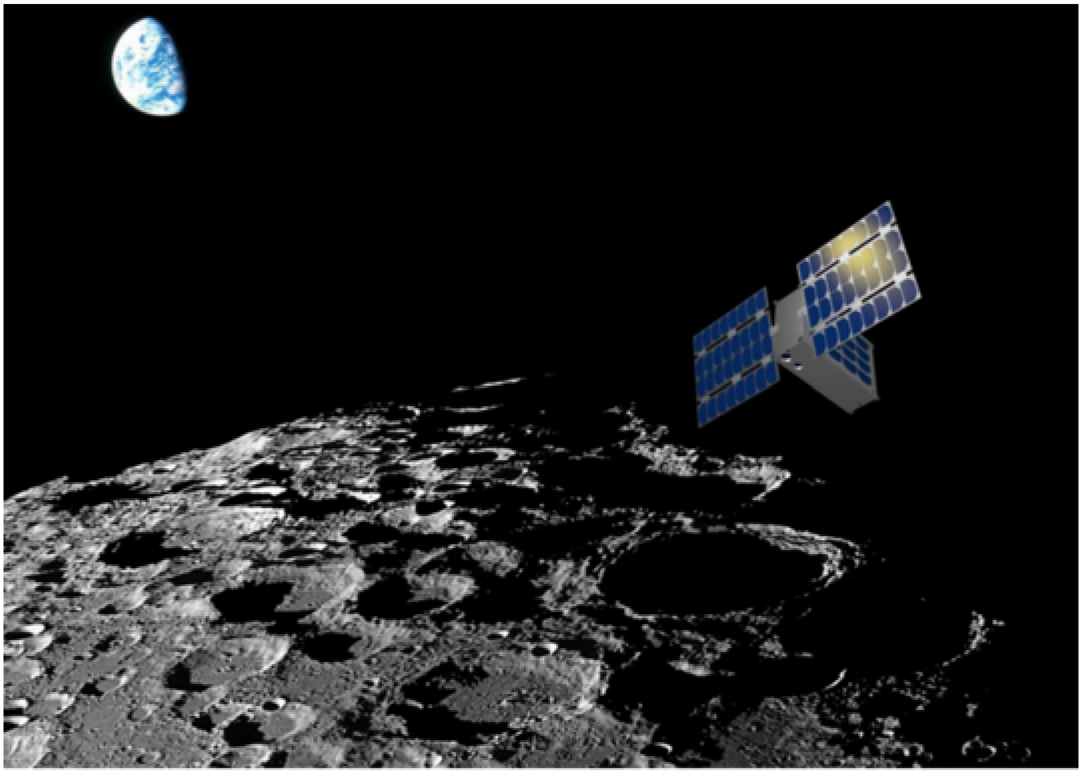
Casey Dreier • September 2, 2015

CubeSats to the Moon

An interview with the scientist behind NASA's newest planetary exploration mission

On Tuesday, NASA announced its selection of two CubeSats to fly beyond Earth as part of its *Small, Innovative Missions for Planetary Exploration* (SIMPLEx) program. The CubeSats were limited to a total budget of $5.6 million (though they were encouraged to be cheaper), and will ride along on the first flight of the Space Launch System (SLS) in 2018. They were competitively selected from a number of proposals submitted by the scientific community.

The Lunar Polar Hydrogen Mapper (LunaH-Map) was one of the two missions selected. Led by 33-year-old planetary scientist Dr. Craig Hardgrove, a post-doctoral scholar at Arizona State University, it will attempt to map the distribution of water-ice over the south pole of the Moon at high resolutions.



Sean Amidan / ASU / SpaceTREx

LUNAR POLAR HYDROGEN MAPPER (LUNAH-MAP)
Artist's concept of the Lunar Polar Hydrogen Mapper (LunaH-Map), an Arizona State University-built CubeSat about the size of a shoebox that will be used to produce a map of the water resources on the Moon for future human exploration.

I interviewed Dr. Hardgrove about his lunar CubeSat, how it came together, and how NASA's support for small missions are important for early career scientists like himself.

First, tell us about your cubesat. What is it going to do at the Moon? What will this tell us that we don't already know?

LunaH-Map is a 6U CubeSat, about the size of a large shoebox, that will make measurements of the abundance and location of water-ice that is hidden within permanently shadowed regions (areas that never see sunlight) at the Moon's South Pole.

LunaH-Map will play a role in understanding just how much water-ice could be hiding within the permanently shadowed regions of the lunar South Pole. LunaH-Map will also help answer geologic questions about whether or not this water-ice could have been delivered by passing asteroids or comets, or if there might be another source.

Our CubeSat will launch on NASA's SLS rocket and will enter a highly elliptical orbit with a closest approach directly over the South Pole of the Moon. The closest approach (called perilune) is only about 5km above the surface. We need to get very close because our science instruments—two neutron spectrometers—have a very large effective field of view. For a neutron spectrometer the spatial resolution is about one and a half times the height above the ground, so the closer we get to the surface the better we can spatially isolate the location of any enrichment in water-ice.

Previous missions to the Moon have carried neutron spectrometers, but they orbited from much higher elevations than LunaH-Map, resulting in measurements that do not allow us to isolate the specific abundance and location of water-ice within the permanently shadowed regions. We know water-ice is abundant in small regions (from previous NASA missions), but our current, low spatial resolution maps of water-ice from neutron spectrometers could be consistent with both highly concentrated water-ice in a small region, or less water-ice spread out across a much larger region.

How did you come up with your idea for this CubeSat?

I'm a member of the Mars Science Laboratory Curiosity science team where I work on the neutron detector (called DAN, or Dynamic Albedo of Neutrons) that is mounted to the back of the rover. As part of this work, I've been thinking a lot about what rocks and surface features are within the DAN effective field of view. It turns out the field of view of DAN is only about 3 meters centered around Curiosity's back two wheels.

When trying to compare the neutron data from Curiosity to a map of water from one of the neutron detectors in orbit around Mars (the Neutron Spectrometer on Mars Odyssey), I was struck by how unfortunate it was that the spatial resolution from orbit was hundreds of square kilometers. Scientists have been thinking about flying neutron detectors on gliders, or airplanes flying autonomously around Mars for many years and I always thought that those were really cool ideas to solve the problem of spatial resolution with neutron detectors. So when I was chatting with the (future) LunaH-Map Chief Engineer at ASU about possibilities for a SIMPLEx mission, and what might be possible, we immediately started thinking about big questions in planetary science that could be answered for the Moon. We focused on the Moon because, with our current technology and the launch opportunity on SLS, this would allow us the most fuel to stay in orbit and collect the most data.

Then it was a question of what would make a compelling science goal, and since I tend to think about neutrons and neutron detectors which tell us about water, it made a lot of sense to think about places on the Moon where we might want to detect water—like the permanently shadowed regions.

But we really need to get close to the surface to make the neutron measurements worth it. The mission wouldn't make sense unless we knew we could get into a low perilune orbit to make that high spatial resolution measurement. That really tough part was eventually solved by a small company called KinetX, who have provided orbital solutions for both New Horizons and MESSENGER. With the orbital solution in hand, it was just a matter of building up the best team we could around the mission concept. We brought in some great team members from NASA - Ames who have experience with LCROSS, the Jet Propulsion Laboratory, Radiation Monitoring Devices, Catholic University of America, and Planetary Resources.

How is a mission like the LunaH-Map different than what most people think of as a NASA lunar mission?

Most NASA missions to the Moon (or other planets) carry large suites of instruments that have been competitively selected from a pool of U.S. and international institutions. LunaH-Map has a relatively small number of instruments: only two neutron detectors and an engineering camera.

The other way this mission is different is that most mission architectures are defined in advance—at least at the high level. The really fun thing about developing this a SIMPLEx mission was that the possibilities were relatively unconstrained: limited only by whatever we could dream up that fit within a CubeSat platform. You can really see this in the diversity of proposals that were selected both for flight and those that were selected for technology development. LunaH-Map is destined for the Moon, while the other missions were proposed to Earth orbit and even Mars!

The real difference from other NASA missions, however, is that LunaH-Map will be designed, built, tested and operated by Arizona State University (ASU). This is the first mission being led by ASU, so this means that instead of ASU delivering an instrument to NASA (as was just recently done with OTES for the OSIRIS-Rex mission), all of our partners are delivering components to ASU so that they can be integrated into the spacecraft and tested. We will then operate the spacecraft, downlink all the data, and perform the required modeling to turn our neutron counting data into maps of water-ice abundance.

What did having the constraints of a CubeSat (both in physical size and a $5.6 million budget cap) force you to do with regards to the design of your spacecraft?

We had to think creatively, and leverage a lot of the developments that have taken place in CubeSats and small satellites over the past 5 – 10 years.

We built strong collaborations with a variety of small businesses who have been developing components for CubeSats and small sats. The great thing about this is that many of these businesses have been developing their products and technologies through NASA Small Business Innovation Research (SBIR) and Space Business Technology Transfer (STTR) contracts. So some of the development and the investment in these innovative technologies has already been made through other NASA programs, we're just making use of it for planetary science as opposed to commercial enterprise.

Are you able to learn anything from the Planetary Society's LightSail cubesat which flew earlier this year?

I watched LightSail very closely, through the many ups and downs, and it was amazing it see everything work so well in the end. The community developing CubeSats that are capable of leaving Earth-orbit (interplanetary) is still relatively small, and I absolutely plan to learn as much as I can from everyone who has experience in this arena to ensure that these small satellite platforms are best they can be for science and exploration of our solar system.

Most people out there aren't familiar with the proposal process itself. What’s it like to ask NASA for millions of dollars to send your idea to the Moon?

The SIMPLEx call was much different than any other full mission call from NASA. For most missions, proposers have a year (or years) to formulate, conceptualize and perfect their mission concepts. In our case, we had somewhere around 4 – 5 months to complete the entire process and submit the proposal.

It was so much fun to see everything come to together. Most of the days were spent making calls, chatting with all the various Co-Investigators to make sure that everyone was working towards a common goal that they all agreed with. It was really important to keep everyone on track, and to curate all the ideas that everyone had (which were all brilliant) into a fully formed mission concept.

As a planetary scientist, however, most of my time was spent crafting the science section of the proposal, but I also spent a great deal of time drafting up the project schedule, management plan, cost narratives, concept of operations, data management plans, and science traceability matrices! As for building the team, a lot of it was through personal connections either that I had, or the team had. We had to limit ourselves to just the team that we knew could get the job done.

Why are opportunities like SIMPLEx important for early-career scientists?

In my experience as a post-doc over the past several years, the job market in academia seems nearly saturated.

Almost every day I see an article about the backlog of postdocs with nowhere to go. I feel really strongly that it's important to retain highly trained scientists who can do research and teach. After two or three postdoctoral appointments, it can really become a sticking point in one's career where a person who is likely in their mid-30's is going to have to decide if their passion for science is strong enough to be comfortable going from short-term to short-term job with only modest benefits, no ability to save for retirement and the inability to settle in one place. We're slowly pushing these types of highly trained individuals out of research and teaching, and more opportunities like this might help.

If we don't come up with ways to retain highly trained individuals in science we're really going to have a problem fostering anyone into STEM fields in the future. So SIMPLEx is important because it gives early-career scientists the chance to design their own experiment, build a team and either test it or fly it. You can become your own Principal Investigator and design your own experiments. It's not happening quite yet, but if missions like LunaH-Map, Lunar IceCube and Lunar FLASHLIGHT are successful, it will open up the possibilities for planetary exploration not only in terms of budgets but in terms of schedules. Right now we have to wait years between missions to other moons and planets, but with CubeSats, a single launch of the SLS could launch 11 different missions (as secondary payloads).

CubeSat launches are being planned for other large launch vehicles as well, so we could be talking about dozens and dozens of planetary science missions split across only a few launch opportunities. This is not only exciting for lovers of planetary science and exploration, but for the planetary science experts who have been trained to study the data from these missions, or (perhaps) to those who want to be Principal Investigators for those missions.

What role do you think CubeSats will have in the future of planetary exploration?

I'm a huge fan of technology and love following the video game and tech sectors. I think that we've seen a similar type of entrepreneurial development happen in the tech sector already. In software development, it can be relatively cheap to make an app, and small teams can make a beautiful app that is wildly successful. That was enabled in part by reducing the cost of the development platform itself, the personal computer. It was also aided by infrastructure, the internet. There are some similarities between what could happen with CubeSats as a platform and what we've already seen happen in software application development.

If these first SLS CubeSat missions show they can make scientific measurements on a small spacecraft platform, it should open up the playing field and get more of the traditional scientific groups interested in working on CubeSats.

The other beautiful thing about CubeSats is that they require expertise across many disciplines. We need computer engineers, programmers, aerospace, electrical and mechanical engineers, orbital mechanics specialists, and yes, even planetary scientists! More mission opportunities and more opportunities to design CubeSats means more reasons to encourage kids (and adults) to go into Science, Technology, Engineering and Mathematics (STEM) fields. CubeSats were developed as an open-source educational platform, and I expect they will always maintain those roots even as they are used for bigger planetary science missions like LunaH-Map.

The big NASA missions aren't going away (and shouldn't!), but CubeSats open up the possibility of using all the available space within larger spacecraft payloads to hold mini-missions within the main mission. This distributes the risk and allows these small missions to not jeopardize the main payload. It also allows a large mission to deploy CubeSats as "scouts", carrying specialized payloads that are focused on specific planetary bodies or to be used as impactors that could transmit data as they approach (similar to LCROSS). As long as the launch opportunities continue to grow, the possibilities of making planetary spacecraft cheaper and more accessible to everyone are really endless.

I really think this is the tip of the iceberg for CubeSats and I'm extremely honored and privileged to be leading one of the first interplanetary CubeSat missions that's singularly focused on planetary science.

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