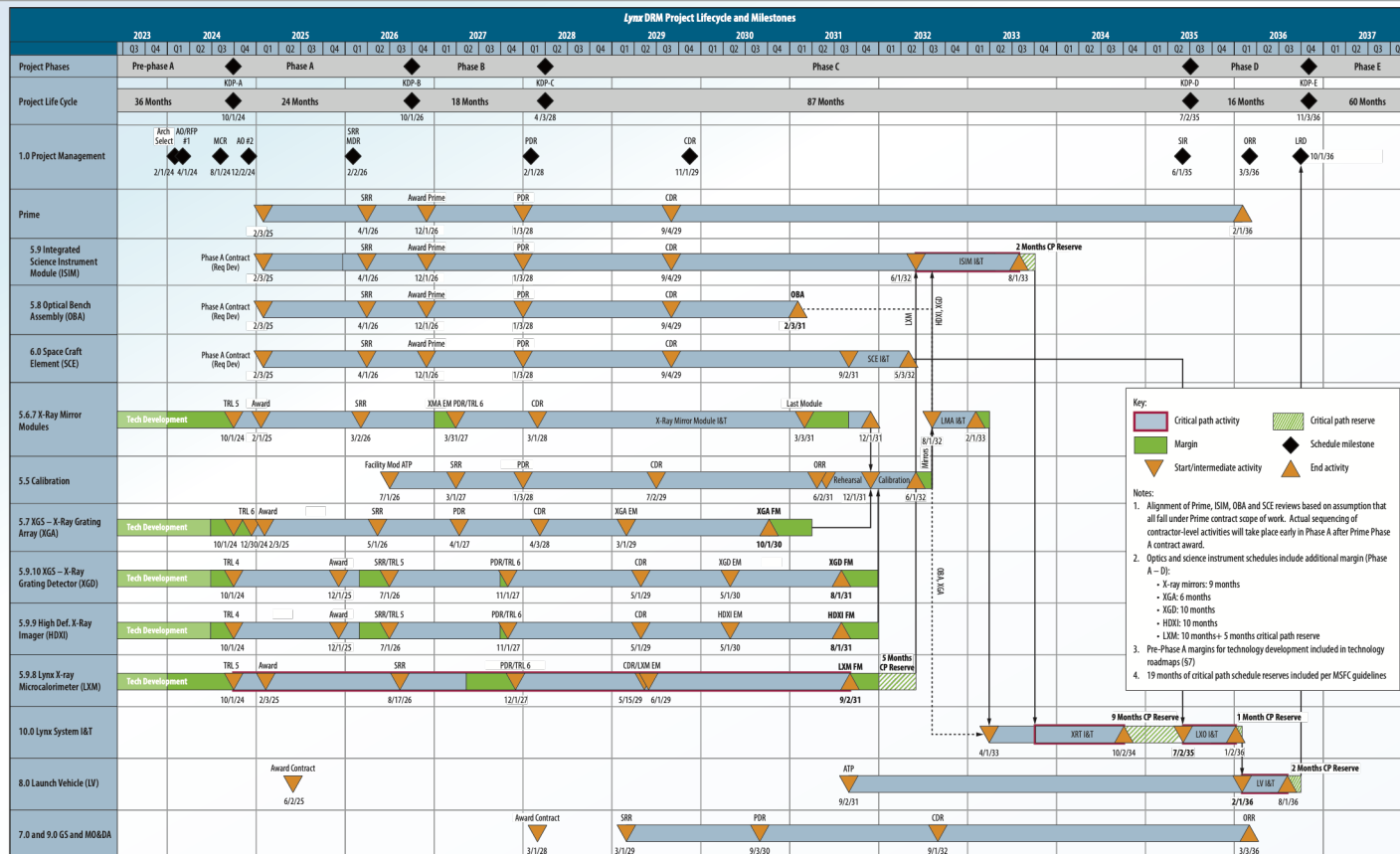
- **Schedule Realism:** Lynx assumed a 15-year schedule. TRACE modeling estimates 18.25–19 years for 70% confidence.
- **Cost Impact:** Added reserves account for 3–4 extra years of "standing army" costs and likely complexity growth.

3. Overhead & Support (~\$500M Delta)

- **The Issue:** Extended 19-year schedule requires proportional funding increases for Management, Systems Engineering, and Mission Assurance.
- While seemingly severe, a \$2B delta for (2) and (3) is consistent with 3-4 years of peak 'standing army'.



Schedule



Schedule - Optics

