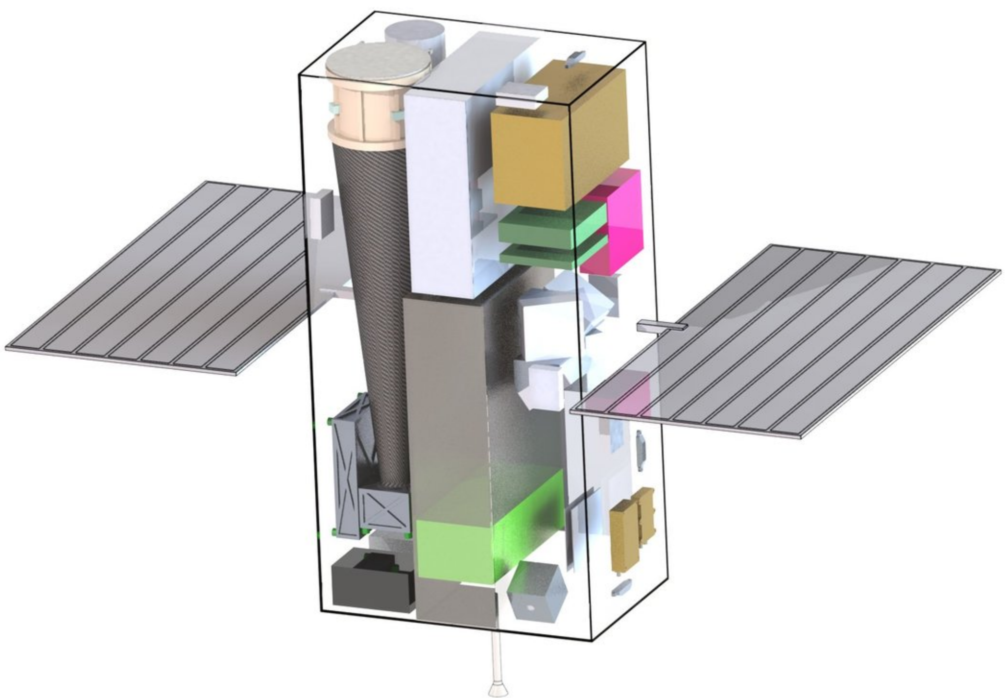
X-ray navigation considered for possible CubeSat mission

May 3 2018, by Lori Keesey



This rendering shows the conceptual CubeX spacecraft, which would demonstrate X-ray navigation during its mission investigating the Moon. Credit: Harvard University

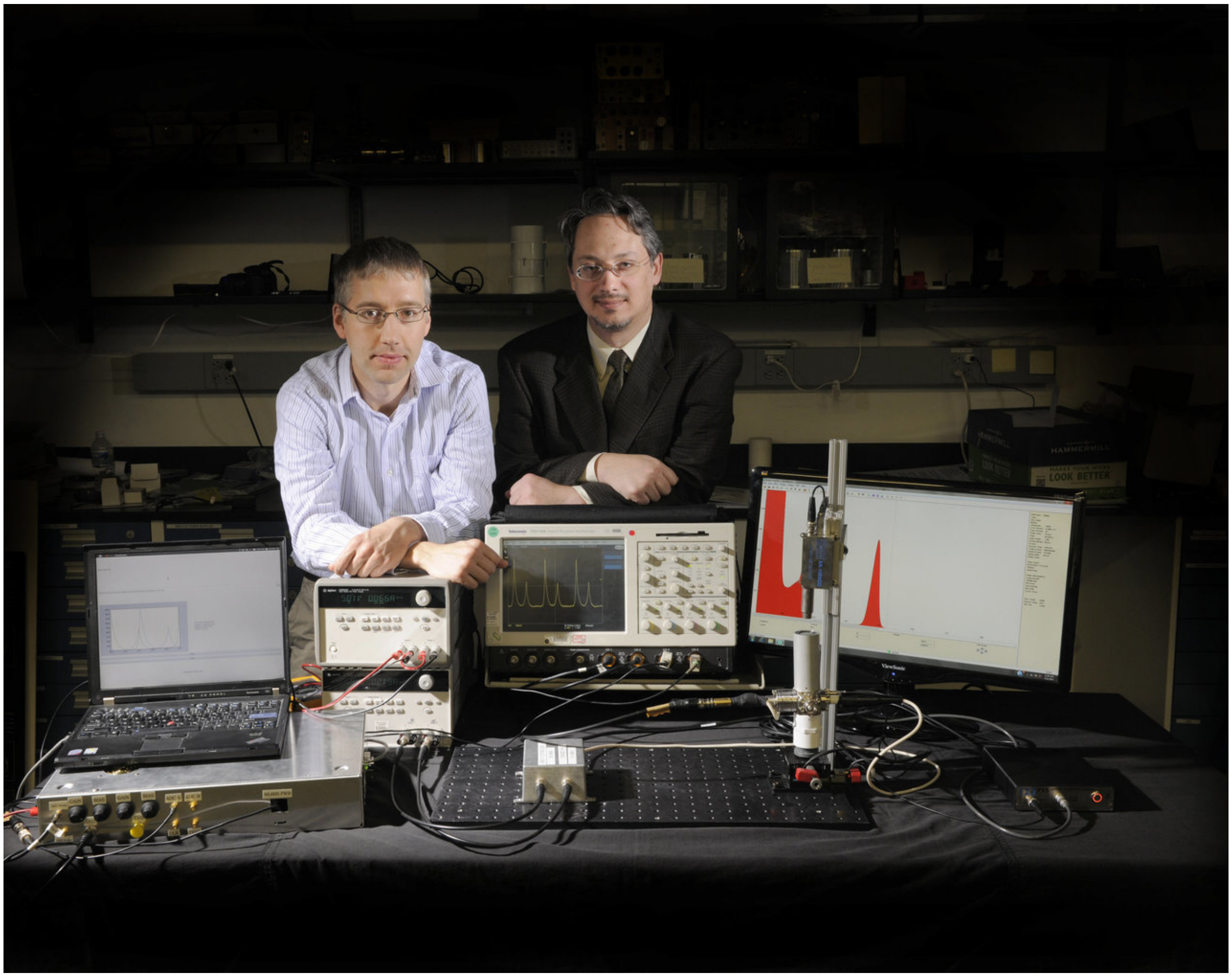
Now that NASA has shown the viability of autonomous X-ray navigation in space, a team led by the Smithsonian Astrophysical Observatory plans to include the technology on a proposed CubeSat mission to the Moon, and NASA engineers are now studying the possibly of adding the capability to future human-exploration spacecraft.

Interest in this emerging capability to guide spacecraft to the far reaches of the solar system comes just months after NASA scientist Keith Gendreau and his team at the agency's Goddard Space Flight Center in Greenbelt, Maryland, successfully demonstrated the technique—commonly known as XNAV—with an experiment called Station Explorer for X-ray Timing and Navigation Technology, or SEXTANT.

The SEXTANT technology demonstration, which NASA's Space Technology Mission Directorate had funded under its Game Changing Development program, took place late last year and demonstrated that millisecond pulsars could be used to accurately determine the location of an object moving at thousands of miles per hour in space. These pulsations are highly predictable, much like the atomic clocks used to provide timing data on the ubiquitous GPS system.

During the demonstration, SEXTANT took advantage of the 52 X-ray telescopes and silicon drift detectors on NASA's Neutron-star Interior Composition Explorer, or NICER, to detect X-rays emanating from four millisecond-pulsar targets. The pulsars' timing data were fed into onboard algorithms that autonomously generated a navigation solution for the location of NICER in orbit around Earth.

The team is expected to carry out another XNAV demonstration later this spring to see if it can improve on the technology's already impressive accuracy, said SEXTANT Project Manager Jason Mitchell, who works at Goddard.



Engineers Luke Winternitz (left), Jason Mitchell (right) and their team developed a unique tabletop device -- aptly described as a 'pulsar on a table' -- to simulate rapid-fire X-ray pulsations needed to test algorithms and other advanced technologies for the X-ray navigation. The team recently delivered the special testbed to the Aeromechanics and Flight Mechanics Division's Electro-Optics Lab at the Johnson Space Center. Credit: NASA/P. Izzo

Navigation Testbed

In another development that could broaden XNAV's use, the SEXTANT team recently delivered a special testbed to the Aeromechanics and Flight Mechanics Division's Electro-Optics Lab at NASA's Johnson Space Center in Houston. The team developed the unique tabletop device - sometimes described as a 'pulsar on a table' - to simulate the low-strength signals received from pulsars. The measurements obtained from XNAV will be used to test algorithms being developed for future crewed missions.

XNAV sensors complement optical-navigation (OpNav) sensors. Together, they can serve as an autonomous navigation package to aid vehicles in case of loss of communications with the ground and to relieve the navigation tracking burden on NASA's Deep Space Network.

Mitchell said NASA's Lunar Orbital Platform-Gateway, where astronauts will participate in a variety of science, exploration, and commercial activities in orbit around and on the Moon, could employ XNAV capabilities.

CubeX: Characterizing the Lunar Surface

And in another development, the SEXTANT team is working with Suzanne Romaine, a scientist with the Smithsonian Astrophysical Observatory, and JaeSub Hong, a researcher with Harvard University, to fly XNAV on a CubeSat mission called CubeX.

"This is a push to move the technology into the operational mode," said Mitchell, who, along with Gendreau, is a CubeX collaborator. "This is great opportunity for XNAV and showing its value to navigating in deep space."

As currently conceived, the small satellite would gather timing data from the list of SEXTANT millisecond pulsars using CubeX's miniature X-ray telescope. An onboard algorithm would then use the data to determine the spacecraft's trajectory. The team would compare CubeX's solution against that provided by NASA's Deep Space Network, a communications and navigational capability used by all NASA deep-space missions.

Demonstrating XNAV on an operational satellite, however, isn't the mission's only objective.

The other half of its mission will be spent measuring the composition of the Moon's lower crust and upper mantle to understand the origin and evolution of Earth's only natural satellite, which scientists believe may have formed when a huge collision tore off a chunk of Earth.

"There's a lot we don't know about the Moon. Many mysteries remain," said Hong. A better understanding of the mantle layer could be key to determining how the Moon and the Earth formed. To get this information, CubeX would use a technique called X-ray fluorescence, or XRF.

XRF, which is widely used in science and industry applications, is based on the principle that when individual atoms in sediment, rocks, and other materials are excited by an external energy source—in this case, X-rays emanating from the Sun—they emit their own X-rays that exhibit a characteristic energy or wavelength indicative of a specific element. This can be likened to how fingerprints can identify a specific person.

By capturing these "fluorescing" photons with a miniaturized X-ray optic and then analyzing them with an onboard spectrometer, scientists can discern which elements make up outcrops of the Moon's rocky mantle, which have been exposed by impact craters, and its crust, which overlays the mantle.

The mission would launch no earlier than 2023 to take advantage of the next solar maximum, which would assure a steady bombardment of high-energy X-rays to produce the fluorescence.

Provided by NASA's Goddard Space Flight Center