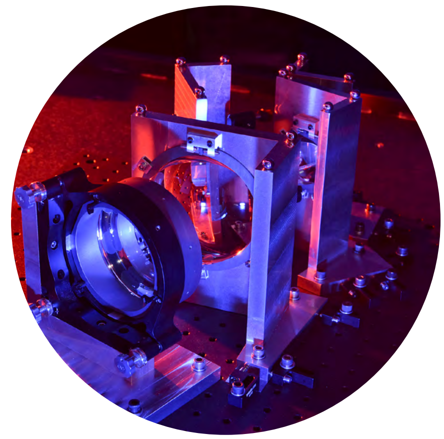
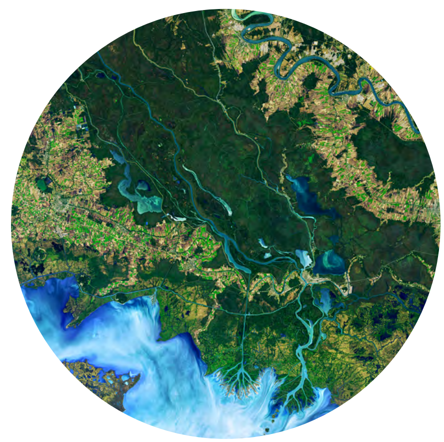
SMALL INSTRUMENTS

Ball Aerospace is at the forefront of miniaturizing instruments for air and space-based applications, offering new, affordable solutions to our customers while continuing to deliver the high-quality data they need to perform their missions. These instruments are small and capable. As your mission partner, we deliver science at any scale.

Bottom image: OLI; Right images (from top to bottom): CHPS; Landsat 8 with OLI, winds trigger pond growth in the Mississippi delta; CIRiS





GO BEYOND WITH BALL.®

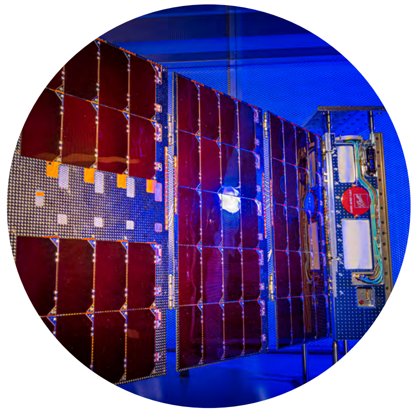
Smaller Size, Same Results

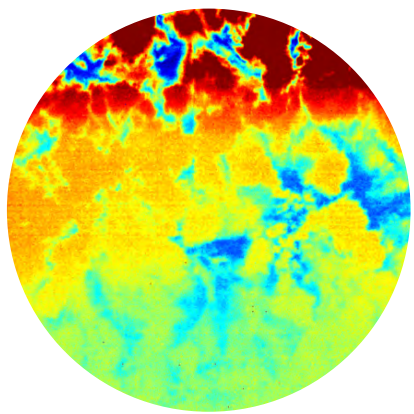
Just as consumer technologies, such as computers and cell phones, have gotten smaller over the years, the same is happening in the aerospace industry, as customers seek systems capable of delivering scientifically-significant data at a fraction of the cost and size. Leveraging our heritage in sensor and instrument development, we are aligning our investments with customer needs to develop and deliver smaller, more capable technologies that meet the needs of tomorrow's missions.

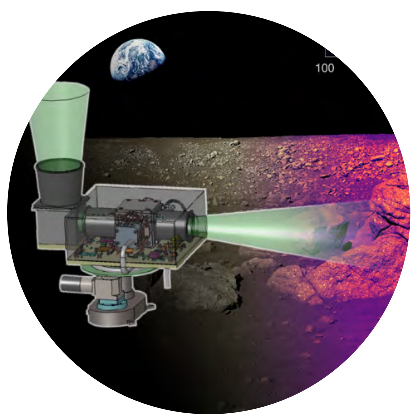
CIRiS

Our Compact Infrared Radiometer in Space (CIRiS) instrument collects highly calibrated infrared images of the Earth and atmosphere from a 6U spacecraft, which is about the size of a shoe box. Funded through NASA's In-Space Validation of Earth Science Technologies (InVEST) program, CIRiS demonstrates the ability of new cubesat-compatible, miniaturized instruments to return highly calibrated data for scientific and operational applications. CIRiS deployed from the International Space Station in January 2020 and is now returning data. The data collected by CIRiS will help scientists better understand cloud phenomena and conditions prior to extreme storms and will also generate maps to show variations in drought and moisture across land.

For on-orbit calibration, CIRiS carries two flat-panel carbon nanotube sources with performance that equals or exceeds older, bulkier technology. CIRiS' next-generation uncooled infrared imaging detector delivers the required sensitivity to scene radiance without the need of a cryocooler – this reduces the power draw, volume, complexity and system risk. Weighing only 1.8 kg (3.6 lbs), the instrument's small size and weight dramatically reduce the cost of launch.







Top image: CIRiS Spacecraft; Middle image: First CIRiS image of clouds acquired from orbit; Bottom image: A false-coloring simulation of L-CIRiS's infrared camera capturing temperature and mineral details of the moon's surface

L-CIRiS

Leveraging the success of the CIRiS program, we are now adapting the instrument for the NASA Artemis program. Lunar-CIRiS (L-CIRiS) will study the mineral composition, temperature and other surface and sub-surface characteristics of the moon. L-CIRiS will be a payload aboard one of the robotic moon landers to be provided through NASA's Commercial Lunar Payload Services (CLPS) initiative.

A multi-spectral infrared imaging radiometer, L-CIRiS will produce images in the infrared region of the electromagnetic spectrum. Further processing will reveal features at never-before-seen scales at less than 1 cm across. Data from L-CIRiS will support lunar geological studies, as well as preparation for future lander, rover and astronaut missions by determining the density and compactness of lunar soil. As a candidate for landing near the lunar south pole under the CLPS program, L-CIRiS will potentially go where no astronaut has been before. This will support NASA's long-term lunar ambitions.

Like CIRiS, L-CIRiS incorporates miniaturized, high performance, on-board calibration systems that greatly increase the scientific value of the data they acquire. Features of L-CIRiS specifically added for lunar operation include a mechanism for panoramic scanning of the lunar scene and an enclosure to regulate the instrument's temperature while on the moon.

MethaneSAT

We are developing the high-performance instrument at the heart of MethaneSAT, a small satellite mission. Designed to locate and measure methane emissions around the world with a precision and at a scale never before achieved, MethaneSAT will give decision makers a new ability to track, quantify and reduce these emissions.

A 200-kilometer view path coupled with high-resolution sensors makes MethaneSAT unique from other methane monitoring satellites in that it will both deliver methane measurements across large geographic areas and at pre-determined locations. This allows stakeholders to track area trends, while also identifying specific emission locations and rates, filling a key measurement gap between point source and global mapping satellites.

Ball Aerospace is responsible for designing and building the MethaneSAT instrument, as well as providing flight systems integration and testing, launch support and commissioning services. Two extremely sensitive spectrometers sit at the heart of the instrument that will measure a narrow part of the shortwave infrared spectrum where methane absorbs light, allowing it to detect concentrations as low as two parts per billion.

The MethaneSAT mission is being developed by MethaneSAT LLC, an affiliate of Environmental Defense Fund (EDF), Incorporated, a leading international nonprofit organization.

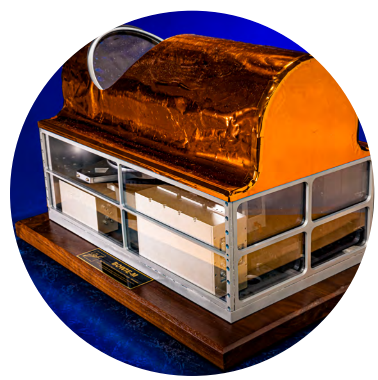
BOWIE

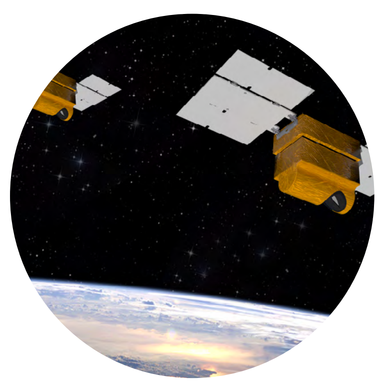
Ball Aerospace is a partner of choice for next-generation operational weather satellite systems. In 2020, NOAA awarded Ball Aerospace several contracts to study instrument concepts that will provide information on technology and sensing strategies to enable future operational weather architectures. Several of the studies further ongoing internal development work under the Ball Aerospace Operational Weather Instrument Evolution (BOWIE) program. BOWIE studies funded by NOAA include:

BOWIE-Microwave
BOWIE-M leverages recent advances in microwave component miniaturization and antenna technology to enable a future disaggregated constellation of low-cost, high-performance atmospheric sounding instruments. Approximately half the size of current operational instruments, BOWIE-M will deliver similar capability at reduced cost.

BOWIE Compact Hyperspectral Infrared Observations (CHIRO)
BOWIE-CHIRO represents a cost-effective, high-performance solution for hyperspectral infrared sounding from geostationary orbit.

BOWIE LEO Infrared Sounder
BOWIE LEO IR is an infrared instrument concept designed to meet NOAA's atmospheric vertical temperature and moisture profiling requirements.





Left image: An artist's rendering of the MethaneSAT mission; Top images (top to bottom): BOWIE-M Model; An artist's rendering of a BOWIE-M free-flyer satellite mission concept

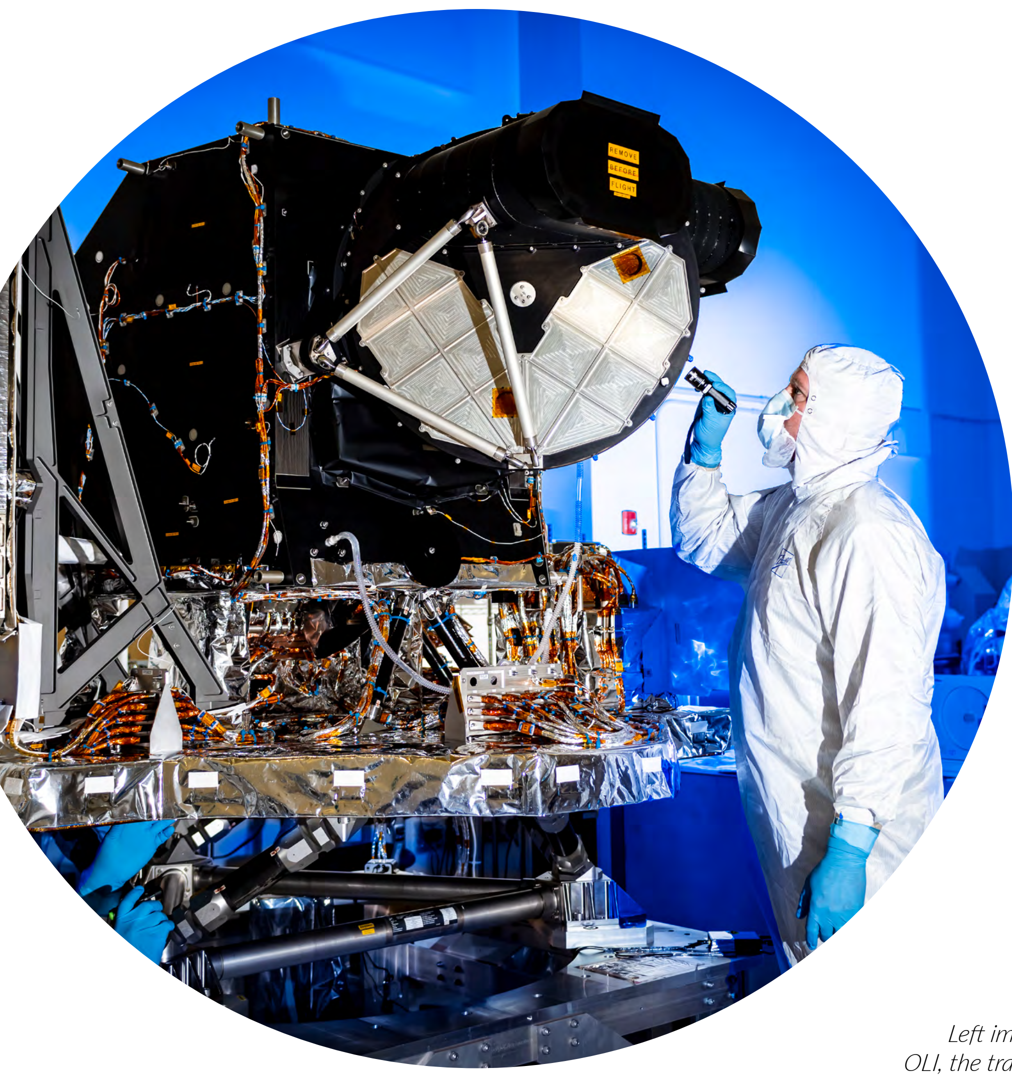
Sustainable Land Imaging

Every day for almost 50 years, Landsat satellites have provided essential scientific measurements to help the nation make informed decisions about natural resource management.

The instruments on Landsat satellites have evolved significantly over the years, with the Ball Aerospace-built Operational Land Imager (OLI) on Landsat 8 representing the most advanced technology launched to date. Instrument innovation is continuing under NASA's Sustainable Land Imaging-Technology (SLI-T) program. SLI-T has yielded a partnership with industry to design and demonstrate the Landsat instruments of the future, focusing on reducing size and cost, and incorporating emerging technologies.

With study funding from the SLI-T program, Ball Aerospace developed and flight tested two land imaging technologies with significantly reduced size and mass: the Compact Hyperspectral Prism Spectrometer (CHPS) and the Reduced Envelope Multi-Spectral Imager (REMI). REMI delivers Landsat continuity in a significantly smaller sensor with no image quality loss, and CHPS provides the enhanced science potential of a compact hyperspectral spectrometer. Both instruments offer size reductions by a factor of eight (volume = a 1.5 × 1.9 × 1m rectangle to 0.5m on a side. Mass = 455 kg to ~60kg) and cost reductions of a factor of two ($180M to $60M) over heritage Landsat instruments.

As the provider of Landsat's current Operational Land Imager instruments, we are leveraging our expertise in Earth observation technologies to enable a more flexible and sustainable next-generation Landsat architecture.



Left image: OLI-2; Top image (top to bottom): Landsat 8 with OLI, the transformative power of water, wind, and gravity in Iraq's Ga'ara Depression; CHPS and REMI flight test

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