NASA builds unusual testbed for analyzing X-ray navigation technologies

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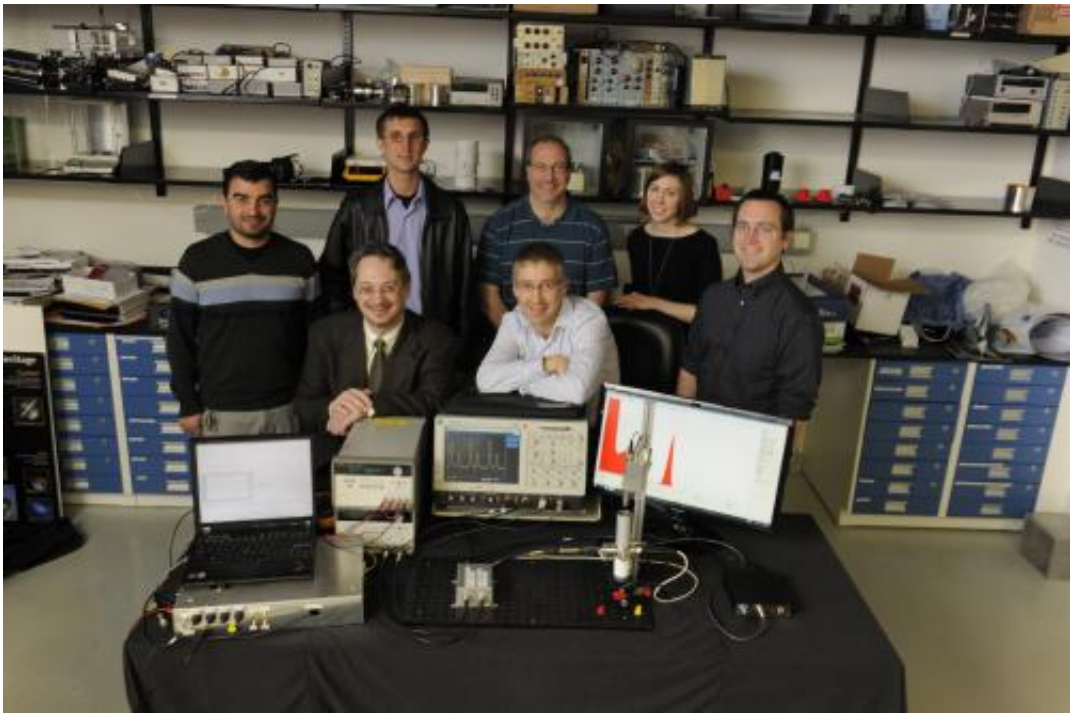

Technologists at NASA's Goddard Space Flight Center in Greenbelt, Md., created what they believe is the world's first "pulsar-on-a-table," a laboratory system shown here for testing emerging X-ray navigation technologies. Back row, left to right: Monther Hasouneh, John Gaebler, Harry Stello, Jennifer Valdez and Sam Price. Front row, left to right: Jason Mitchell and Luke Winternitz. Credit: NASA/ Pat Izzo

Pulsars have a number of unusual qualities. Like zombies, they shine even though they're technically dead, and they rotate rapidly, emitting

powerful and regular beams of radiation that are seen as flashes of light, blinking on and off at intervals from seconds to milliseconds. A NASA team has built a first-of-a-kind testbed that simulates these distinctive pulsations.

The pulsar-on-a-table, known as the Goddard X-ray Navigation Laboratory Testbed, was built to test and validate a next-generation X-ray navigation technology to be demonstrated on a dual-use instrument recently selected as a NASA Explorer Mission of Opportunity.

"This is a unique capability," said Jason Mitchell, an engineer at NASA's Goddard Space Flight Center in Greenbelt, Md., who helped develop the tabletop-size facility that simulates the rapid-fire pulsations that distinguish this unusual class of stars, considered the densest objects in the universe. "We needed a capability that would let us retire technological risks early and test as many of the technology's components as possible," he said.

NICER/SEXTANT Mission

The facility is validating advanced technologies for the Neutron-star Interior Composition Explorer/Station Explorer for X-ray Timing and Navigation Technology, or "NICER/SEXTANT," for short. Slated to fly on the International Space Station in 2017, the instrument will study the interior compositions of neutron stars largely through observations of their pulsating next-of-kin, pulsars, and from the same platform, demonstrate pulsar-based navigation, also called XNAV, a concept advanced after the discovery of these objects in 1967.

Pulsars offer a potentially revolutionary navigational solution because of their rapid rotation and the powerful beams of light that emanate from their magnetic poles. On Earth, these beams are seen as flashes of light, blinking on and off as the pulsar rotates into view. Because of their

predictable pulsations, they can provide high-precision timing just like the atomic-clock signals supplied through the 26-satellite, military-operated GPS.

However, unlike GPS signals, which are geared to Earth-based applications, pulsars are accessible in virtually every conceivable flight regime, from low-Earth to interplanetary science, making the technology ideal for travel throughout the solar system and beyond.

From its berth on the International Space Station, the NICER/SEXTANT instrument will use its 56 bundled X-ray telescopes, silicon detectors and other advanced technologies to detect X-ray photons in the pulsars' powerful beams of light to estimate their arrival times. With these measurements, the system will stitch together an onboard, completely autonomous navigational solution using specially developed algorithms.

"X-ray navigation has the potential to become an enabling technology for very deep space exploration and an important augmentation to NASA's Deep Space Network" (the network of ground stations that communicate with spacecraft to make course corrections), said co-developer Luke Winternitz, also of NASA Goddard, whose curriculum vitae also includes the development of another advanced navigation technology, the Navigator receiver that captures the GPS signal even in low-signal environments.

With the Explorer win, the NICER/SEXTANT team will begin building and integrating the telescope package and associated hardware and software.

But as with all spacecraft missions, end-to-end testing presents another set of challenges. "We had to have a way to test the technology," Winternitz said. "We have GPS constellation simulators that make our

GPS receivers think they are in orbit; we needed something analogous for an XNAV receiver."

Mimicking Pulsar Pulsations

In essence, the pulsar-on-a-table does just that.

It leverages several Goddard-developed navigation and orbit-determination software tools and specialized hardware to mimic a pulsar's spin rates, its location in the sky, the station's orbital parameters, and other considerations needed to simulate the environment and conditions that NICER/SEXTANT will encounter when formulating a navigational solution. "You can change a lot of the parameters in the testbed and add hardware in the loop, to perform a full suite of tests," Winternitz said. "We now have a way to take our mission concept and test it fully."

A central component of GXNLT is Goddard's Modulated X-ray Source, which produces X-ray photons with rapidly varying intensity, turning on and off many times per second to simulate the target star's pulsations. Each MXS-produced photon travels through a short channel and impinges on a silicon-drift detector, where it receives a time stamp. The photon events are grouped into batches and processed by algorithms to extract pulse-arrival time and Doppler measurements. A set of tools then uses these measurements to estimate the orbital outpost's position—all needed to ultimately formulate a navigational solution.

To ground-truth the calculations, the team will run comparisons with an onboard GPS receiver based on the Goddard-developed Navigator receiver. Two NASA missions will use the Navigator technology to acquire GPS signals in weak-signal areas. Experiments with the testbed have shown that NICER/SEXTANT, once deployed, will demonstrate real-time calculations with sub-kilometer accuracy, Winternitz said.

"The whole point is to test as you fly," Mitchell said. "This testbed enables that." But what is the facility's most notable attribute? It's the fact that "it can simulate a pulsar," Mitchell said. "To my knowledge, nothing in the world can do this."

More information: heasarc.gsfc.nasa.gov/docs/nicer/

Provided by NASA's Goddard Space Flight Center