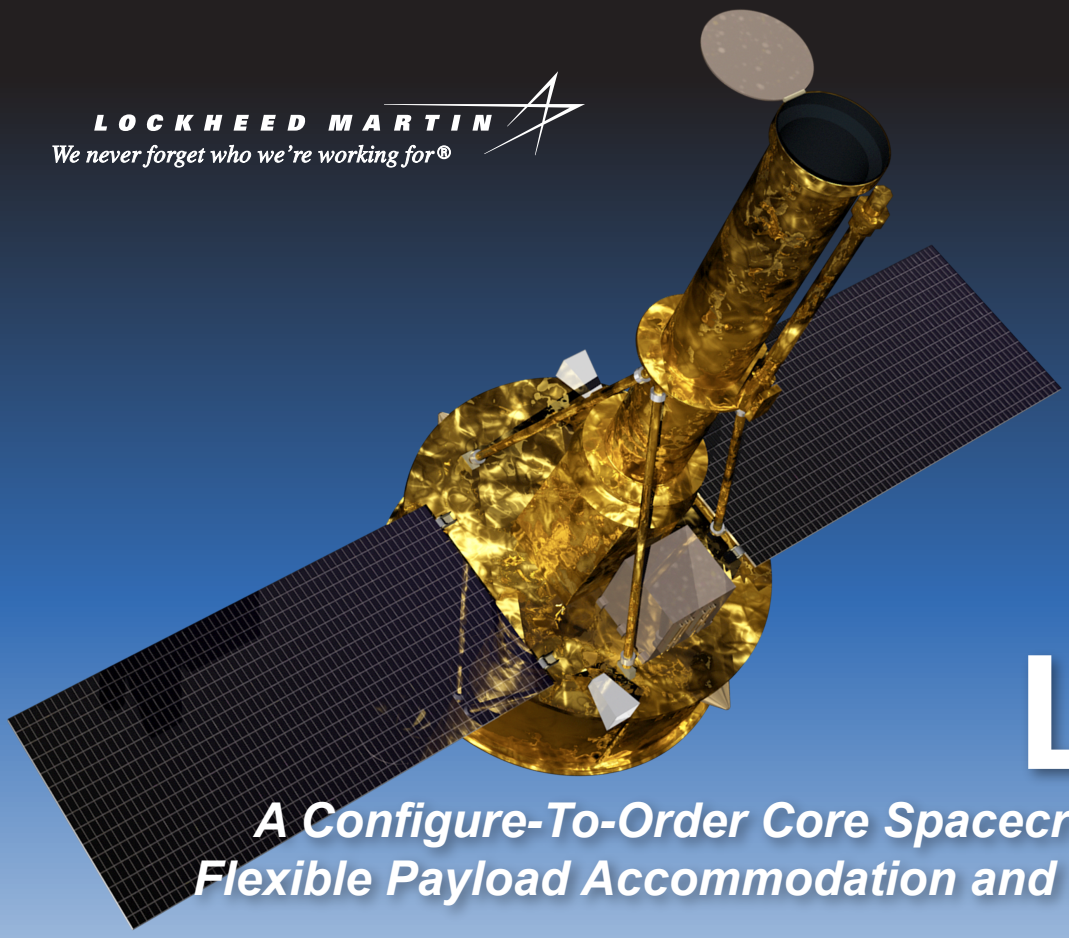
LOCKHEED MARTIN
We never forget who we're working for®



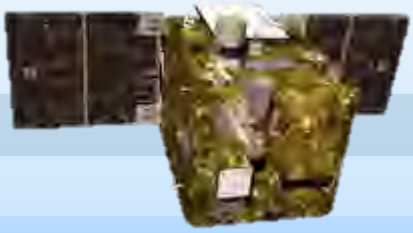
LM100

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

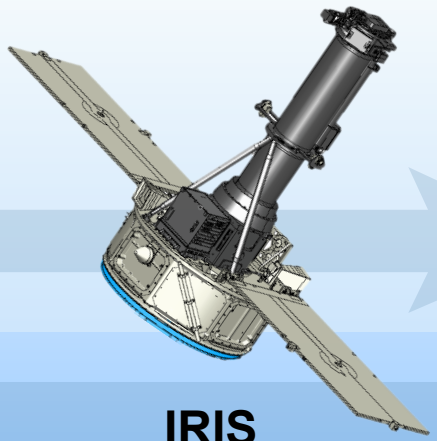
LM100 Core Spacecraft (Bus) Overview, Heritage and Evolution

Lockheed Martin has built over 100 civil remote-sensing spacecraft for various user communities. This breadth of experience has gone into the RSDO offering—LM100, a stable, agile, and high-precision-pointing vehicle designed to address a range of remote sensing missions. It was designed to work with precision optical payloads. LM100 represents a modular family of spacecraft that can be scaled up or down in size and performance to address the unique requirements of a particular remote sensing or space physics (astrophysics, heliophysics, etc.) mission for up to three years of life.

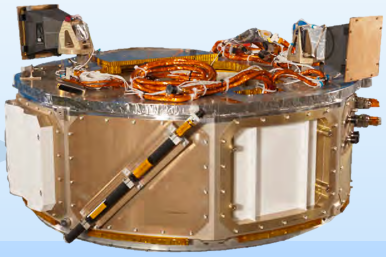
The baseline LM100 bus uses single string avionics flown on our heritage spacecraft, the Interface Region Imaging Spectrograph (IRIS) program launched in 2013 that is still in operation. The IRIS spacecraft employs the Moog Broad Reach (MBR) avionics suite which also has heritage from our XSS-11 program for the Air Force. For our baseline LM100 offering, we retain the IRIS-based avionics and structure that accommodate internally and/or externally-mounted payloads in smaller candidate launch vehicles.



XSS-11



IRIS



LM100 Bus

LM100 Platform Capabilities

The LM100 is a 95 kg bus that is capable of accepting a range of remote sensing payloads. With the baseline complement of two solar arrays, the bus is capable of providing an orbit average payload power of 155 W. With larger arrays, this can be increased to 373 W. The 3-axis stabilized bus can support payloads of up to 152 kg and maintains a pointing capability of 200 arc-sec per axis with 40 arc-sec knowledge (3-σ), and slew rates of 0.25 deg/sec.

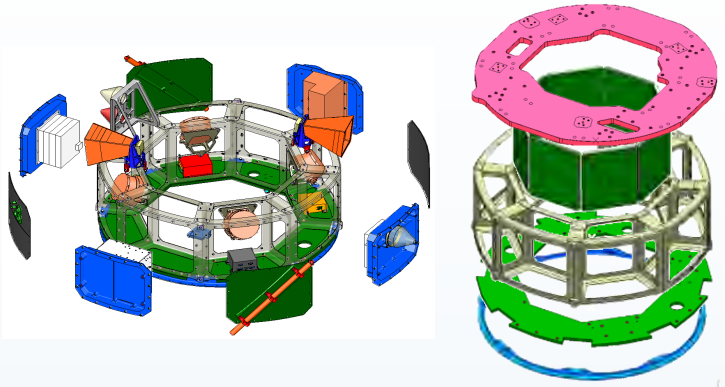
The Command and Data Handling subsystem uses the Moog Broad Reach Integrated Avionics Unit which has very successful flight heritage on the IRIS, XSS-11, TACSAT2, and AMS missions. It satisfies all requirements for Commanding, Telemetry, Data Handling, Electrical Power Controls, Payload Storage as well as the Flight Computers that host our Flight Software. It provides Spacewire, LVDS, 1553, RS422, and analog interfaces for payloads. The baseline configuration provides 48 Gbit SDRAM for store and forward payload data.

In the baseline configuration, data is downlinked through an X-band transmitter at 15 Mbps which is scalable up to 50 Mbps. Command and control is handled through an S-band transponder with uplink rates of 2 to 128 kbps, and downlink rates of 4 kbps to 5 Mbps .

The LM100 bus structure uses a monolithic machined 6061-T6 Aluminum spacecraft structure consisting of eight bays. The forward, aft, and inner panels are honeycomb construction with aluminum face sheets. Bus equipment is housed in the eight outer bays. Four reaction wheels are housed in the outer bays close to the spacecraft center of gravity. Electronics equipment are mounted to closeout panels that are also the exterior radiators for each bay. In the baseline configuration, the payload is bolted directly to the forward structure of the bus. Payloads can also be mounted through rigid or isolating struts to mount points on the nadir deck. In the bus structure inner octagonal cylinder, an additional section, 97,000-cm3 is available for payload boxes.

Mission-Specific Configure-to-Order

LM100 is configurable and offers a wide range of mission-specific modifications (available at extra cost) for reconfiguring or scaling the core capabilities to meet mission specific requirements, as shown in the figure below. Components such as the global positioning system (GPS) receivers, propulsion, and wide-band communications options, are available in varying mission-unique configurations. The particular configuration required will be determined in response to mission-specific requests for offers.



Structural Configuration

LM100 Configure-To-Order Bus

Meeting a Wide Range of Mission Needs

Legend: Configure-to-Order Modifications; Scalable Modifications

Communications
Wide-Band Communications - X-Band, Ka-Band

Structure
Custom Payload I/F

Mechanisms
Solar Array Gimbals
HGA Gimbals

Electrical Power
Custom Solar Array Designs (Fixed and Articulating)

LM100 BUS BASELINE (RSDO)

Command & Data Handling
Integrated Avionics Unit

Structure
LM100

Mechanisms
IRIS Solar Array Deployment Mechanism

Flight Software
IRIS Flight Software
Highly Modular

Communications
S-Band Transponder
X-Band Transmitter
Omni Antennas

Electrical Power
Two Wing IRIS Solar Array
Li-Ion Battery

Command & Data Handling
Custom P/L interface & Mission Sized Memory

Propulsion
(Not In Baseline)

Guidance, Navigation & Control
- 2-Star Trackers
- 6-Sun Sensors
- 4-Reaction Wheels
- 3-Torque Rods
- 1-Magnetometer

Thermal
Passive w/ Heaters

Thermal Mods
Custom Radiators
Heat Pipes

Flight Software
Payload-Specific Module Updates

Propulsion
Center Mounted Tank and 0.2 lb Thrusters

GN&C High-Precision Mods
High-Precision Star Trackers
High-Precision Inertial Reference Unit

GN&C LEO Knowledge
GPS Receivers
GPS Antennas

Bus Design Features

Structure
- Monolithic machined aluminum frame with aluminum face sheet and honeycomb core panels, and eight machined aluminum radiators

Command and Data Handling (C&DH)
- Centralized RAD750 processor control supported by 1553B and RS-422 serial connections
- Autonomous processor fault protection
- Payload data interfaces—LVDS, 1553B, RS-422, Spacewire
- Integral Solid State Memory sized to meet mission-specific* storage needs

Flight Software
- Flight-proven package with heritage back to XSS-11 and IRIS
- LMSSC GN&C flight software autocoded from Simulink as application layer of the MBR Bus manager software

Electrical Power
- Two-panel solar array using GaAs triple-junction cells
- Lithium-Ion battery of varying capacity
- Unregulated 28V bus

Guidance, Navigation and Control (GN&C)
- Zero momentum 3-axis stabilized gyro-less baseline design
- Mission-specific* sensors based on precision requirements

Communications
- S-band transponder for command and telemetry (2 to 128 kbps U/L, 4 kbps to 5 Mbps downlink) through omni antennas
- X-band transmitter for science data (15 – 50 Mbps D/L) through omni antenna
- Mission-specific* wideband systems for data downlink (Ka-Band)

Propulsion
- Mission-specific* blow-down hydrazine monopropellant system available

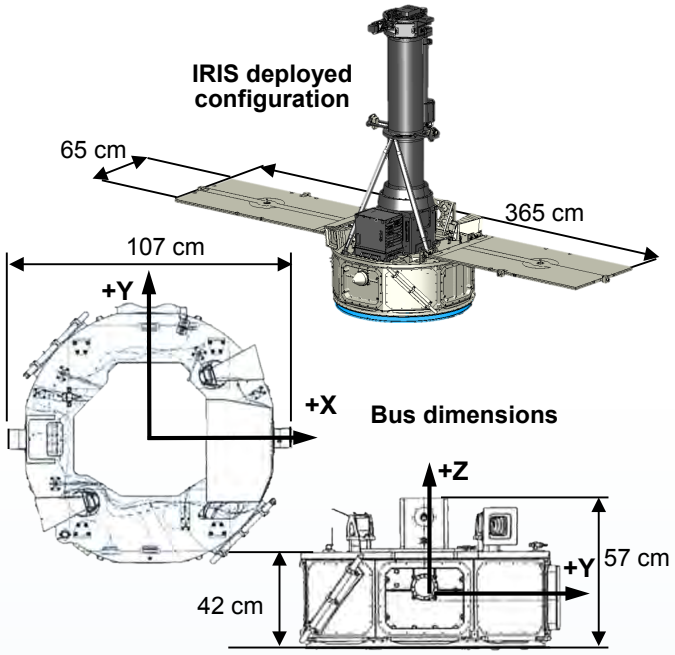
Thermal
- Passive design with redundant heater systems controlled by on-board computer
- Dedicated radiators with direct unit mounting and embedded heat pipes available for mission-specific* needs

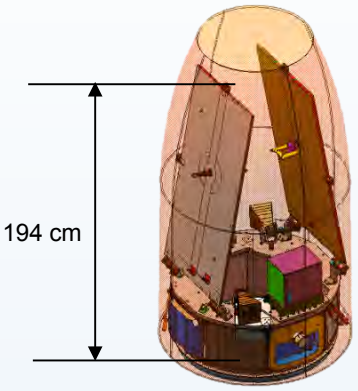
Mechanisms
- Hold-down and deployment mechanisms
- Heritage solar array and antenna gimbals available for mission-specific* applications

Launch Vehicle Compatibility
- Baseline launch compatibility: Pegasus LV
  Compatible with Minotaur I, Minotaur IV, Taurus XL, Taurus 2, Athena IIc, Falcon 9, and Atlas V

*Mission-specific modifications available at extra cost

Baseline LM100 Dimensions





Baseline accommodation in a Pegasus Fairing

Bus Capabilities

Mission Parameters

Lifetime	1-3 yrs w/ selected redundancy (IRIS: Ps>0.822 for two year mission duration)
Orbit	LEO 400 to 1000 km, 0° to Sun Synchronous
Launch Vehicle	Pegasus XL, Minotaur I, Minotaur IV, Taurus XL, Taurus II, Athena IIc, Falcon 9, Atlas V
Bus dimensions	Octagonal structure 103 cm across flats, 40 cm high (core bus structure)
Payload mass capacity	152 kg
Payload power capacity: base, max	155 W (orbit average), 373 W (orbit average)
Internal payload volume	90,000 cm^3
External payload volume	Octagonal 103 cm, 139 cm high tapering to 65 cm diameter at 175 cm high

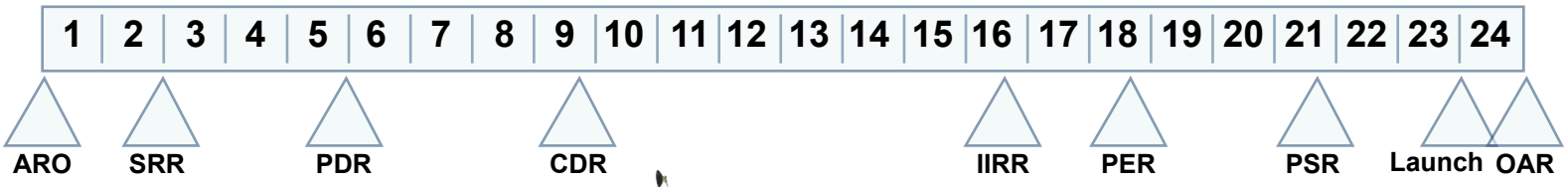
Pointing

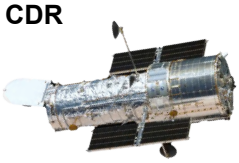
Type	3-axis stabilized, zero momentum
Pointing modes	Sun, nadir, offset, inertial
Pointing control accuracy	200 arcsec per axis (3σ)
Pointing knowledge	40 arcsec per axis (3σ)
Pointing stability (jitter)	5 arcsec/sec (3σ)
Slew rate	0.25 deg/s

Propulsion

Propellant capacity	Mission-specific

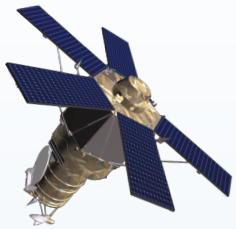
24 Months from ARO to Spacecraft Launch





World Class Facilities

The LM100 program capitalizes on our existing Lockheed Martin Space Systems Company (LMSSC) facility in Sunnyvale, CA. This facility was the home of IRIS, Hubble Space Telescope, Spitzer Space Telescope, Polar Orbiting Environmental Satellite System (POES), Defense Meteorological Satellite Program (DMSP), IKONOS, and GeoEye-2. Our Denver facility is available to support the Sunnyvale facility as required. This facility is home to several Mars missions, the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx), and the Geostationary Operational Environmental Satellite (GOES-R).



B159 Integration Facility
(All Environmental testing under one roof)

Integration Area
10K area within 100K hi-bay

Acoustic Chamber

EMI/EMC Chamber

Dynamics Facility

Horizontal Thermal Vacuum Chamber

Mission Support Area

LM100 on tilt dolly

Rapid Spacecraft Development Office (RSDO)
NASA Goddard Space Flight Center
Mail Code 401.1
Greenbelt, MD 20771 USA
Phone: 301-286-1289
Email to: rsdo@rsdo.gsfc.nasa.gov