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The Large UV/Optical/Infrared Surveyor Decadal Mission Concept Thermal System Architecture

ICES Paper 2019-312

Kan Yang – NASA GSFC
Matthew Bolcar – NASA GSFC
Jason Hylan – NASA GSFC
Julie Crooke – NASA GSFC
Bryan Matonak – NASA GSFC
Andrew Jones – NASA GSFC
Joseph Generie – NASA GSFC
Sang Park – Harvard Smithsonian Center for Astrophysics

International Conference on Environmental Systems,
Boston, MA 2019

Outline

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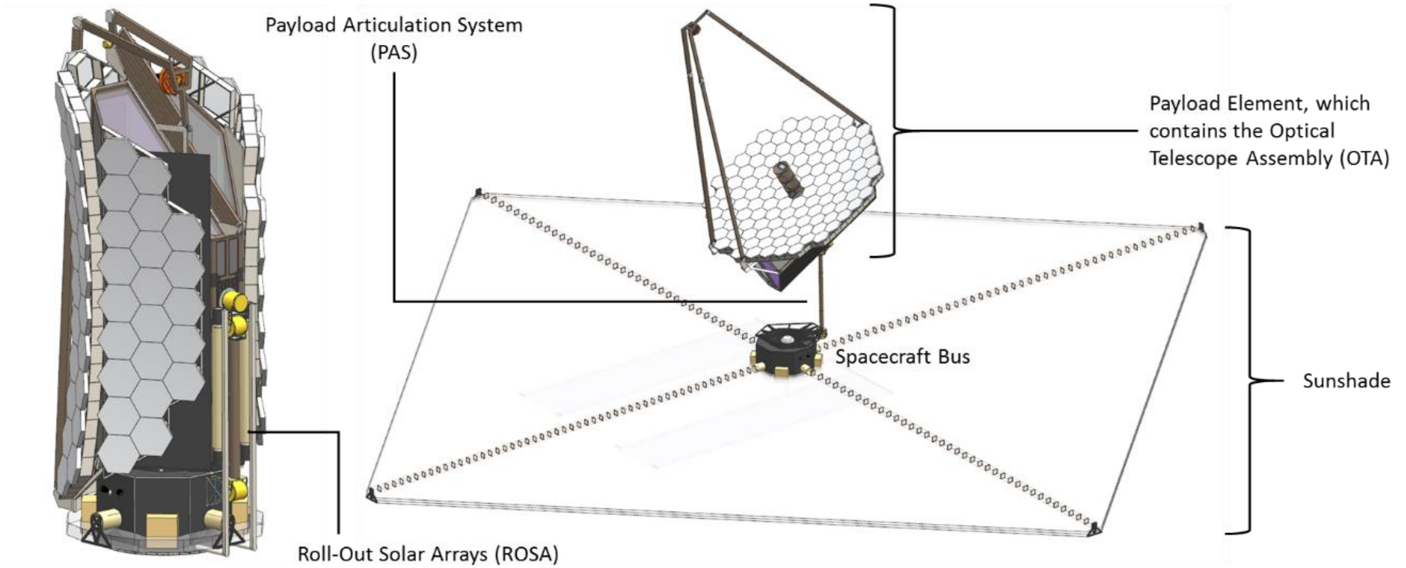
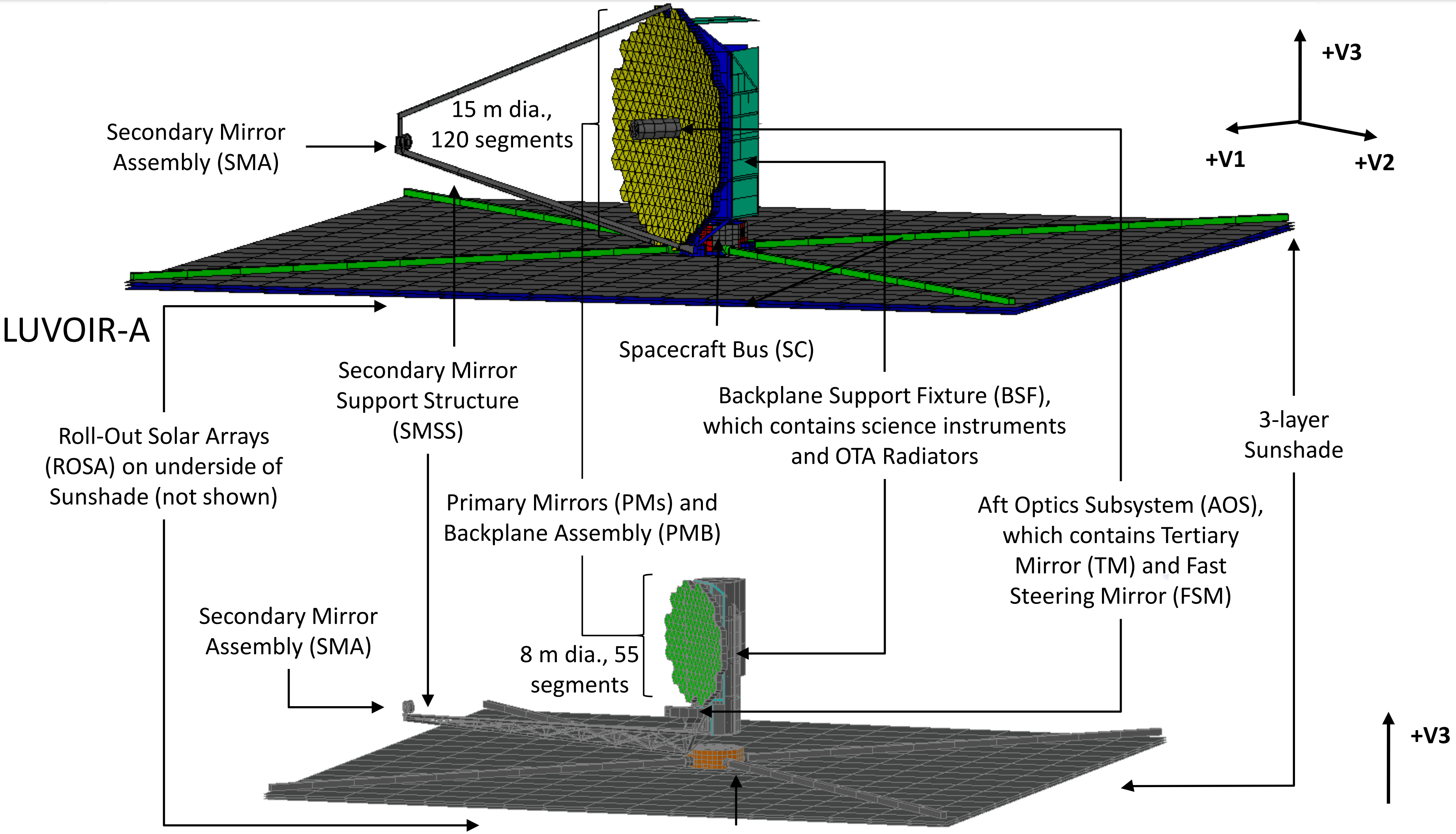
  - Spacecraft Bus (SC)
  - System-level Heat Flows
- Preliminary Analysis Results
  - Heater Power
  - Radiator Area
- Conclusions and Recommendations

What is LUVOIR?



- The Large Ultraviolet/Optical/Infrared Surveyor (LUVOIR) is a multi-wavelength general-purpose space observatory
  - One of four concept studies for the 2020 Decadal Survey in Astronomy / Astrophysics
- LUVOIR enables broad range of astrophysics to be performed: studies of galaxy and planet evolution, star and planet formation, exoplanet atmospheric and surface composition (assessing habitability, biosignatures)
  - Exoplanet direct imaging seeks to answer question “are we alone?”

Two LUVOIR Architectures



Secondary Mirror Assembly (SMA)

15 m dia., 120 segments

LUVOIR-A

Spacecraft Bus (SC)

Secondary Mirror Support Structure (SMSS)

Backplane Support Fixture (BSF), which contains science instruments and OTA Radiators

3-layer Sunshade

Roll-Out Solar Arrays (ROSA) on underside of Sunshade (not shown)

Primary Mirrors (PMs) and Backplane Assembly (PMB)

Aft Optics Subsystem (AOS), which contains Tertiary Mirror (TM) and Fast Steering Mirror (FSM)

Secondary Mirror Assembly (SMA)

8 m dia., 55 segments

Spacecraft Bus (SC)

LUVOIR-B

Thermal Design Requirements

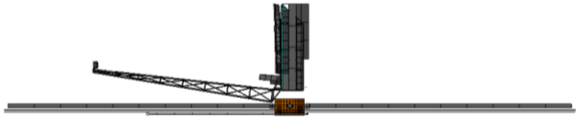
Temperature Requirements

- Actively Heated OTA structure to 270 K
  - Temperature chosen to keep composite structure and Ultra Low Expansion (ULE) glass mirrors with favorable material properties resulting in near-zero Coefficient of Thermal Expansion (CTE)
  - Allows science in near-Infrared (NIR)
- Telescope optical element thermal stability requirement of ±0.001 K
  - Ultra-stable wavefronts are necessary to enable high-contrast exoplanet science

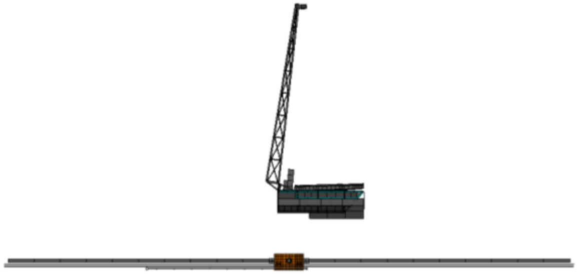
Observatory Orientations

- LUVOIR is at 2nd Lagrange Point (L2): stable environment
- Worst-case thermal environments are bound by orientations shown on right
  - Sunshade pitch: positive angle describes cant towards solar vector
  - OTA pitch: payload's orientation with respect to sunshade

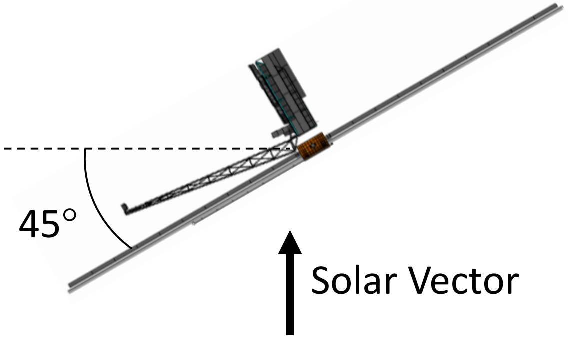
Sunshade pitch 0°, OTA pitch 90°



Sunshade pitch 0°, OTA pitch 0°



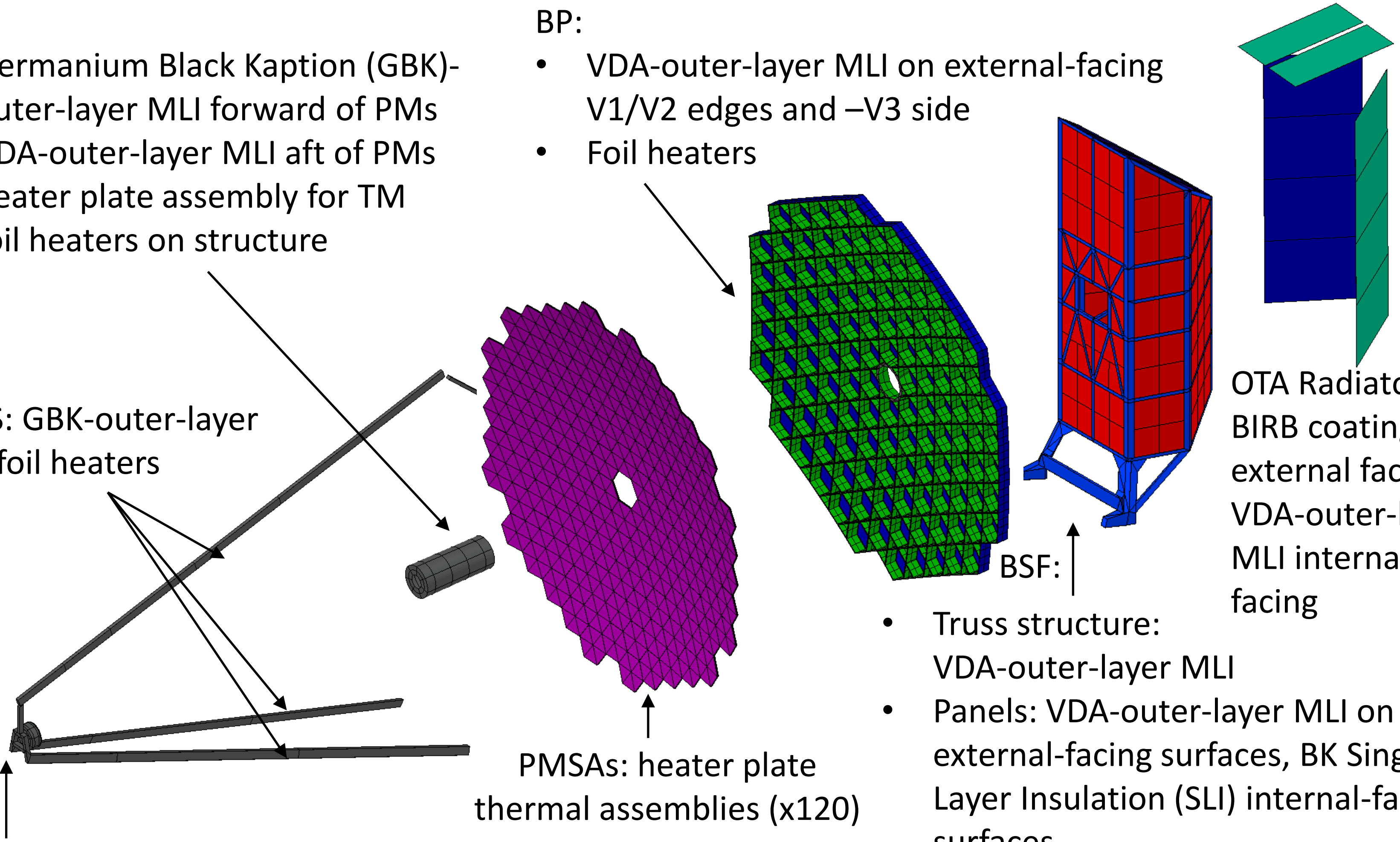
Sunshade pitch 45°, OTA pitch 90°



Thermal Design Overview

- Heaters over entire OTA structure and spacecraft to actively control temperatures to 270 K and achieve desired thermal stability
  - Bulk of telescope structure is insulated with Multi-Layer Insulation (MLI) to prevent excess heat loss to space (conserve heater power)
- Mostly passive thermal design for transport and rejection of heat to space
  - Heat pipes transport heat generated from OTA instruments and electronics boxes to radiators on ±V2 sides and +V3 side of BSF
- Large 3-layer sunshade to provide cold sink environment for instrument and electronics dissipations
  - Trade studies established that a silicon-doped Vapor-Deposited Aluminum (VDA) –V3 side coating, VDA internal layer coatings, and Black Kapton (BK) +V3 side coating provided the coldest sinks
- Modular design, multiple thermal zones
  - Each separate assembly is partitioned into its own thermal zone to reduce the amount of heat exchange / cross-talk between assemblies
- Dedicated heat pipes and radiators for instrument temperature requirements
  - Instruments have 100 K, 170 K, and 270 K components, all passively cooled
  - Each instrument thermal zone has dedicated heat pipes to transport heat to radiators which are at least 20 K colder than component itself

OTA Thermal Architecture (LUVOIR-A)



AOS:

- Germanium Black Kaption (GBK)-outer-layer MLI forward of PMs
- VDA-outer-layer MLI aft of PMs
- heater plate assembly for TM
- foil heaters on structure

BP:

- VDA-outer-layer MLI on external-facing V1/V2 edges and –V3 side
- Foil heaters

OTA Radiators: BIRB coating external facing, VDA-outer-layer MLI internal facing

SMSS: GBK-outer-layer MLI, foil heaters

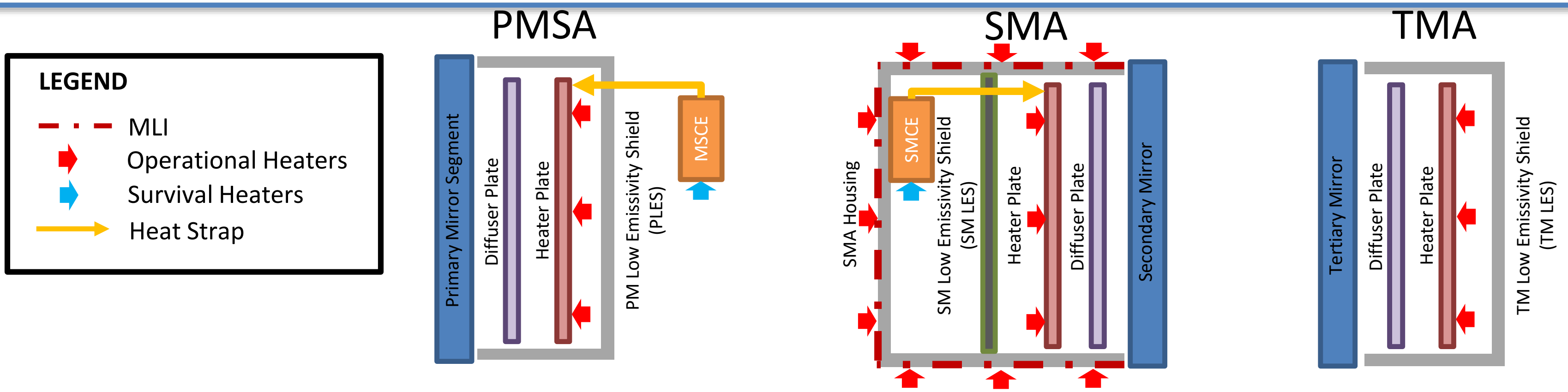
PMSAs: heater plate thermal assemblies (x120)

BSF:

- Truss structure: VDA-outer-layer MLI
- Panels: VDA-outer-layer MLI on external-facing surfaces, BK Single-Layer Insulation (SLI) internal-facing surfaces
- Foil heaters covering all surfaces

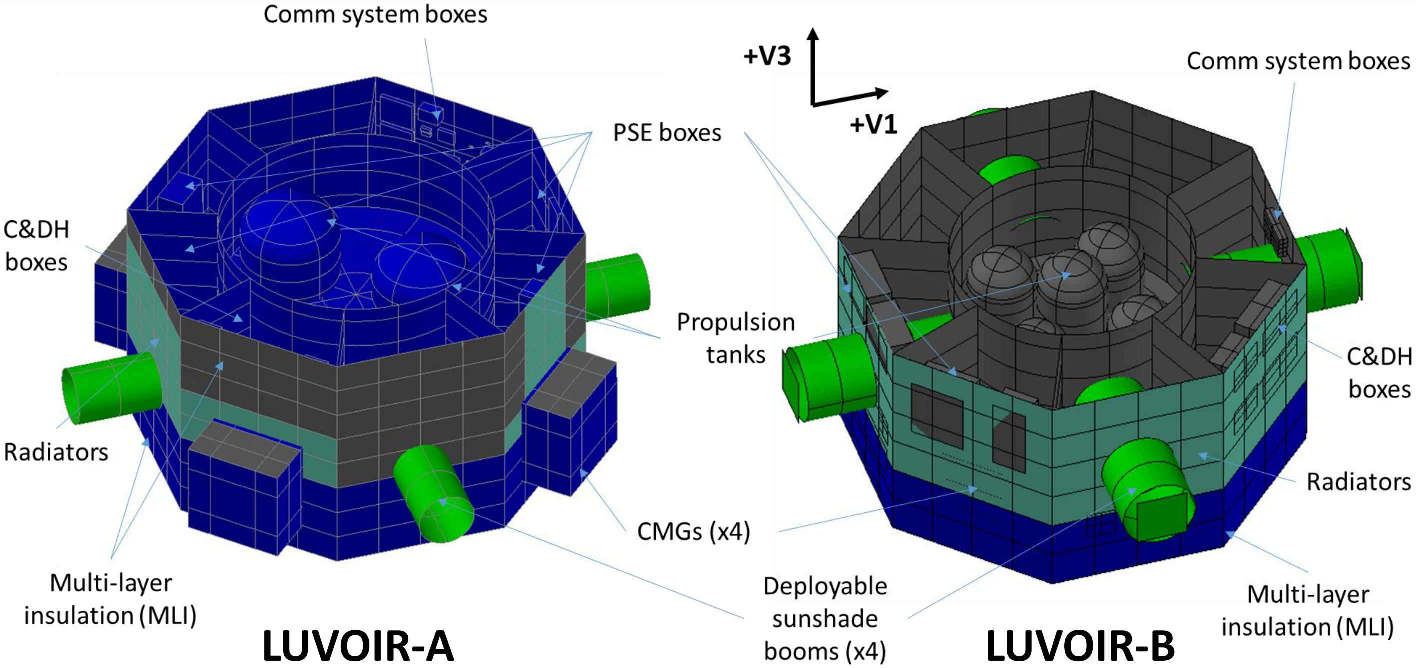
SMA: GBK-outer-layer MLI, heater plate thermal assembly

Mirror Thermal Control



- PMSA, SMA, and TMA employ thermal assemblies to heat mirrors
  - Designed to allow for active heating of the mirrors without direct contact between heater and mirrors (mirror optical and thermal stabilities not directly impacted by heater control scheme)
- Assemblies consist of a diffuser plate, heater plate, and low-emissivity shield (LES)
  - Heater plate is the only active thermal component, which is high-emissivity and controlled to radiatively drive the temperature on the mirror substrate to 270 K
  - Diffuser plate is aluminum with high-emissivity and designed to smooth spatial and temporal gradients from the heater plate
  - LES is covered with VDA SLI to reduce radiative losses from assembly
- Heat strap to transport excess heat from mirror control electronics to limit amount of heat that needs to be generated at the heater plate

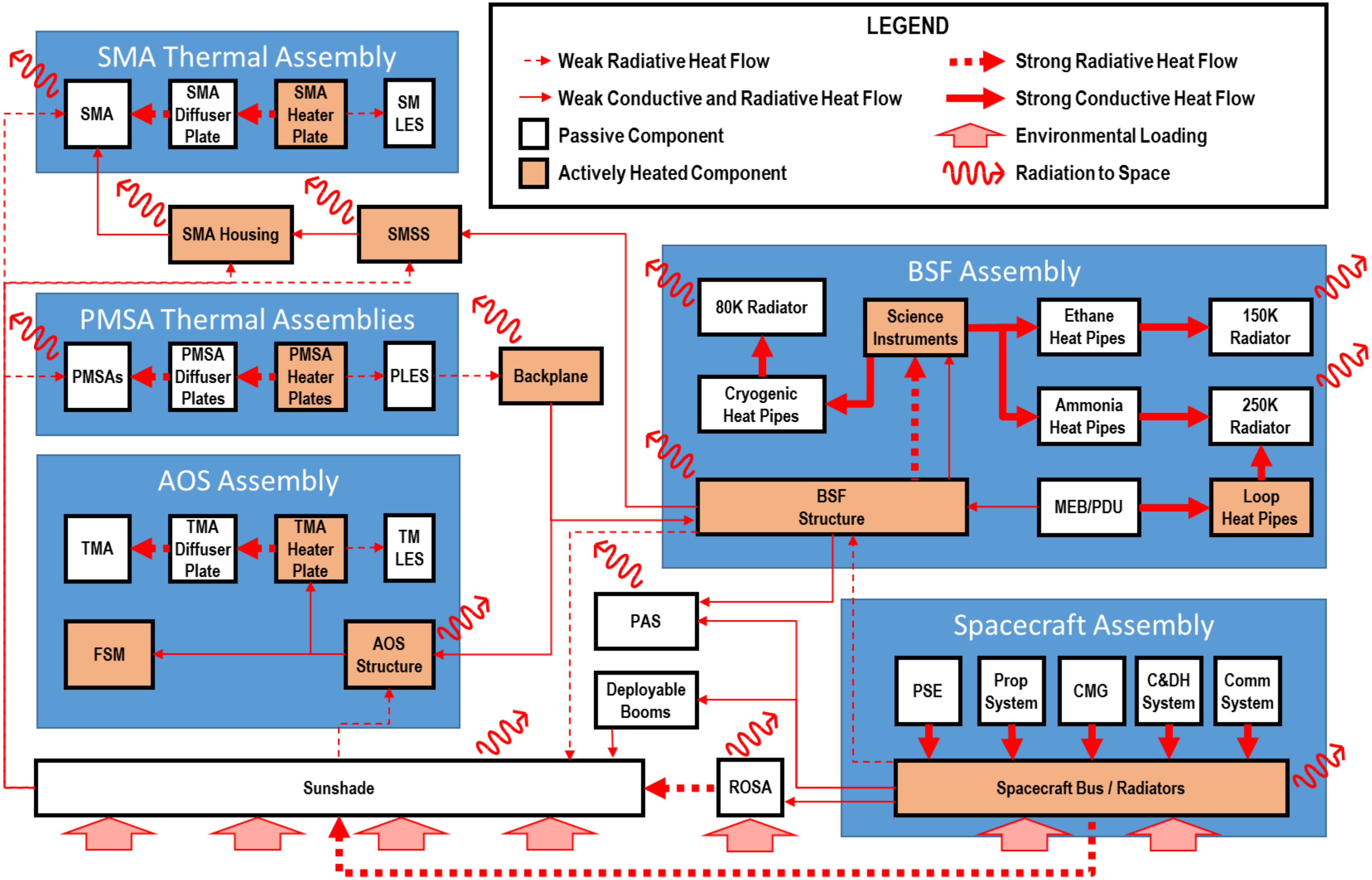
SC Thermal Architecture



LUVOIR-A **LUVOIR-B**

- On external-facing surfaces of SC bus above plane of +V3 sunshade layer, GBK-outer-layer MLI for locations where insulation is desired, Z93 white paint for radiators
- Embedded ammonia heat pipes in SC bus honeycomb panels
- VDA-outer-layer high temperature MLI on all surfaces below plane of +V3 sunshade
- Foil heaters to achieve 270 K ± 3 K operational requirement on SC

LUVOIR Heat Flows



LEGEND

- Weak Radiative Heat Flow
- Weak Conductive and Radiative Heat Flow
- ☐ Passive Component
- 🟧 Actively Heated Component
- Strong Radiative Heat Flow
- Strong Conductive Heat Flow
- Environmental Loading
- Radiation to Space

SMA Thermal Assembly

SMA

SMA Diffuser Plate

SMA Heater Plate

SM LES

SMA Housing

SMSS

PMSA Thermal Assemblies

PMSAs

PMSA Diffuser Plates

PMSA Heater Plates

PLES

Backplane

AOS Assembly

TMA

TMA Diffuser Plate

TMA Heater Plate

TM LES

FSM

AOS Structure

BSF Assembly

80K Radiator

Science Instruments

Ethane Heat Pipes

150K Radiator

Cryogenic Heat Pipes

Ammonia Heat Pipes

250K Radiator

BSF Structure

MEB/PDU

Loop Heat Pipes

PAS

Deployable Booms

Spacecraft Assembly

PSE

Prop System

CMG

C&DH System

Comm System

Spacecraft Bus / Radiators

Sunshade

ROSA

Preliminary Analyses

- Thermal models constructed using Thermal Desktop
  - 21000 nodes for LUVOIR-A, 10400 nodes for LUVOIR-B
  - Intended to generate preliminary estimates for radiator area and heater power
- Analysis performed in steady-state
  - Transient thermal effects during mission operational phase are expected to be minimal in L2 thermal environment
- Margins for sizing radiators: 170 K component parasitic heat leaks have 50% margin added, 100 K component parasitics have 100% margin added
- Heater powers have 40% uncertainly margin added
  - From NASA Goddard Space Flight Center Goddard Open Learning Design ("GOLD") Rules
- Worst-case radiator areas and heater powers are assessed from all Sunshade and OTA configurations / orientations

Required Heater Power

Component	LUVOIR-A Power (W)	LUVOIR-B Power (W)
Backplane (PMB)	498	163
Primary Mirror Segment Heater Plates	2914	936
Backplane Support Fixture (BSF)	497	451
Secondary Mirror Support Structure (SMSS) and Secondary Mirror Assembly (SMA)	348	534
Aft Optics Structure (AOS), including Tertiary Mirror (TM) and Fast Steering Mirror (FSM)	144	107
Spacecraft Bus (SC)	2126	2475
TOTAL Current Best Estimate (CBE)	**6527**	**4666**
TOTAL with 40% Heater Margin	**10878**	**7777**

All Heater Powers Reported in Watts

Required Radiator Area

	LUVOIR-A		LUVOIR-B	
	Required Area (m^2)	Max Sink Temp (K)	Required Area (m^2)	Max Sink Temp (K)
250 K OTA Radiators	66.1	105	34.7	95
150 K OTA Radiators	6.9	105	5.7	95
80 K OTA Radiators	4.4	70	2.4	58
Spacecraft Bus Radiators	9.7	232	11.5	192

Conclusions and Recommendations

- Design was presented for passive and active control of two LUVOIR architectures
  - Passive thermal design to reject waste heat from separate thermal zones to space
  - Large amounts of heater power required for both architectures to reach target temperatures
    - OTA heater power is smaller for LUVOIR-B than LUVOIR-A, but SC requirements comparable between architectures
  - Both architectures have enough surface area to accommodate the amount of fixed radiator space needed
- Development of LUVOIR requires a series of thermal challenges to be addressed via in-depth studies
  - Achievement of required thermal stability on both composite structure and optical assemblies
  - Reducing parasitic heat leaks to each thermal zone / transporting heat efficiently to radiators
  - Verification of thermal design through test given size of LUVOIR observatory

Acknowledgements

The authors would like to thank

The LUVOIR Engineering and Science Teams
for their tireless work and dedication