Optical Design and Status of the Large Ultra-Violet Optical Infrared Surveyor (LUVOIR)

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LUVOIR

Introduction

In preparation for the Astrophysics 2020 Decadal Survey NASA's Goddard Space Flight Center is studying a segmented aperture telescope with broad astrophysics, solar system, and exoplanet science capability called the Large Ultra-Violet Optical Infrared Surveyor (LUVOIR). This telescope design incorporates many heritage design concepts from the Hubble Space Telescope (HST), James Webb Space Telescope (JWST), and the Wide-field Infrared Survey Telescope (WFIRST). This includes similar ultraviolet instrumentation from HST, deployable segmented optics from JWST, and high-contrast coronagraph technology from WFIRST. Several optical design trades were completed to maximize the science product while maintaining reasonable packaging and fabrication constraints. Other technology developments such as freeform optics, UV enhanced coatings, coronagraph design, and ultra-stable mirrors are being studied to further improve the observatory performance.

Telescope Overview

The LUVOIR telescope consists of an Optical Telescope Element (OTE) and several science instruments including the Coronagraph ECLIPS, wide field broadband imager HDI, ultraviolet multi object spectrograph LUMOS, and a spectro-polarimeter POLLUX. Each instruments sits inside serviceable modules within the Backplane Support Frame (BSF) behind the segmented Primary Mirror (PM). These elements, OTE+BSF+instruments, are considered the science payload and are connect to the spacecraft bus via an articulating arm which both points the payload and isolates it from vibration. The spacecraft bus contains the large deployable sun shield, solar panels, reaction wheels, and other spacecraft components.

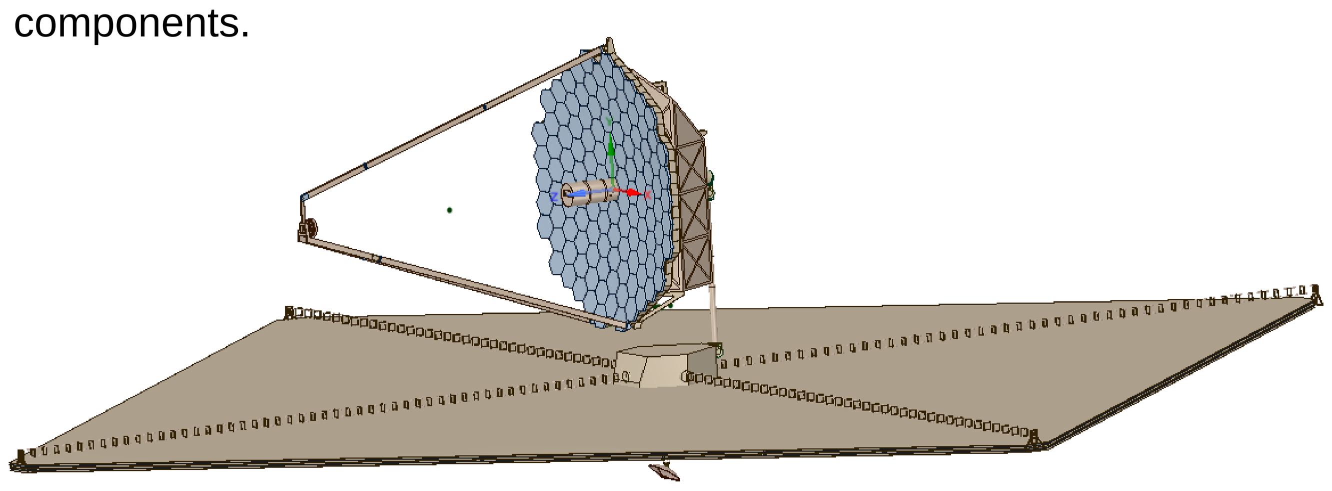

Figure 1: LUVOIR A Telescope model with an 15m diameter Primary Mirror and 56.8m edge-to-edge sunshield

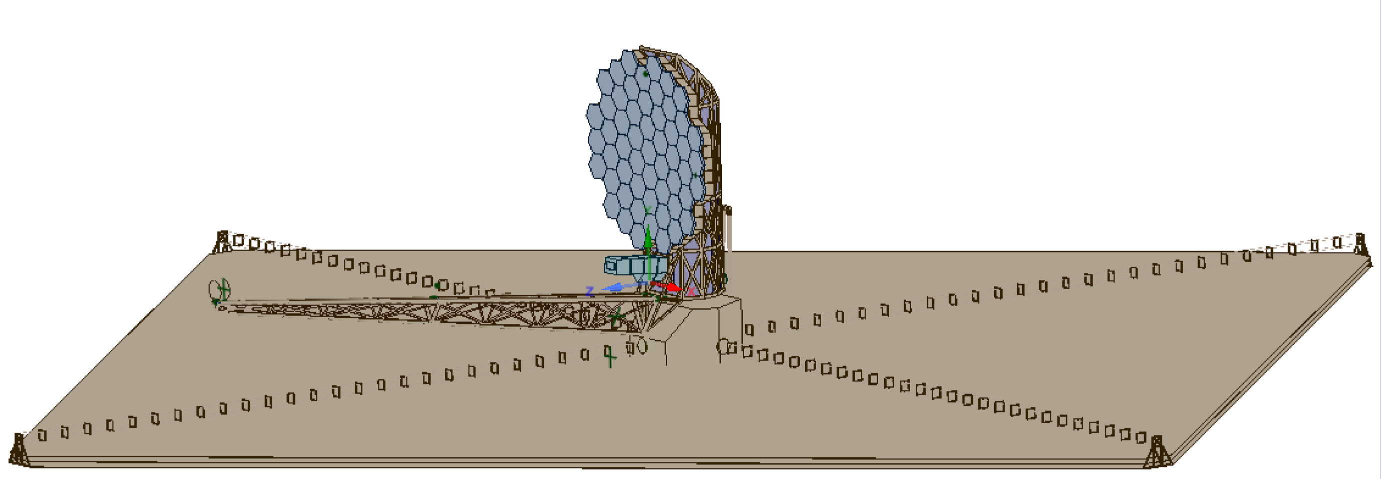

Figure 2: LUVOIR B Telescope model with an 8m diameter unobscured Primary Mirror and 45.5m edge-to-edge sunshield

Optical Design

In an effort to increase the Exoplanet yield for the coronagraph instrument the previous LUVOIR telescope was redesigned to increase collecting area and reduce the obscuration size. Two telescope architectures are currently being studied in detail for the decadal Survey. LUVOIR A is a 15m diameter Primary Mirror (PM) with a 1 segment obscuration, while Architecture B is an 8m diameter PM with no obscuration.

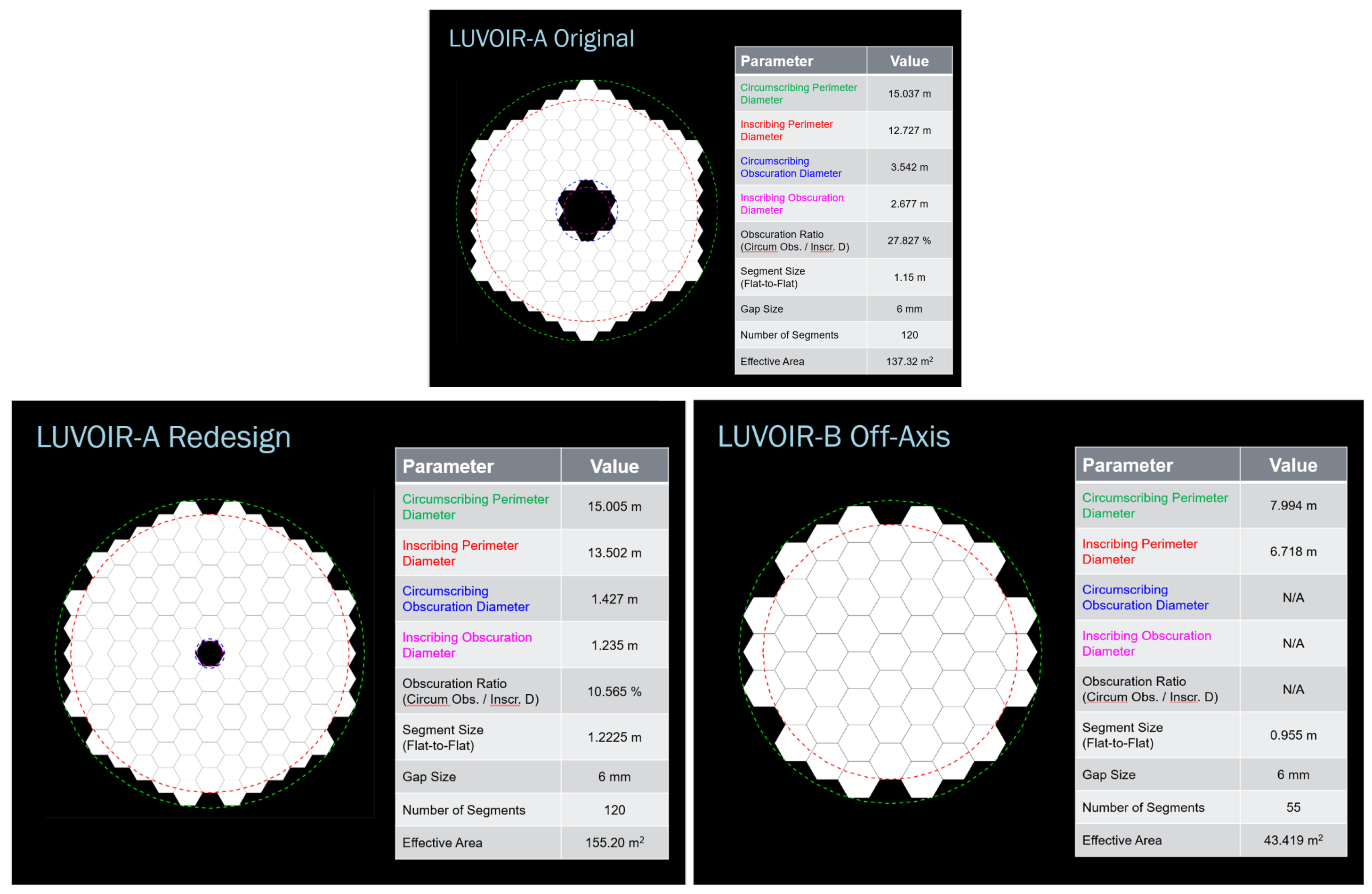

Fig. 3 The segmented primary mirror apertures of the previous LUVOIR A and current A and B designs. [1]

The optical design form of LUVOIR A and B is a Three Mirror Anastigmatic (TMA) similar to JWST and WFIRST. Both designs have 3 powered optics and a flat Fast Steering Mirror (FSM) located at the exit pupil. The TMA design enables excellent aberration corrections across the FOV.

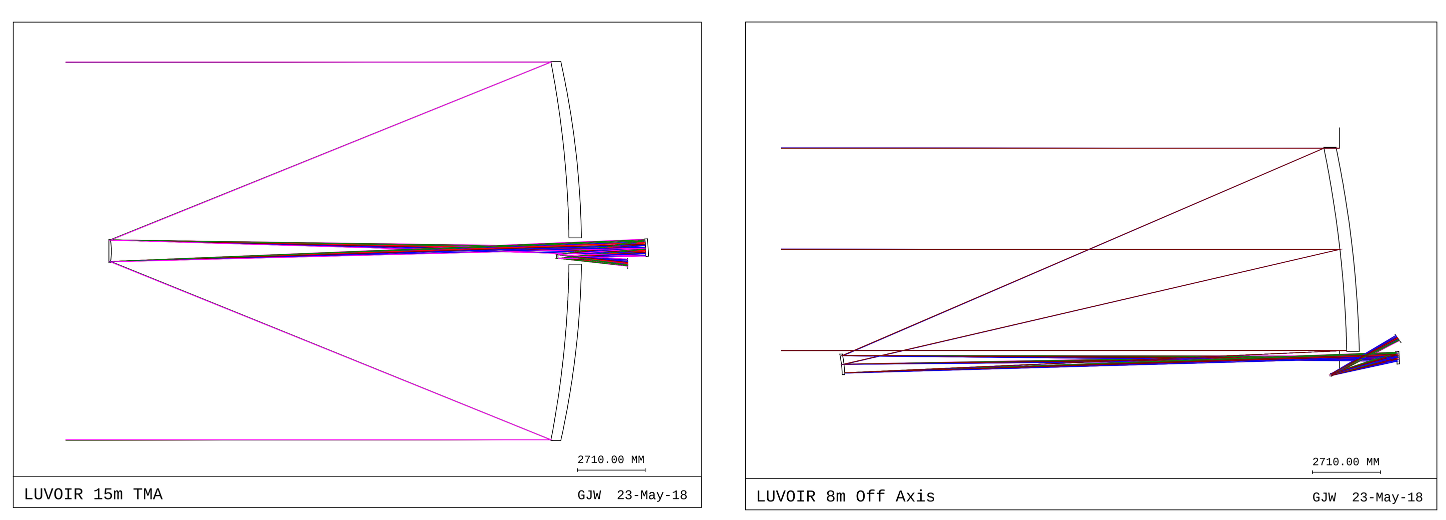

Fig. 4 The raytrace for the LUVOIR A and B OTE.

	LUVOIR A	LUVOIR B	Units
Launch Vehicle	SLS Block 2	Blue Origins New Glenn	--
F/#	20	36.9	--
Focal Length	297	295	m
Field of View (FOV)	10' x 8'	10' x 8'	arcmin
LUMOS MSA FOV	2' x 2'	2' x 2'	arcmin
Plate Scale	0.694	0.699	arcsec/mm
Field Average RMSWFE	6.25	1.64	nm
Maximum AOI for ECLIPS	11.8	12.0	degrees

Driving Design Parameters

- **Telescope FOV:** driven by the sum of each instruments required FOV plus margin for spacing between instruments
- **PM and SM spacing:** driven by the maximum AOI <12° to reduce polarization for ECLIPS. This is linked to the PM F/#.
- **Mirror Prescriptions and Locations:** The telescope is optimized to achieve the best image quality possible while meeting some key packaging constraints. These packaging constraints include the location of the TM and OTE focal surface within the BSF, the maximum PM-SM spacing, and the FSM location.
- **Telescope Focal Length:** driven by the Microshutter Assembly (MSA) angular FOV and plate scale. In the Architecture B design the focal length is also driven by the requirement to have the OTE focal plane tucked behind the PM. This allows the instruments to be packaged behind the PM in a similar design to Architecture A.

Technology Development

NASA is investigating several key technology developments necessary to make the LUVOIR mission a reality. Some of those key technologies are listed here.

- **Freeform Mirrors:** Freeform mirrors are needed to reduce the volume and mass of the instruments while improving the image quality. High quality freeform mirrors with low surface roughness and figure errors are needed to meet the UV stray light and imaging requirements.
- **Stable, Stiff and Lightweight Mirrors:** The mirror segments especially needed to be light-weighted to reduce the mass of the payload, stiff to reduce dynamic deformation, and thermally stable to reduce thermal deformations.[1]
- **High Reflectance Coatings in the UV:** High reflectivity coatings especially around 100-200nm are needed to increase throughput in the UV instrument LUMOS.[1]
- **Coronagraph Design:** Several coronagraph designs are being investigated to increase the potential Exoplanet yield. Some of the key technologies include improving the starlight suppression through mask design, deformable mirrors for stability and image quality, and active telescope alignment.[1]

Current Status

Both telescope architectures are being modelled and refined to develop a Master Equipment List and Wavefront Error Budget. Optical design of the science instruments is ongoing as the engineering team optimizes the science output with mass and packaging constraints. The final Decadal Survey report is being submitted to NASA HQ June 2019.

REFERENCES: 1. LUVOIR Interim Report. NASA GSFC. April 2018