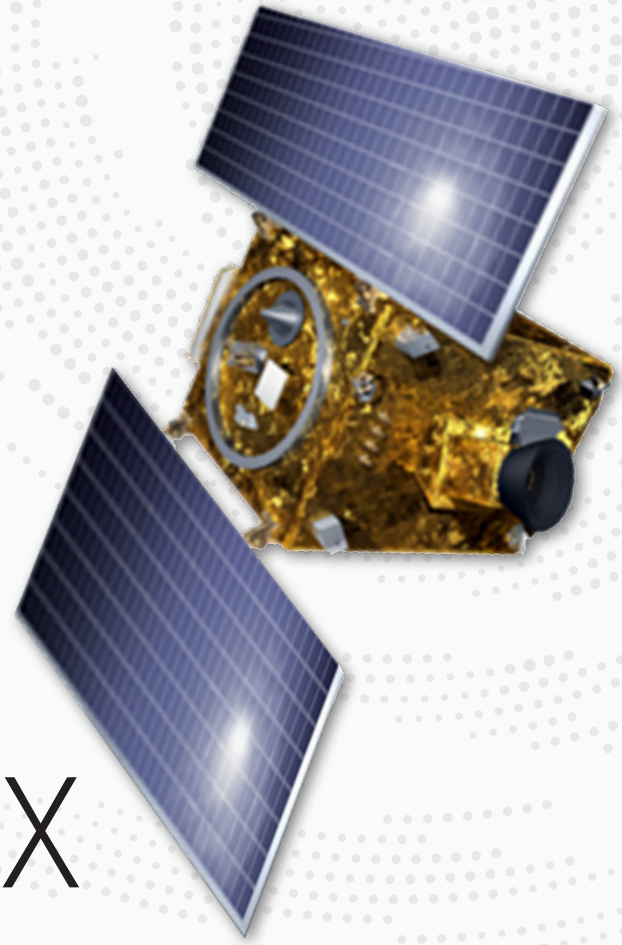

# LM4XX

## A Configure-To-Order Core Spacecraft (Bus) Design for Flexible Payload Accommodation and Mission Operations

### LM4XX Core Spacecraft (Bus) Heritage and Evolution

Lockheed Martin has built over 100 civil remote-sensing spacecraft for various user communities. This breadth of experience has gone into the RSDO offering—LM4XX, a stable, maneuverable vehicle designed to address a range of government and commercial missions. LM4XX is modular and can be scaled to accommodate specific mission assurance and payload performance requirements.

The baseline LM4XX bus uses single string avionics flown on our heritage spacecraft, the Gravity Recovery and Interior Laboratory (GRAIL), launched in September 2011. The GRAIL avionics evolved from the Mars Reconnaissance Orbiter (MRO) product line. It is based on our common avionics architecture developed on our earlier missions and has evolved through a continuous series of upgrades. The avionics line is currently used on the MAVEN and OSIRIS-REx programs. For GRAIL, our MRO "Lite" (MROL) Unit combines the command and data handling (C&DH) and electronic power supply (EPS) electronics into a single enclosure for tighter packaging.

For our baseline LM4XX offering, we retain the GRAIL avionics and structure that accommodate internally and/or externally mounted payloads in smaller candidate launch vehicles. The GRAIL spacecraft design was based on heritage from the Air Force's Experimental Satellite System-11 (XSS-11) program. XSS-11 flew the Broad Reach Integrated Avionics Unit (IAU) that combines the C&DH and EPS electronics. The Broad Reach IAU is also available for LM4XX.


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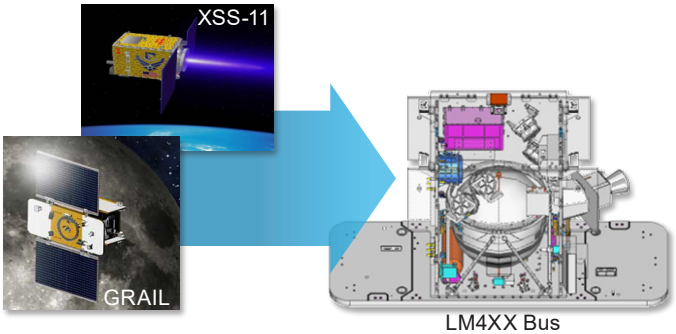


LM4XX Bus

## LM400 Platform Capabilities

The LM4XX platform was originally designed for low Earth orbit (LEO) proximity operations and was modified for a Lunar remote-sensing mission. Our LM4XX offering has an attitude control system capable of supporting both scanning maneuvers with a linear array sensor and staring maneuvers with an area array sensor. In both modes, LM4XX is able to move rapidly between collection targets and provide precision pointing with low residual jitter. This remote-sensing capability is of enormous value not just for optical imaging but also for other payloads, such as LIDAR where high stability and precise pointing are required. LM4XX is a highly capable platform ideal for a range of remote sensing missions.

The LM4XX is also a highly reliable platform offering selective redundancy as a baseline with full redundancy available at additional cost to meet mission-specific needs. This combination of redundancy and mature flight-proven avionics and flight software, from either our MRO product line or the Broad Reach IAU, ensures high mission availability and extended life.

Lockheed Martin is currently investing in and developing more modern and configurable options for the LM4XX bus to further improve performance and cost-competitiveness.

These improvements to the heritage LM4XX platform enable us to leverage synergies across our diverse customer base, driving down cost and schedule through bulk procurement, and realizing production line efficiencies.

## Configure-to-Order for Mission-Specific Needs

The LM4XX is a configurable platform. The core MROL avionics (combines our RAD750-based C&DH unit and power distribution electronics), flight software and narrow-band communications equipment are standard and can interface with a set of configure-to-order sensors and actuators. While the RAD750 processor represents tried and true radiation hard technology, the core avionics for the current LM4XX platform utilizes the BRE440 based processor board which also has a long line of flight heritage.

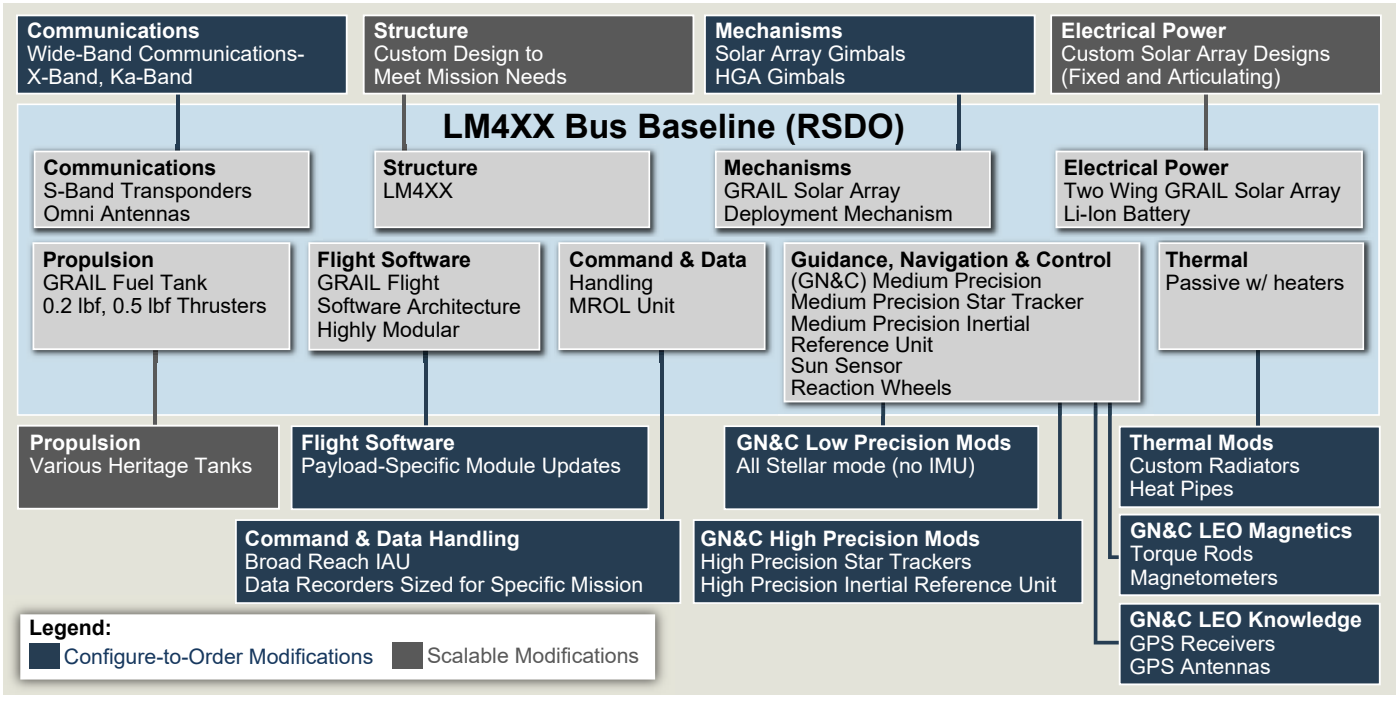
The LM4XX design provides an avenue to low cost operational vehicles, but can also be scaled to support applications that require longer design life, higher power, and higher mission assurance.

LM4XX offers a wide range of mission-specific modifications (at additional cost) for reconfiguring (alternate component selection) or scaling (enlarging/reducing component size) the core capabilities to meet mission specific requirements, as shown in the figure below.

Components such as the global positioning system (GPS) receivers, solid state data recorder, wide-band communications, and GNC components are available in varying mission-unique configurations. The particular configuration required will be determined in response to mission-specific requests for offers.

## LM4XX Configure-To-Order Bus

Meeting a Wide Range of Mission Needs



# Bus Design Features

**Structure**
- Aluminum honeycomb core with graphite epoxy facesheets- 6 panel rectangular box structure with aluminum clips

**Command and Data Handling**
- Centralized RAD750 processor control supported by 1553B and RS-422 serial connections (current LM4XX platform uses the BRE440 processor)
- Autonomous processor fault protection
- Payload data interfaces—LVDS, 1553B, RS-422, Spacewire (Direct to SSDR)
- Solid State Data Recorder selected to meet mission-specific* storage needs

**Flight Software**
- Flight-proven package across industry with GSFC Core Flight System (cFS)
- FSW written in C/C++ tested in Digitally Simulated and Hardware-based environment

**Electrical Power**
- Two-panel solar array using GaAs triple-junction cells (current LM4XX platform uses quad-junction cells)
- Lithium-Ion battery of varying capacity
- Unregulated 28V bus

**Guidance, Navigation and Control**
- Zero momentum 3-axis stabilized design
- Mission-specific* sensors based on precision requirements

**Communications**
- S-band transponders for command and telemetry (0.5, 1, or 2 kbps U/L, 1 to 128 kbps D/L)
- Mission-specific* WB systems for data downlink (X-Band, Ka-Band)

**Propulsion**
- Blow-down hydrazine monopropellant system
- Current LM4XX platform can also use electric propulsion for mission-specific* applications
- Mission-specific* heritage tank sizes available
- Eight 0.2 lbf thrusters and one 5 lbf (tailored to meet mission-specific* needs) (current LM4XX baseline is four thrusters)

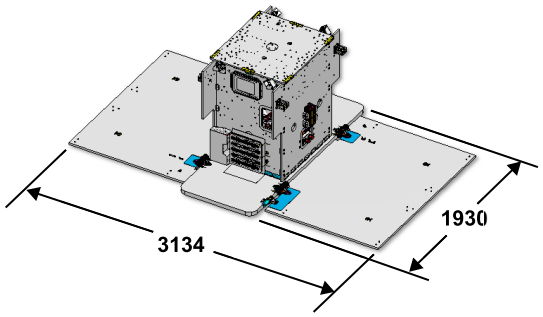
**Thermal**
- Passive design with redundant heater systems controlled by on-board computer
- Dedicated radiators with direct unit mounting and embedded heat pipes available for mission-specific* need

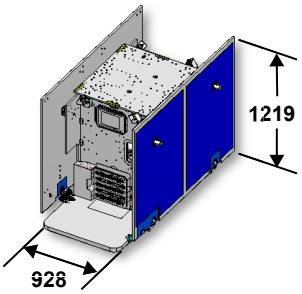
**Mechanisms**
- Hold-down and deployment mechanisms
- Heritage solar array and antenna gimbals available for mission-specific* applications

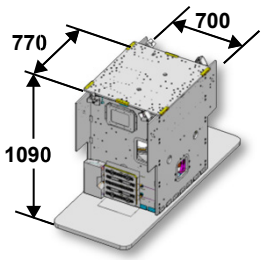
**Launch Vehicle Compatibility**
- Fits in the Minotaur IV and Taurus XL fairings and larger, with ample payload volume available
- Compatible with smaller Pegasus XL and Minotaur I fairings with minor mission-specific* structure modifications

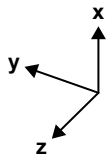
**Mission-specific modifications available at extra cost*

# Baseline LM4XX Dimensions

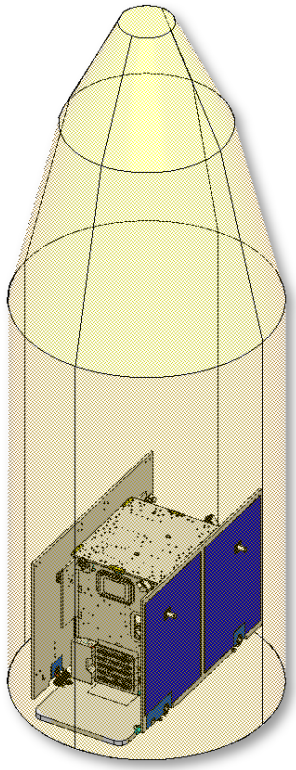



Dimensions in mm

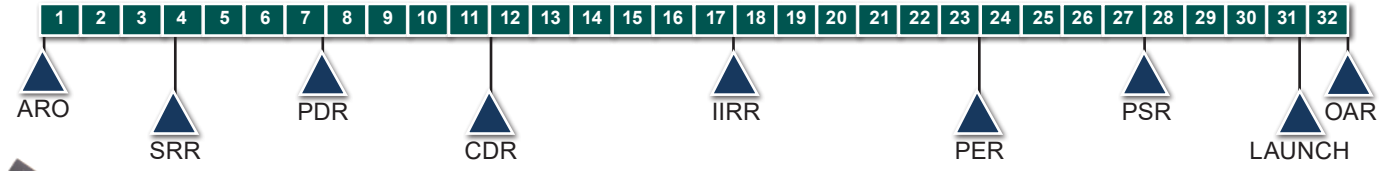


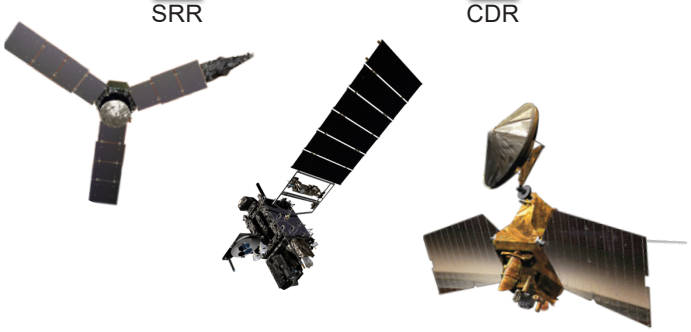
Taurus XL Fairing

# Bus Capabilities

| | |
|---|---|
| **Mission Parameters** | |
| Lifetime | 1-3 yrs w/ selected redundancy, 5+ yrs with full redundancy modification (GRAIL: Ps > 0.85 for 260 day mission duration) |
| Orbit | LEO 400 to 1000 km, 0° to Sun Synchronous, Lunar |
| Launch vehicle | Pegasus XL, Minotaur I, Minotaur IV, Taurus XL, Taurus II, Delta II, Athena IIc, Falcon 9, EELV |
| Bus dimensions | 700 mm x 770 mm x 1090 mm height (core bus structure) |
| Payload mass capacity | 75 kg (Current LM4XX capability is up to 1250 kg payload mass) |
| Payload power capacity (EOL) | 409 W orbit average, 576 W peak (Current LM4XX capability is >5kW OAP, 12 kW peak power) |
| Internal payload volume | 70,000 $cm^3$ |
| External payload volume | 600 mm x 660 mm x 300 mm high on +X panel, 380 mm x 700 mm x 400 mm high on –Z panel |
| **Pointing** | |
| Type | 3-axis stabilized, zero momentum |
| Pointing modes | Sun, nadir, offset, point track, inertial, push broom, whisk broom scanning, proximity operations & rendezvous |
| Pointing control accuracy | 462 arcsec per axis (3σ) |
| Pointing knowledge | 413 arcsec per axis (3σ) |
| Pointing stability (jitter) | 5 arcsec/sec (3σ), pointing stability for a 1 sec window |
| Slew rate | 44 deg/min |
| **Propulsion** | |
| Propellant capacity | Tank capacity is 106 kg (49 kg LM400 baseline propellant load) |

## 31 Months from ARO to Spacecraft Launch

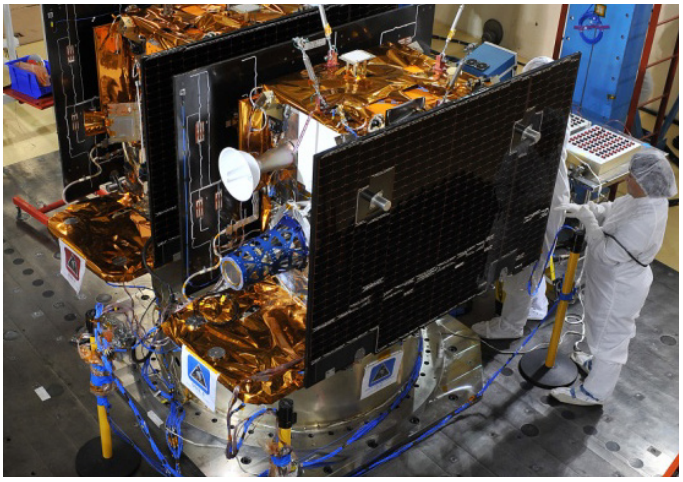


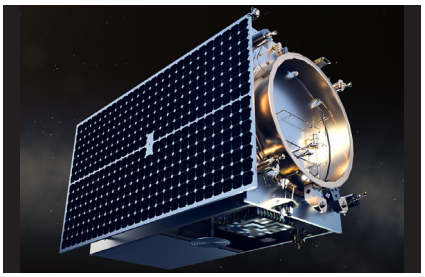
The LM4XX program capitalizes on our existing Lockheed Martin Space Systems Company facility in Denver, CO. This facility was the home of many spacecraft, including Mars Odyssey, XSS-11, MRO, GRAIL, Lucy, and GOES-S/T.

It is currently home to several programs in development, including the LM400 Technology Demonstration 2022 spacecraft.

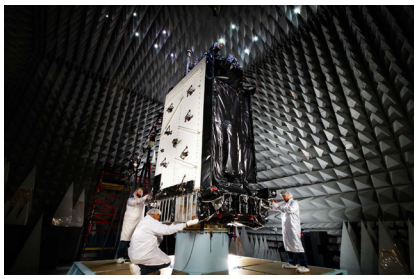
Our Sunnyvale, CA plant was the home of the Interface Region Imaging Spectrograph (IRIS) spacecraft. This facility also offers the full set of manufacturing and test facilities required of an LM4XX Rapid III program.



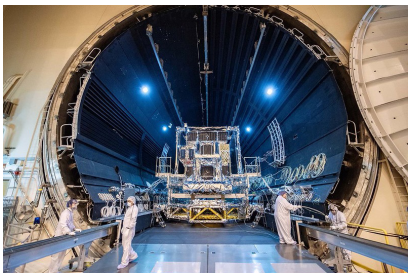
*Two LM4XX Buses in Production*



Tech Demo 2022



Anechoic Chamber



TVAC Testing

IRIS

Highbay / Clean Room

Mission Support Area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