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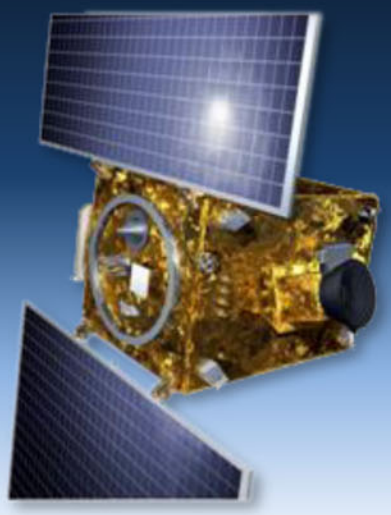


LM400

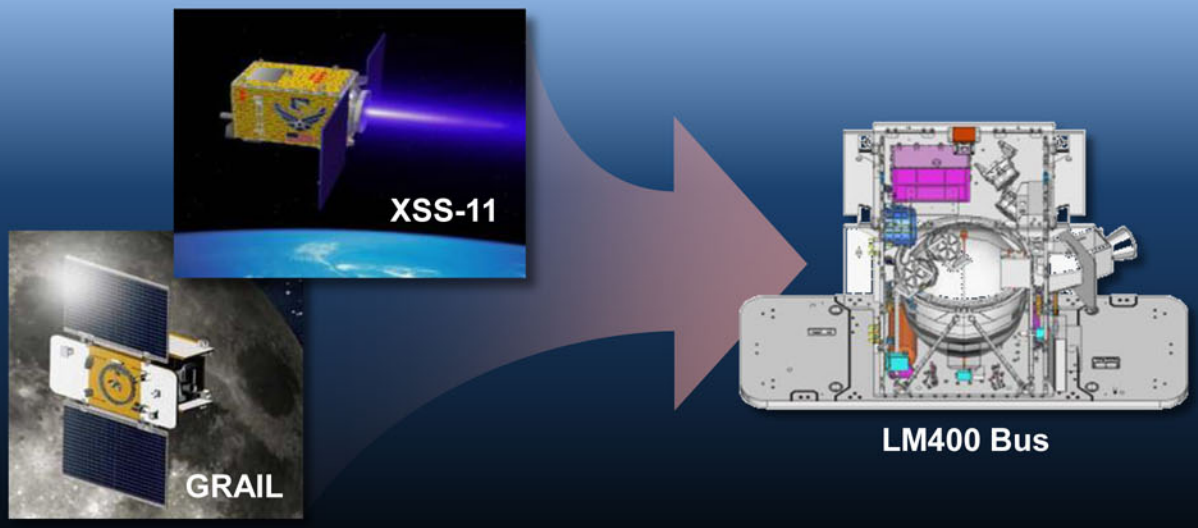
A Configure-To-Order Core Spacecraft (Bus) Design for Flexible Payload Accommodation and Mission Operations

LM400 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—LM400, a stable, maneuverable vehicle designed to address a range of remote sensing missions. LM400 is modular and can be scaled in size and performance to address the unique requirements of a particular mission.

The baseline LM400 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, OSIRIS-REx and GeoEye-2 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 LM400 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 LM400.



LM400 Platform Capabilities

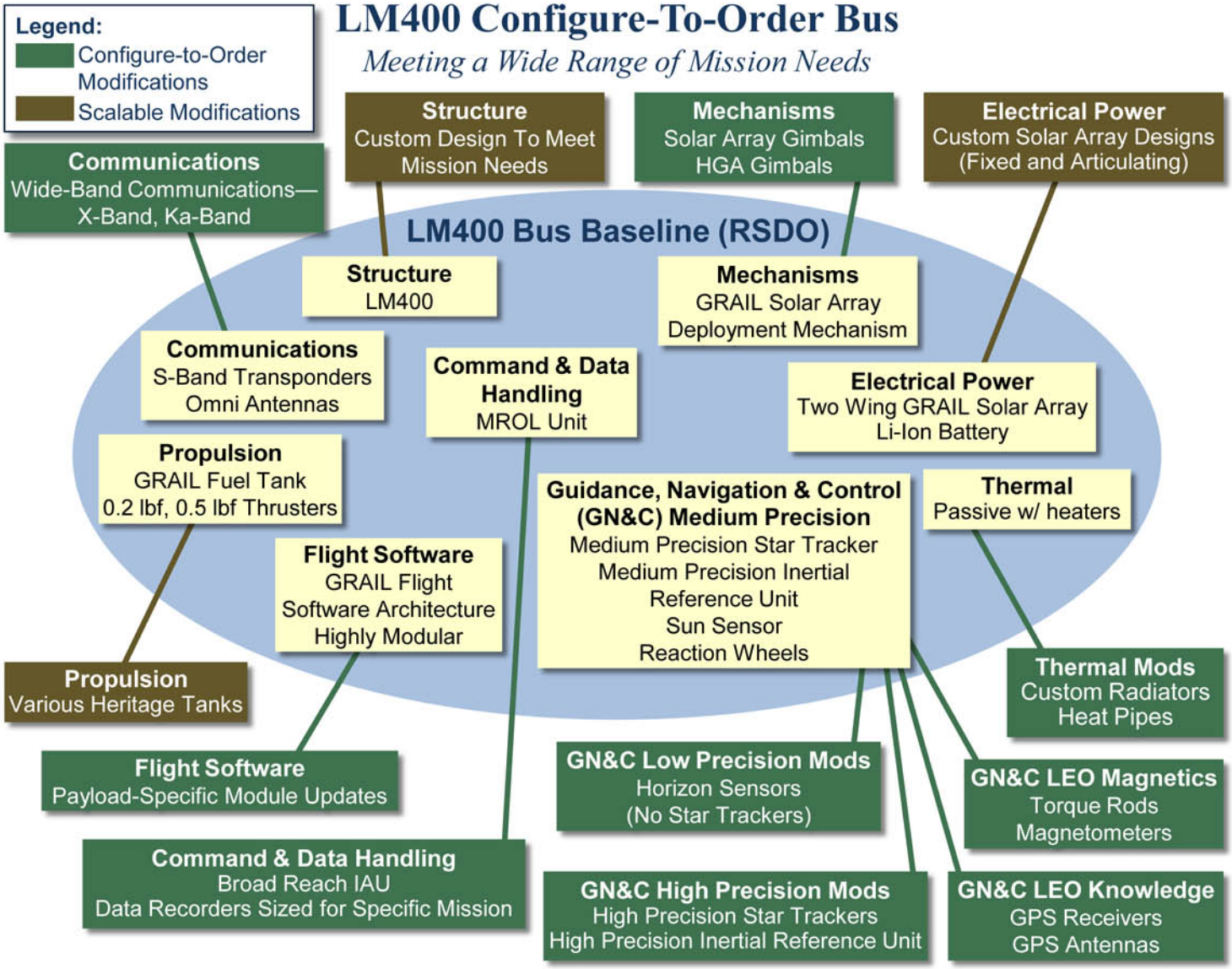
The LM400 platform was originally designed for low Earth orbit (LEO) proximity operations and was modified for a Lunar remote-sensing mission. Our LM400 offering has an attitude control system capable of supporting both scanning maneuvers with a linear array sensor and staring maneuvers with an area array sensor. In both modes, LM400 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. LM400 is a highly capable platform ideal for a range of remote sensing missions.

It 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.

Configure-to-Order for Mission-Specific Needs

LM400 is configurable. 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.

LM400 offers a wide range of mission-specific modifications (available at extra 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 and wide-band communications, are available in varying mission-unique configurations. The particular configuration required will be determined in response to mission-specific requests for offers.

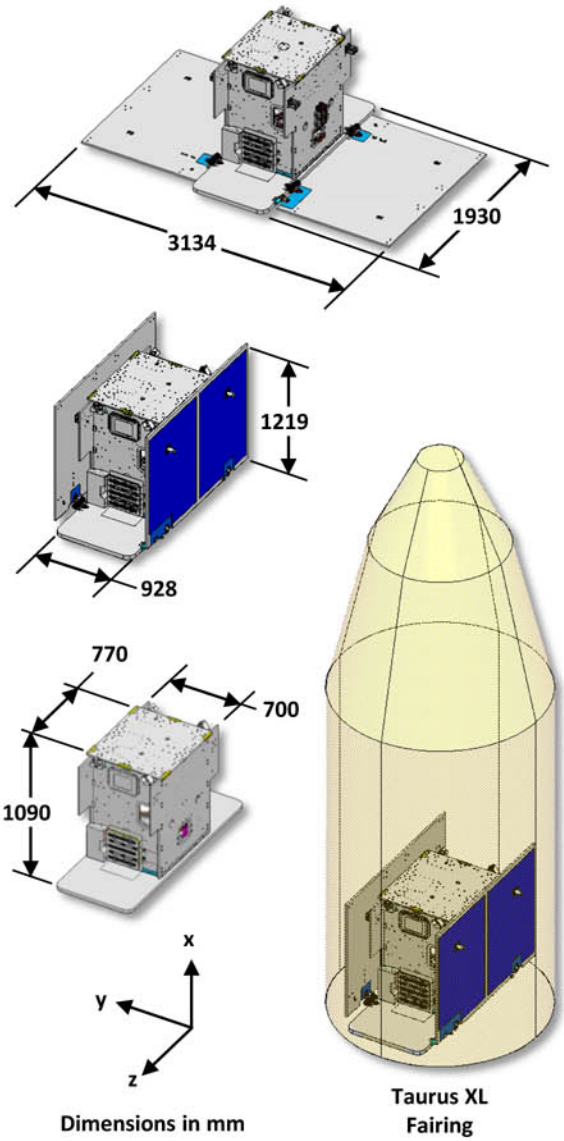


Bus Design Features

- ***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
  - 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 with heritage back to MRO
  - FSW written in C/C++, certified to CMMI Level 3
- ***Electrical Power***
  - Two-panel solar array using GaAs triple-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
  - Mission-specific* heritage tank sizes available
  - Eight 0.2 lbf thrusters and one 5 lbf (tailored to meet mission-specific* needs)
- ***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 LM400 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
Payload power capacity (EOL)	409 W orbit average, 576 W peak
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

World Class Facilities

The LM400 program capitalizes on our existing Lockheed Martin Space Systems Company facility in Denver, CO. This facility was the home of Mars Odyssey, XSS-11, MGS, MRO, the Phoenix Mars Lander, Juno and GRAIL. It is currently home to several programs in development, including MAVEN, OSIRIS-REx and GOES-R. Our Sunnyvale, CA plant also offers the full set of manufacturing and test facilities required of an LM400 Rapid III program.

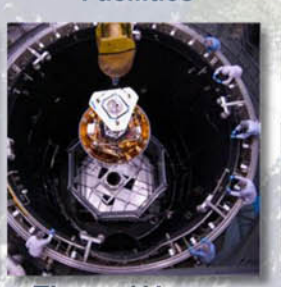
Electronics Mfg Facility

Special Test Facilities

High Bays/Clean Rooms

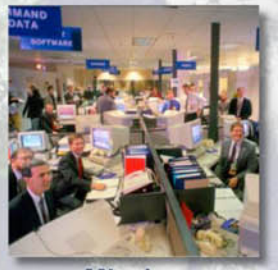
Multifunction Test Facility

Acoustic Lab

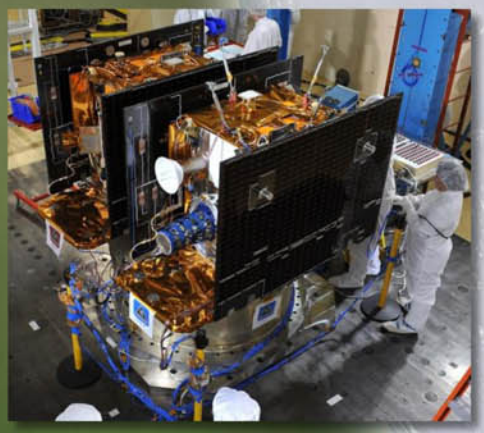


Thermal Vacuum Chambers

Test Control Center



Mission Support Area



Two LM400 Buses in Production

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