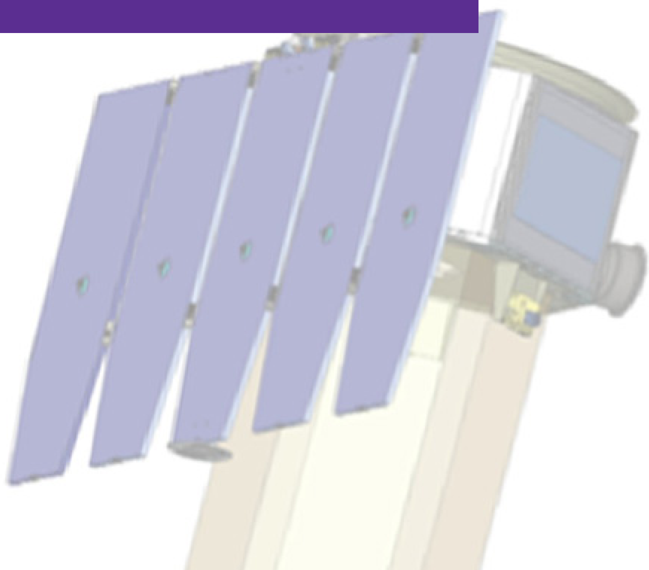
BCP-SMALL



The Ball Aerospace Rapid-IV catalog BCP Small core spacecraft leverages the NASA Green Propellent Infusion Mission (GPIM) spacecraft. GPIM was launched in June, 2019 with an ESPA attachment aboard a Falcon Heavy. GPIM was decommissioned as planned after successful completion of all mission objectives.

Ball's Rapid-IV Ball Configurable Platform (BCP) Small core spacecraft reflects ongoing refinements from multiple missions. It is a single string design based on high quality parts and proven processes, producing a reliable platform for shorter duration missions (Ps >0.9 at 1 year). Excellent pointing, agility, data throughput, and optional propulsion capabilities enable cost-effective implementation of a broad range of missions.

The BCP design is highly configurable, and can accommodate Earth-pointing or space-pointing instruments, or support technology demonstration applications. The BCP Small is compatible with low-earth orbits up to 1,200 km and all inclinations. This spacecraft is compatible with Pegasus, Minotaur-C, EELV (including ESPA-G), Falcon IX, and other launch vehicles. Nominal characteristics are presented here.

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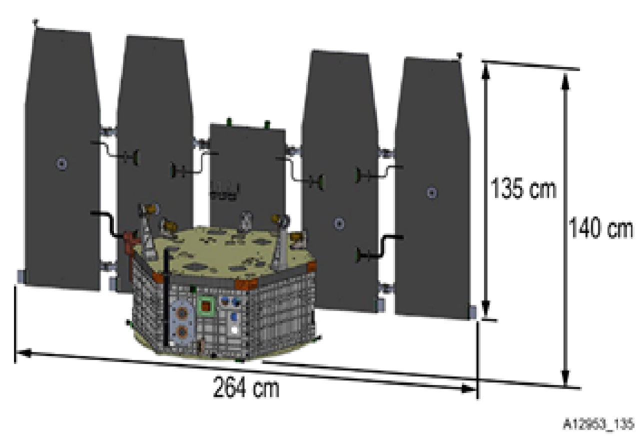
Structure and Mechanisms

Our core structure provides a rigid platform for mounting spacecraft components, and offers clean interfaces to the instrument and launch vehicle. The compact structure provides a large instrument volume fitting within the fairing dynamic envelope of many candidate launch vehicles.

The BCP Small's structure accommodates spacecraft components mounted on interior panels, enabling a deployable solar array wing to be folded around the structure for launch on smaller launch vehicles. The external panel surfaces provide thermal radiator areas.

The solar array is a simple flight proven foldout panel design, consisting of two fixed wings, each comprised of three rigid panels.



Deployed Spacecraft. *Payload interfaces on the top deck (payload volume illustrated on next page).*

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 A11750

Characteristic	Heritage Bus GPIM	Rapid IV BCP Small
Observatory Mass	158 kg	340 kg
Payload Mass	44 kg	170 kg
Bus Mass	114 kg	170 kg
Payload Power (EOL, orbit avg)	100 W	90 W
Battery Capacity	29 A-Hr	29 A-Hr
Mission Life and Reliability	>0.9 Ps at 12 months (GPIM decommissioned after 4 months)	0.9 Ps at 12 months
Launch Vehicle	Falcon Heavy (shared)	Various
Downlink Data Rate	0.524 Mbps	2 Mbps
On Board Memory Storage	0.254 Gbits	48 Gbits
Pointing Control (3-sigma)	108 arcesec	25 arcesec

Electrical Power

The Electrical Power and Distribution Subsystem (EPDS) provides reliable power generation, energy storage, and power distribution to support payload and spacecraft power demands. The EPDS implements an unregulated, direct energy transfer system connecting the solar arrays and the lithium ion battery directly on the power bus with segment switching to affect battery charge control.

The BCP Small uses a single Li-ion battery pack. The high efficiency battery has demonstrated, long cycle life and significant flight heritage. The solar array contains diode-isolated strings and undergoes a one-time deployment to a fixed configuration.

Communication

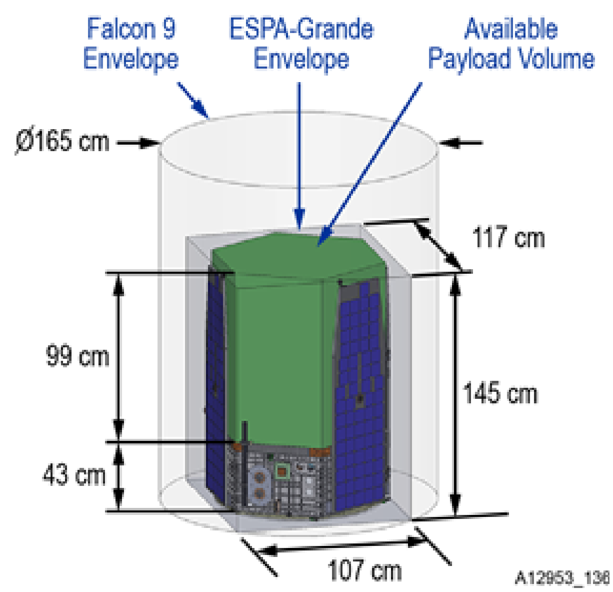
The BCP Small communications subsystem links the spacecraft and the ground. The uplink/downlink uses a STDN-compatible transponder, ensuring compatibility with NASA ground stations. The communications subsystem includes low gain antennas located on opposite sides of the spacecraft and passively coupled together to provide near 4π steradian coverage. The command channel supports multiple uplink rates, and the telemetry channel provides up to 2 Mbps.

Attitude Control

The BCP Small three-axis stabilized system provides a highly stable and agile platform for fine pointing payloads. The ADCS uses reaction wheels as the primary control actuators and star trackers as the primary sensor.

The ADCS also employs sun sensors and a magnetometer to complement the primary sensor and provide data in fault/safe mode, and magnetic torque rods for backup control authority and momentum management. This zero-momentum control system provides precise control torques and momentum storage.

The ADCS employs flight-proven algorithms and a modular table-driven design that provide capability and flexibility for on-orbit operations. Table parameters affecting ADCS calibration and performance are adjusted via table loads rather than FSW changes, to simplify operations while optimizing performance. ADCS modes include: mission (fine pointing), de-tumble, and safe modes. All modes are based on heritage, flight proven algorithms.



Stowed Spacecraft. *Compact spacecraft bus allows for ample payload volume – shown configured for launch*

Command and Data Handling

The C&DH subsystem performs all command, telemetry processing and routing. In addition, it controls the central data network; collects, formats, and stores all spacecraft and observatory housekeeping and mission data; and provides the flight software the ability to monitor and control all other spacecraft functions. The C&DH subsystem provides a platform not only for command and telemetry processing, but also for execution of attitude determination and control system algorithms, payload commanding/data interfacing, mass storage and power distribution services.

The subsystem is built around a RAD750 processor, and incorporates 1 Gbyte of SDRAM. The C&DH subsystem supports the upload of new flight software to the computer on-orbit. Because two or more copies of the flight software image are stored in the computer, the spacecraft can be operational while new on-orbit software is loaded.

Flight Software

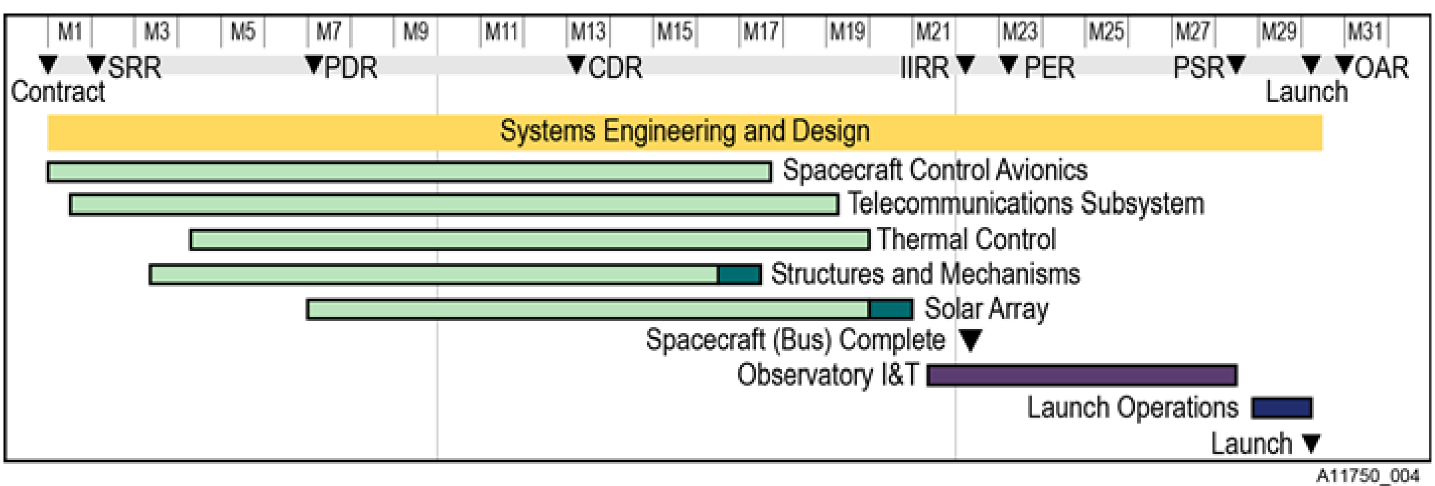
The BCP Small spacecraft flight software (FSW) is highly modular due to its table-driven architecture. Two FSW images are stored onboard to facilitate code changes on orbit if needed. BCP Small uses the heritage Flight Software flown on GPIM and earlier larger spacecraft: QuikSCAT, CloudSat, and ICESat. It runs on the RAD750 single board computer. The FSW performs the following functions: command processing; FSW table and code loads; absolute and relative time-tagged stored command management; telemetry collection, filtering, monitoring and packetization; current time bulletin, position, attitude, and attitude rate information to the payload instrument and telemetry and mission data collection from the payload instrument; fault detection and response; attitude determination and control, and orbit propagation; heater control; and battery charge control.

Thermal Control

The BCP Small Thermal Control Subsystem (TCS) design employs standard, proven, passive thermal control techniques, including, multi-layer insulation (MLI), radiator surfaces, and thermal control surface finishes with active heater bias to satisfy thermal requirements with margin. Payloads and payload electronic boxes are isolated from the bus with isolating mounts and MLI. Temperature telemetry is provided for payloads and critical bus components.

Payload Electrical Interface

The Payload Interface Board (PIB) within the C&DH subsystem provides four identical high-rate data, command, and real-time telemetry interfaces to the payload(s). Each high-rate interface can be either a synchronous interface (clock, data, and enable) operating at up to 2 Mbps or an asynchronous interface (UAR) operating at a BAUD rate of up to 460,800. The PIB also provides each payload electrical interface with an identical 1 PPS timing signal.



The typical Rapid IV program is a 30-month program which includes two months of schedule margin and a one-month commissioning phase.

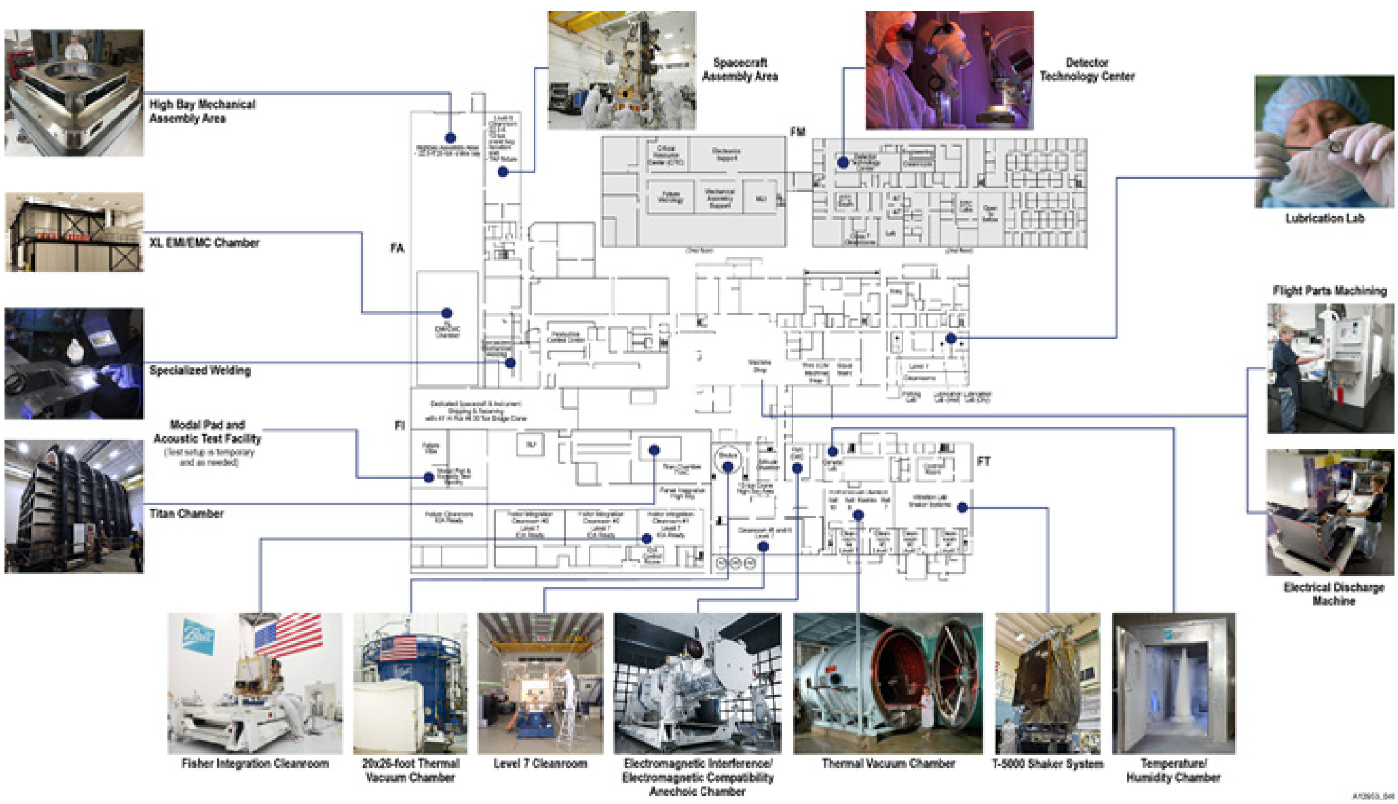
Configurable

The core spacecraft is specifically designed for ease of mission-specific reconfiguration as shown below.

Item	Capability
Data storage	Up to >5 Tb
Downlink transmission rate and bands	Up to >1.2 Gbps, Ka-band
High agility	Up to >4.5 deg/sec^2
High speed data interface	IEEE-1394, LVDS, Spacewire
Proplusion, High delta-v	300 to >1,500 m/s
High power	Up to >1,500 W
High payload mass	Up to >300 kg
Exquisite pointing	To <0.5 arcsec, 3-sigma

Facilities

As an end-to-end producer of space systems, Ball has all of the development and production facilities required for the design, production, assembly, integration, and test of components, spacecraft, space instruments, and fully inte- grated observatories. Facilities include an EMI/EMC Test Lab for EMI/EMC and compatibility testing nominally 10 kHz to 40 GHz, a large Semi-Anechoic Chamber, a Dynamics Lab for random, sine, mixed mode and sine burst vibration testing, Thermal Vacuum testing in small, medium and large test chambers, and a Climactic Laboratory. Ball facilities accommodate instrument needs from initial delivery, through integration with the spacecraft, and on to integrated system-level testing.



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