Searching for a pulse

The Neutron star Interior Composition Explorer (NICER) is looking for neutron stars and pulsars from its perch on the International Space Station. Keith Gendreau and Zaven Arzoumanian provide an overview of its capabilities.

NICER is an International Space Station (ISS) Mission of Opportunity that was selected as part of NASA's Explorers Program. It is the first NASA mission dedicated to the study of neutron stars and has been in operation since its 13 June 2017 installation on the ISS (following a 3 June launch), nearly 50 years after the discovery of neutron stars. NICER studies the energetics, dynamics and structure of neutron stars through observations in the soft X-ray band, exploring rapid brightness and spectral fluctuations with high-precision time-stamping and spectroscopy of individually detected X-ray photons. Compared with its predecessor X-ray timing astrophysics mission, the Rossi X-ray Timing Explorer (RXTE), which launched over two decades ago, NICER provides order-of-magnitude improvements in spectral resolution, absolute timing resolution and sensitivity. Early observations with NICER are already providing exciting results.

The NICER ISS payload consists of an X-ray timing instrument (XTI) as well as supporting hardware that points the XTI at celestial objects while maintaining an interface to the ISS and its infrastructure (Fig. 1). The XTI comprises an instrument optical bench (IOB) that holds an aligned collection of 56 X-ray concentrators (XRCs) and associated focal plane modules (FPMs). The XRCs are non-imaging optics that concentrate X-ray photons from a distant target onto the FPMs, with a field of view of approximately 30 arcmin^2. Within each FPM is a commercially available silicon drift detector (SDD) that detects individual X-ray photons, recording their energies with a precision of about 2% and their arrival times to better than 100 ns. Combined, the XTI provides an effective collecting area that peaks at nearly 1,900 cm^2 for X-ray energies of 1,500 eV and ranges from 200 to 12,000 eV.

Each XRC consists of a collection of 24 single-bounce grazing-incidence reflective parabolic shells with a focal length of 1.085 m. These shells are thin aluminium foils with smooth replicated gold surfaces. Because NICER's neutron star targets are, for the most part, isolated point sources, concentrating optics are a mass-efficient way of providing a large collecting area.

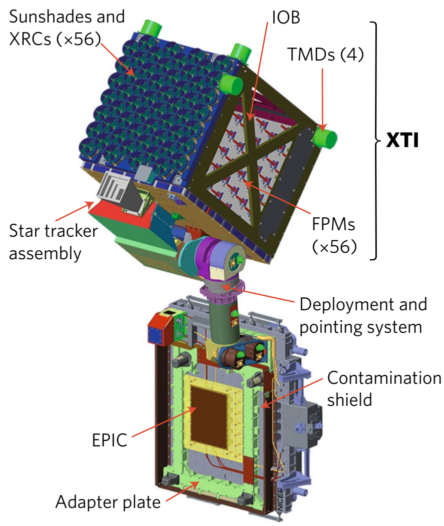

Fig. 1 | Illustration of the NICER payload without thermal blankets installed. Credit: NASA

X-ray photons interact within the SDDs, producing charge clouds proportional to the photon energy. The charge clouds then drift along electric field lines to a central sensing anode where their content is measured with a charge-sensitive preamplifier followed by a pair of shaping amplifiers in parallel. The latter record the pulse amplitude using two different signal smoothing times, which yields a measure of the distance over which the charge cloud drifted from its interaction point in the silicon to the sensing anode; this enables discrimination between X-rays concentrated by the optics and much of the radiation-induced 'background' events also registered by the detectors.

Detector readout electronics record the pulse height produced by each X-ray photon together with its arrival time relative to a precise pulse-per-second signal generated by a global positioning system-steered onboard clock. NICER's timing resolution has been calibrated to 84 ns (root mean squared), including the uncertainty in the location of the instrument. The charge-cloud drift speed in the SDD dominates the overall time-stamping resolution.

The IOB maintains the alignment of the XTI's components through all of the thermal extremes encountered in orbit so that the instrument's effective area is stable. Sunshades on the XRCs, thermal blankets and controlled heaters keep the instrument in a thermally benign state.

As the ISS orbits Earth, the XTI tracks celestial targets to an accuracy better than 66 arcsec more than 99% of the time. NICER's pointing system uses a star tracker, with built-in microelectromechanical gyros and accelerometers, to provide an attitude solution at a 10 Hz rate. This high rate enables pointing control software running in NICER's onboard computer to command an elevation-over-azimuth gimbal system to steer and maintain the XTI on target while overcoming vibrations from the ISS and the NICER payload itself. To minimize some of the vibrations, passive tuned mass dampers (TMDs) attached to corners of the XTI dissipate certain predicted mechanical modes.

The XTI and the pointing system are deployed by a boom from a plate that is connected to a standard ISS payload adapter. This adapter provides the mechanical and electrical interface to the ISS as well as to the SpaceX Dragon spacecraft that delivered NICER to the ISS on top of a Falcon 9 rocket. The ISS provides 28 V and 120 V power via the ExPA Power Interface Controller (EPIC), as well as a 1 Mbps MIL-STD-1553 command and telemetry link and a 6 Mbps ethernet downlink.

Every two or three days, the NICER ground system uplinks commands that include a continuous timeline of celestial targets to track. Typically, NICER tracks two to four targets during each ISS orbit, with a long-term on-target science efficiency of greater than 50%. NICER's baseline mission dedicated to neutron stars will continue until January 2019, after which it will transition into a general-use X-ray astrophysics observatory. ❒

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