Ball Aerospace & Technologies Corp.

Agility to Innovate, Strength to Deliver

Assuring Performance of TMT Instruments with Aerospace Industry Expertise

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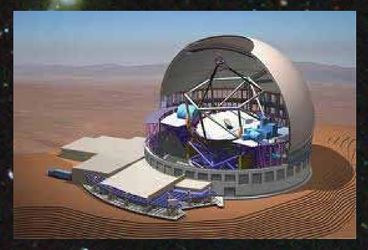


A large and diverse workforce assures expertise in all disciplines needed to create world-class science instruments. We have the depth to maintain continuity during developments that last for many years .

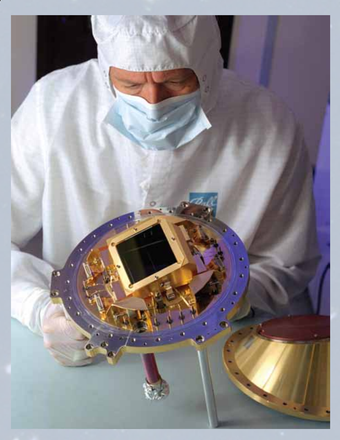
Aerospace rigor will ensure technical and programmatic success

Systems engineering

- Science goals and measurement requirements
- Engineering requirements flow-down and documentation
- Trade studies and resolutions
- Error budgets and allocations
- Definition and management of interfaces
- Risk management
- Technical Performance Metrics
- Documentation to maintain continuity of effort and "corporate memory"

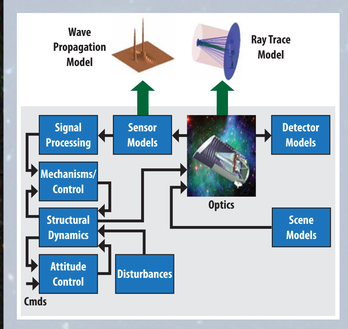
Project management

- Work Breakdown Structure, allocation of tasks
- Budget and resource planning and allocation
- Tracking and reporting
- Contracts, business relationships, non-disclosure agreements
- ITAR compliance, international partners



Focal planes based on CCDs, HgCdTe and other devices are created in our Detector Technology Center.

The focal plane array for Kepler is a mosaic of 42 CCDs assembled on convex substrate.

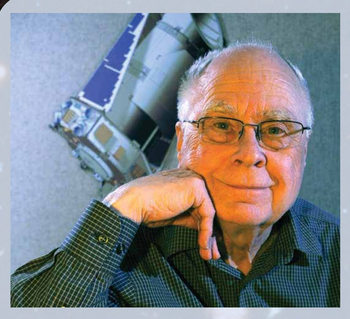


Integrated modeling is a powerful systems engineering tool that combines analysis of components and subsystems to simulate the performance of the larger system.

The Test Bed Telescope is a technology development program that matured the hardware and algorithms for phasing of the segmented primary mirror of the James Webb Space Telescope.

Abstract

The development of science instruments for large ground-based telescopes such as TMT could benefit from including scientific engineering companies, such as Ball Aerospace on the teams. Ball has developed scores of high performance instruments for space astronomy, planetary science, weather and environmental monitoring, commercial remote sensing, defense and other applications. Astronomical examples include high precision wide-field imaging with 100 Mpixel focal plane mosaics (Kepler), high resolution multi-spectral imaging (HST-ACS and WFC3), high sensitivity spectroscopy (HST-COS), high spectral and spatial resolution imaging spectroscopy (HST-STIS) and cryogenic infrared spectroscopy (Spitzer-IRS). TMT could access a very broad set of engineering capabilities, management expertise, human resources and existing facilities. Instruments will be physically large, technologically advanced and scientifically powerful. They will operate in an observatory with complex interfaces for optics, control systems, commanding and data management. They will do so with simple operations but with high reliability and long lifetimes. Desired performance may hinge on an integrated full-systems level understanding of telescope, instrument, and environment, something that Ball often does for high performance systems. Development will involve international partnerships with many institutions, will take many years to complete and will represent substantial financial investments. The requirements for technical excellence and astute management performance are familiar aspects of Ball's experience with space missions, and will be a valuable asset to TMT instrument teams.

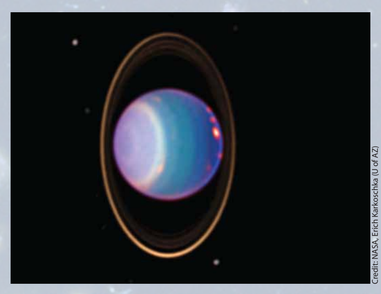


Relationships with our scientific customers is key to success. We work with the teams for years to understand the goals and to implement the right solutions. We take great pride in their discoveries and the recognition they earn in the community.

Science Instruments developed at Ball Aerospace are helping to advance our knowledge of important research priorities

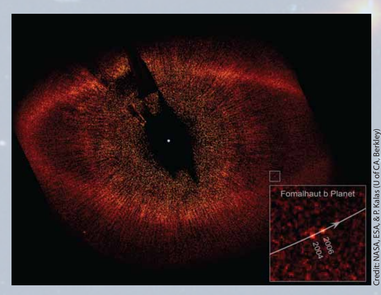
Credit: NASA, Andrew Fruchter & the ERO Team (STScI)

Deep, high resolution multispectral imaging of the distant universe reveals the effects of both normal baryonic matter and the as yet unseen dark matter through gravitational lensing of even more distant galaxies.



Credit: NASA, Erich Karkoschka (U of AZ)

High resolution infrared imaging shows the structure of clouds, belts and rings of outer planets in our solar system. The time domain reveals temporal evolution on diurnal and seasonal time scales.

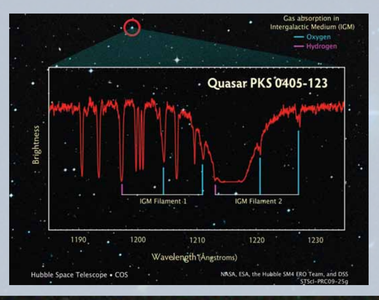


Credit: NASA, ESA, & P. Kalas (U of CA, Berkley)

The High Resolution Channel of ACS, equipped with a coronagraphic capability to suppress starlight, imaged the circumstellar debris disk and attendant exoplanet of Fomalhaut.

Credit: NASA, ESA, SAO, CXC, JPL-Caltech, & STScI

The Advanced Camera for Surveys captured dramatic multi-spectral images of the Antennae, showing burst of star formation in the merging of two galaxies.



The high sensitivity provided by the Cosmic Origins Spectrograph measures absorption along the line of sight to distant quasars, revealing the composition and evolution of gas in the Intergalactic medium.

Engineering capabilities address the full range of technical needs

We employ a full suite of modern design and analysis tools

- Optical
- Structural and mechanical
- Thermal, including cryogenics
- Control systems
- Electrical and electronic
- Integrated models and system performance simulation

Specialty capabilities provide valuable services and products

- Optical assembly, alignment, test
- Focal planes, CCDs, HgCdTe, packaging, mosaics, electronics, test
- Precision mechanisms and actuators
- Materials and processes, contamination control
- Integration and test, calibration
- Segmented telescope architecture
- Wavefront sensing and control
- Research and development for technology maturation

Facilities that can accommodate large instruments

- Cleanrooms with appropriate contamination control
- Modern facilities for test and calibration
- Logistics of storage and shipping
- Delivery, installation and on-site support

Infrastructure for assembly, alignment, test and calibration of sophisticated science instruments is a valuable asset

The HiRISE instrument undergoing final preparation. It is currently in space as part of the Mars Reconnaissance Orbiter.

Clean rooms provide a safe environment in which science instruments are assembled, aligned, tested and stored prior to delivery to the observatory. Two instruments visible in this photo are currently operating aboard the Hubble Space Telescope.

Wide Field Camera 3 is the primary UV/Optical/NIR imager aboard the Hubble Space Telescope.

Background Image: The Hubble Ultra-Deep Field was imaged in the near infrared by the Ball-built Near Infrared Camera and Multi-Object Spectrometer (NICMOS). Rodger Thompson, University of Arizona, was the Principal Investigator.

Credit: NASA, ESA, & S. Beckwith (STScI) & the HUDF team

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