THE POSSIBLE IMPACT OF LARGE LAUNCH VEHICLES ON ASTRO 2020

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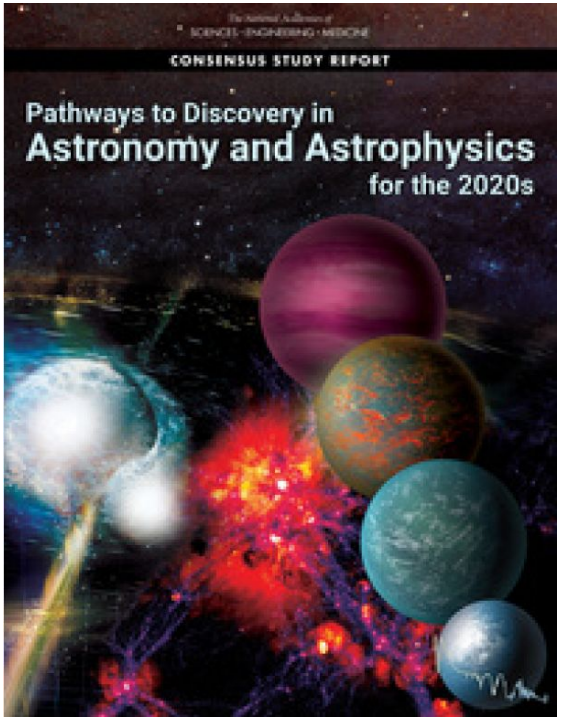
The Astro 2020 Highest Priority:
Great Observatories Mission and Technology Maturation Program

Recognized that spectrum-spanning capability is crucial to 21st century astrophysics

Recommended Mission & Tech Maturation Program for a set of 3 flagship missions to span the spectrum:

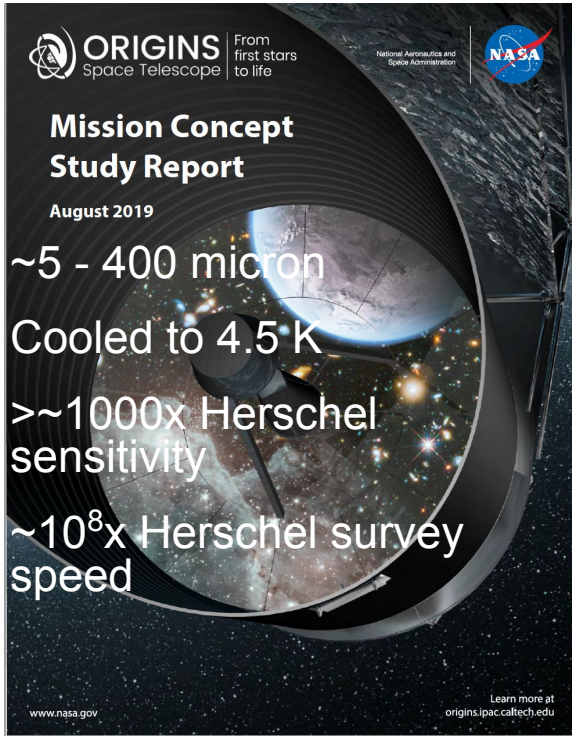
Far-IR, IR/Opt/UV, X-ray

$1.2B in GOMAP program; $800M for HWO, $400M for X-ray & FIR



The Astro 2020 Flagship Missions

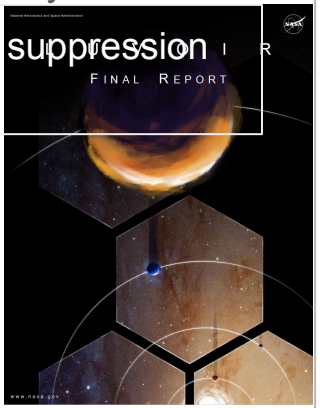
Far-IR “Origins”



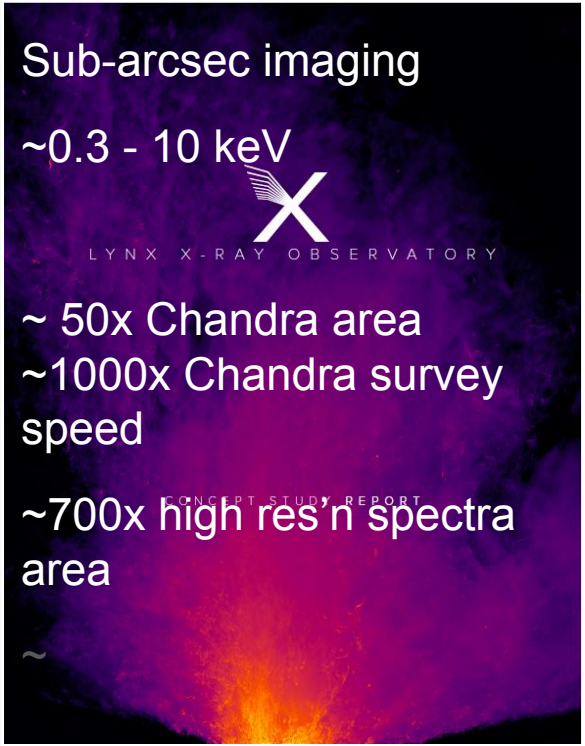
NIR/Optical/UV

Habitable Worlds Observatory

“large (~6 m aperture) infrared/optical/ultraviolet (IR/O/UV) space telescope” “for exoplanet characterization and general astronomy”



X-ray “Lynx”

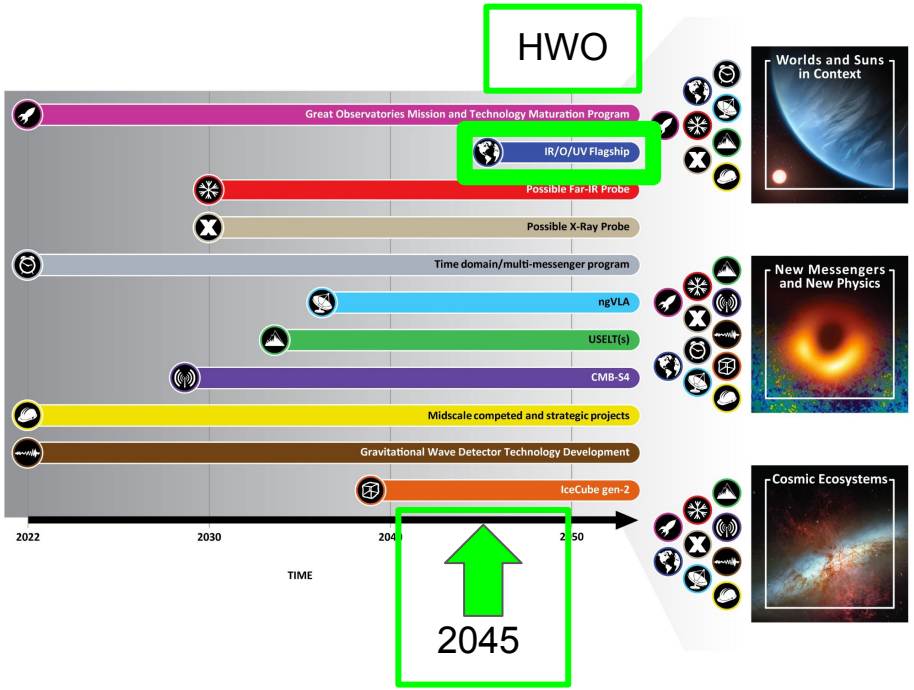


The Astro 2020 Timeline for Flagship Missions

First flagship to launch in 2045

Our motivation:

- Could new launchers accelerate this schedule?



Astro2020 Report

Mission Drivers: Mass, Size, Complexity, Cost

Designs are highly constrained with current launchers

Mass can dominate spacecraft & payload design

E.g., JWST total mass 6.2 t. Required new lightweight mirror technology

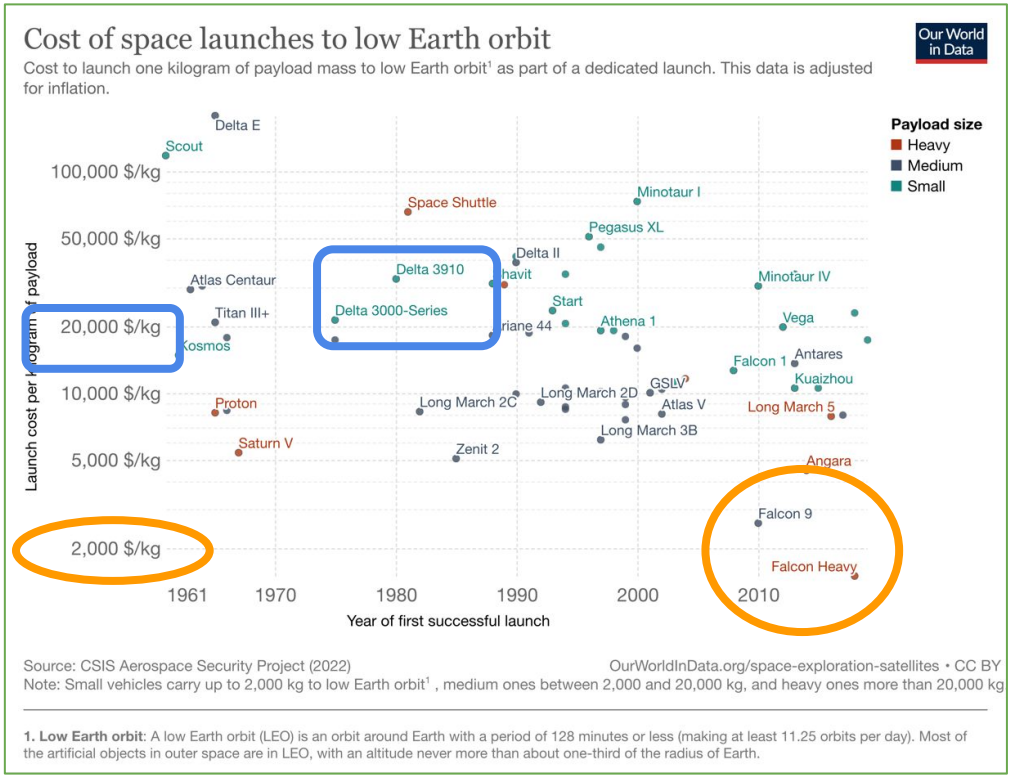
Size: 5 m fairing. JWST required complex folding mirror & “tennis court”-sized folding sunshade

Cost: mass and complexity are cost drivers

Both much eased by Large Launcher capabilities

https://sci.esa.int/web/jwst/-/45742-jwst-launch-configuration

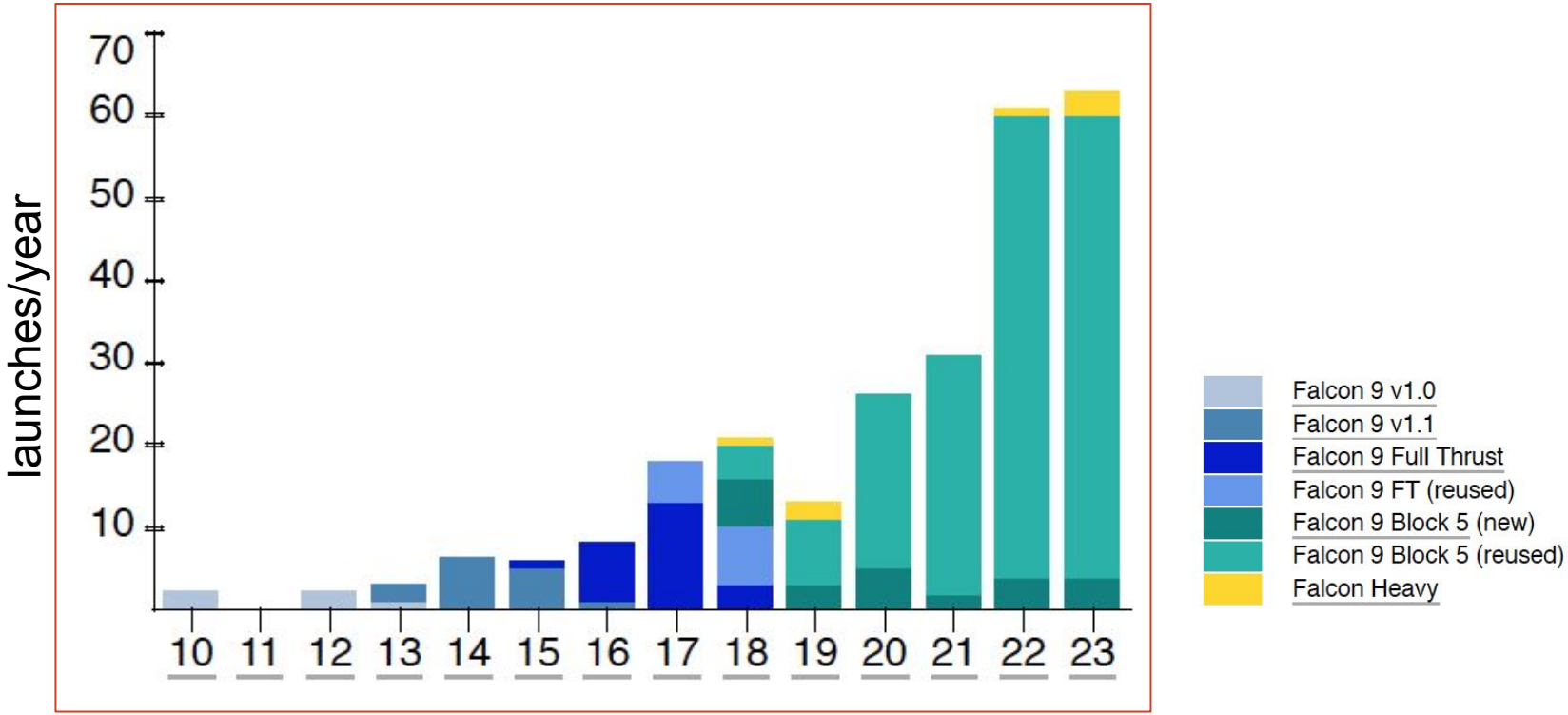
Launch: Cost/kg to LEO has Already Come Down 10x



CSIS Aerospace Security Project (2022)

Goal for Starship

Launch: Weekly Launches for Falcon 9



https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches

Launch: New Generation of Large Launchers

SpaceX Starship

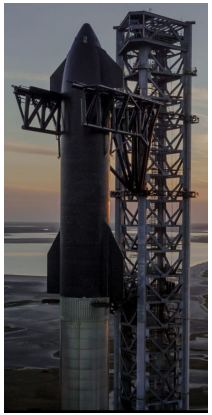
8m (dynamic) fairing

100-150 t to LEO; TBD t to Sun-Earth L2 direct, 100t w. Refueling

Fully reuseable

RUD on 1st test

TBA ~$100M



https://www.spacex.com/vehicles/starship/

Space Launch System

7.5 m (Block 1 dyn.) fairing

38t to deep space (Block 1B); 46t to deep space (Block 2)

Single use

Flawless 1st flight

Expensive (>~$1000M)

https://www.nasa.gov/wp-content/uploads/2021/04/0080_sls_fact_sheet_sept2020_09082020_final_0.pdf?azure-portal=true

Blue Origin New Glenn

6.35 m (dyn.) fairing

45 t to LEO, 13 t to GTO

1st stage reuseable

First launch: TBA

https://www.blueorigin.com/new-glenn

Spacecraft: Use Mass to Solve Problems, Lower Cost

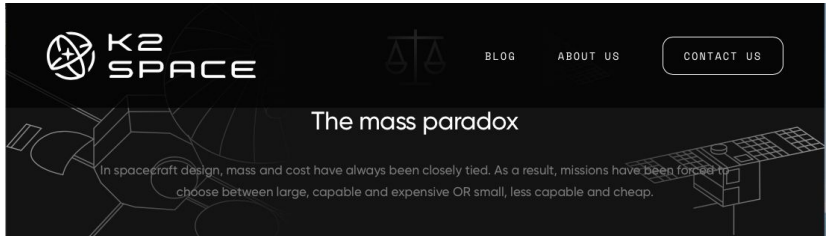
Larger ~200x cheaper Si-based solar panels *(Starlink does this)*

→ more power, ~10 kW (vs ~1 kW for Chandra)

→ cheaper electronics, shielded by Al mass. Shielded cables

And/or, multiple copies and poll (redundancy) *(Falcon 9 does this)*

Standard mechanical structure margins (~3X) - reduced design/manufacturing/test complexity, time



Spacecraft: How Mass, Diameter May Cut Costs

Use mass to solve problems: SphereX example

Allen Farrington, SPHEREx project manager:
“The approach that SPHEREx has taken from proposal through the critical design review is to convert risk to mass. A key example was the Sun-Earth shade, where we swapped out technically challenging, state-of-the-art, soft-goods-based technology for more massive but state-of-practice aluminum honeycomb panels. This resulted in a much lower risk posture and was enabled by the excess mass capabilities of our Falcon 9 launch vehicle.”

Enlarges the design space

Payload: Far-Infrared Gains from Volume

Based on “Origins” study for Astro2020

Assumed large diameter launcher:

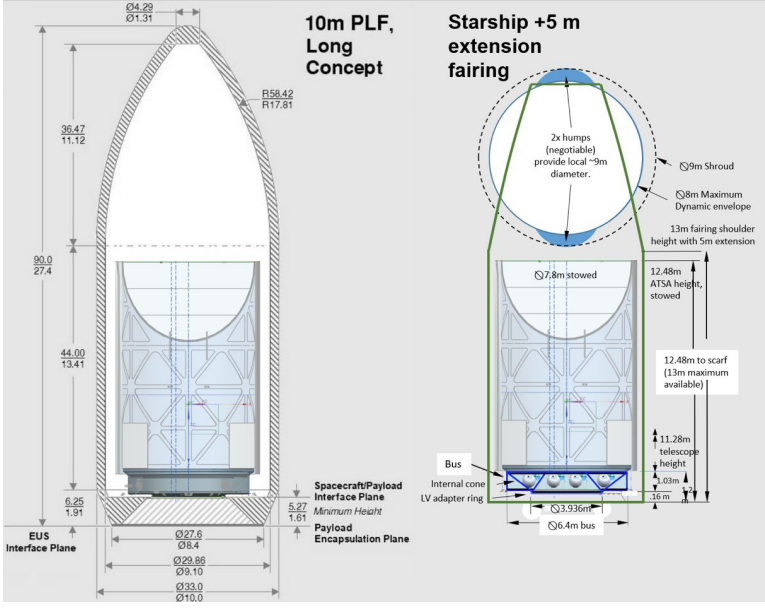
Much simplified design

Non-folding mirror; no “tennis court” heat shield

But used only 25% of available mass.

Opportunities to explore uses of mass:

e.g., mirror material choice, spacecraft savings



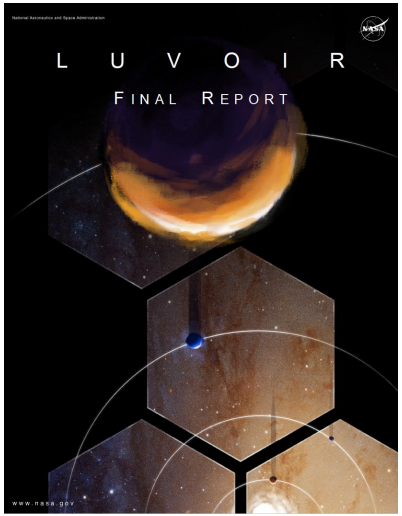
Martin et al., JATIS #044005 Oct-Dec 2022, Vol. 8(4)

Habitable Worlds Observatory

"Inspired by the vision of searching for signatures of life on planets outside of our solar system, and by the … transformative capability, the priority recommendation in the frontier category for space is a **large (~6 m diameter) IR/O/UV telescope** with **high-contrast (10^{-10}) imaging and spectroscopy.**" Pathways to Discovery in Astronomy and Astrophysics for the 2020s

"Precursor science programs, analyses of alternatives, and architecture trades determine what the IR/O/UV Observatory will ultimately look like."

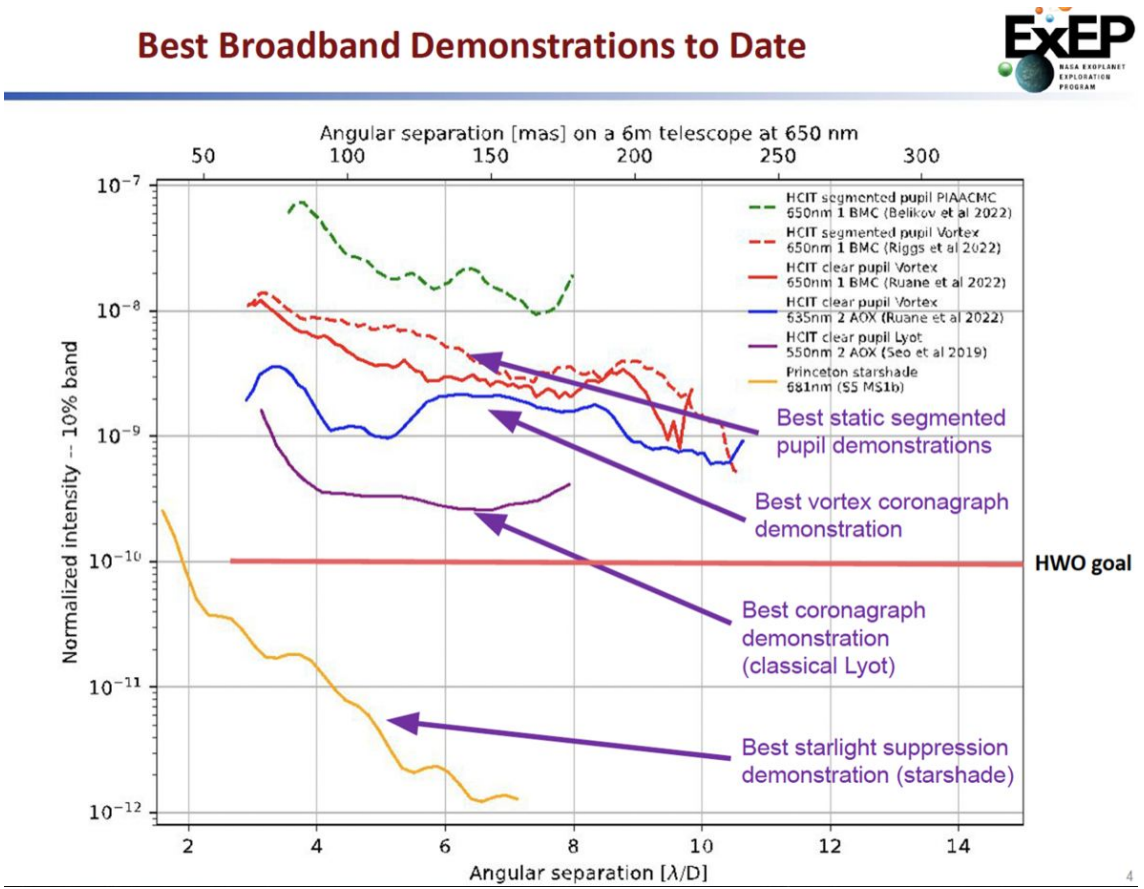
https://www.greatobservatories.org/irouv



HWO Coronagraph

Suppressing starlight to the 10^{-10} required planet-star intensity contrast to reach an Earth-like exoplanet in reflected light orbiting a Sun-like star is a challenging task

Coronagraphs working at static conditions in the lab at broad band (~10 % bandwidth) are more mature for monolithic as compared to segmented apertures



https://exoplanets.nasa.gov/internal_resources/2664/

Payload: X-ray Gains from Mass

Key Lynx weakness identified by Aerospace Corp was X-ray mirror assembly. Added ~$1.5B to cost estimate [TBR]

37,492 mirror segments 0.5 mm thick (10X10cm).

Chosen to minimize mass to 2 t.

Lynx Study Report

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37,492 mirror segments 0.5 mm thick (10X10cm).

Chosen to minimize mass to 2 t.

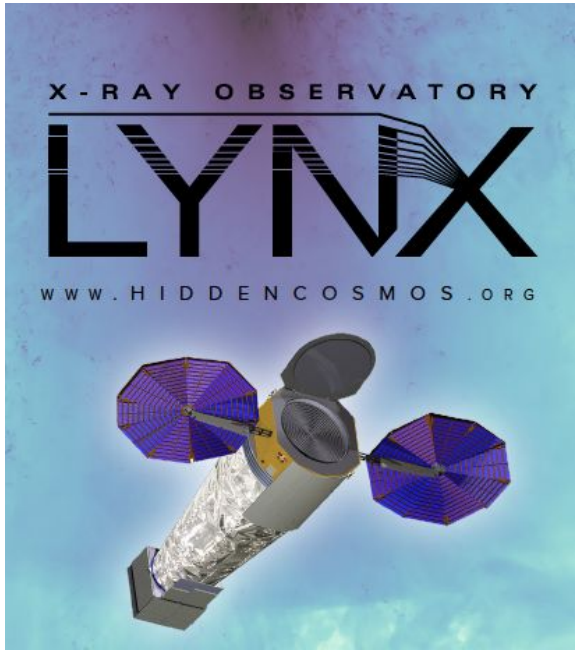
2 mm thick segments 64x stiffer.

Mass ~8t, well within large launcher capability.

→ ~6x fewer, larger, segments

May allow: faster production, easier assembly, alignment

Reduces risk, raises TRL



Lynx Study Report

New launchers expand the design space
But don’t solve every problem

Increased Mass

→ more station keeping propellant

coupled with increased size

→ increased moment of inertia

→ bigger reaction wheels

Source: NanoAvionics

Management Challenges

Mission Creep:

E.g., scientists will ask “why not use mass for bigger folding mirrors?”

Cheaper, faster, but stick with original ambitious goal.

Exercise restraint

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Cost models:

Often modeled costs scale with mass

New paradigm: increased mass may decrease cost. A bold change.

Grass roots costs (“bottom up”) will be the best guide until models catch up

Prepare for Success

Starship will be proven, or not, by the time that the Astro 2020 mid-decade review begins (~2026)

Propose: That GOMAP is the right venue to carry out:

- Studies of all 3 Astro 2020 flagship spacecraft and payloads in the Starship paradigm.
- Take advantage of the design space that has opened up.
- Management study of cost containment to accelerate Astro 2020.

Questions:

- Are major cost savings plausible?
- Can Astro2020 be accelerated?

Allow time to cross-compare and to inform management study

Timescale for reports depends on GOMAP funding