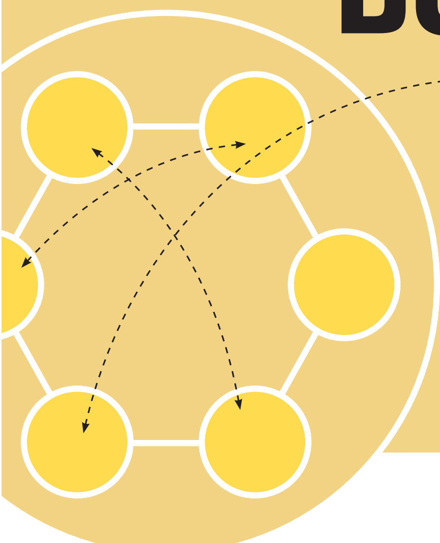
RISKY BUSINESS

By encouraging unfettered brainstorming and the seeding of ideas that traditional funding sources might deem too bold, the Keck Institute for Space Studies at Caltech is helping space scientists and engineers get transformative concepts off the ground.

by Kimm Fesenmaier



In April 2013, NASA announced that it was in the early phases of planning a robotic mission to snag an asteroid and haul it into lunar orbit for study. At the time, NASA chief Charles Bolden said that such an asteroid redirect mission represented "an unprecedented technological feat that will lead to new scientific discoveries and technological capabilities and help protect our home planet."

To many, the plan sounded farfetched—like something from a Bruce Willis movie. But to those scientists and engineers who had been working out the feasibility of just such a plan since 2011—as part of a study funded by the Keck Institute for Space Studies (KISS) at Caltech—the idea was already old-hat and anything but Hollywood fluff.

And it was just the kind of thing that KISS is designed to do. Established in 2008 with funding for eight years from the W. M. Keck Foundation and additional support from JPL, KISS was designed to bring together diverse groups of scientists and engineers to develop revolutionary concepts and technology for future space missions—like one that would lasso an asteroid.

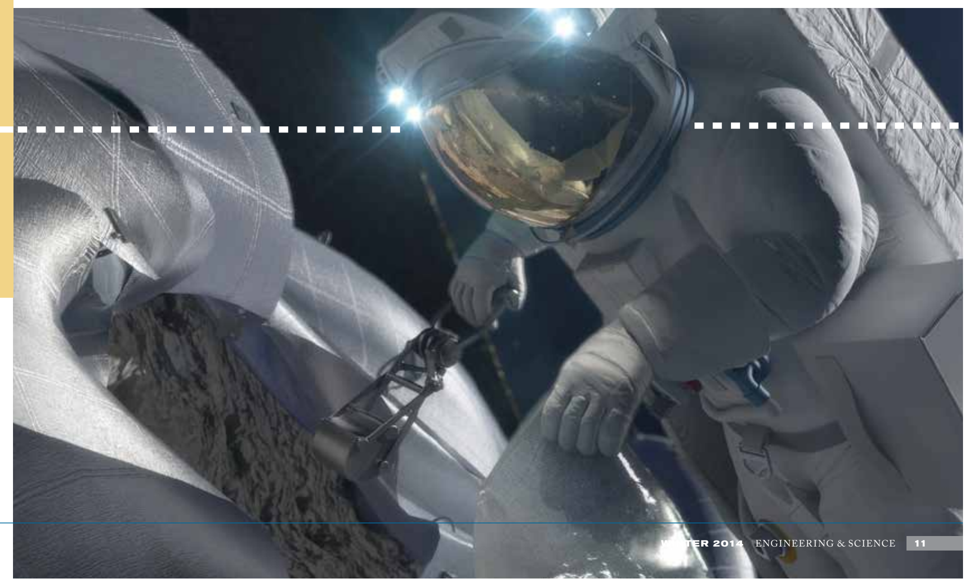
That's not to say that the asteroid concept seemed eminently doable when KISS first reviewed it as a proposed workshop topic in 2010. In fact, KISS director Tom Prince recalls that several members of the steering committee that reviews such proposals thought the concept was rather unlikely to lead to an actual space mission.

"But we're here to take on risky possibilities and see if they work out," says Prince.

"My view is that we need to be a little bit out on the edge. If every single topic that we pick works, then we aren't being bold and aggressive enough."

Since most of the steering committee agreed with that sentiment, the first KISS-sponsored workshop on asteroid retrieval took place on campus in September 2011. A second followed in February 2012. By April of that year, the participants were able to publish a report suggesting that a spacecraft using solar-electric propulsion could reach and capture a 500,000-kilogram near-Earth asteroid—essentially by putting an enormous bag around it—and then haul it into high lunar orbit. And, they added, all of this could be done by around 2025 for a total cost of about $2.6 billion.

That report caught NASA's eye. In late 2012 and early 2013, the space agency had JPL conduct an additional feasibility study in collaboration with the Glenn Research Center and supported by several other NASA centers. They found that the KISS-described mission and timeline was indeed doable, even suggesting that the mission could be accomplished for less than KISS's original estimate.



NASA's plans to capture an asteroid and put it into orbit around the moon—where it could be studied more easily by future robotic and manned missions—was a concept first discussed at a KISS workshop in 2011.

We're here to take on risky possibilities and see if they work out."

—Tom Prince, director of the Keck Institute for Space Studies

Recently, the *New York Times* highlighted another KISS study: one that explored the possible development and use of stratospheric airships for astronomical and Earth-monitoring observations. Airships have been around for more than 200 years, but typically have been flown at altitudes of less than 10,000 feet. The KISS study brought experts together to discuss higher-flying ships, which could soar 65,000 feet above Earth, driving down the cost of space observations while making more science possible. The KISS study noted that a one- or two-meter optical telescope with excellent pointing stability on such a high-altitude airship would have superior viewing conditions night after night as compared to any optical ground-based telescope. It also suggested that airships, with their ability to be deployed quickly and to move as needed, could enable measurements of dynamic events such as wildfires, as well as observations of regions of Earth that have been difficult to study at length but that are critical to our understanding of climate change, such as the Amazon rain forest and the Arctic sea ice.

"KISS encourages work at the interface of science, exploration, and engineering, where something may not be doable, but if it is, there would be the possibility of a key new discovery or capability," says Bethany Ehlmann, a planetary scientist who participated in her first KISS workshop a few years ago and is now a member of KISS's steering committee. While many traditional funding sources require that scientists and engineers demonstrate that a project has a high likelihood of success before it gets funded, she says that KISS takes more of a risk. "KISS occupies an interesting niche, seeking to fund not the 'clearly doable' nor the 'totally crazy,' but the space somewhere in between."

A THINK AND DO TANK

It was actually a biologist, then-Caltech-president David Baltimore, who initially got KISS's ball rolling. Following the successful landings of the Mars Exploration Rovers and the Cassini orbiter's insertion into Saturn's orbit, Baltimore tasked a faculty committee with looking at ways to increase Caltech-JPL collaborations. Chemistry professor Jack Beauchamp was on that committee and first articulated what became KISS's organizing concept: bring experts together to brainstorm a particular space-related topic and to do technical thinking, then fund the initial work on any promising innovation or idea they come up with. Following such a seemingly simple protocol, the institute would serve as a "think and do tank."

"We were really looking to create something that would, in as many ways as possible, benefit collaborative interactions between Caltech and JPL," says Beauchamp. "JPL has enormous capabilities for instrument and spacecraft design, as well as testing and construction. We wanted to tie that together with the science and engineering at Caltech in a synergistic way so that we all benefited. And it seemed that following this model was the best way to do that."

Once a year, KISS solicits proposals for new workshops—in 2014, they funded seven topics ranging from detecting changing landscapes on Earth and other bodies from space to technologies that will enable scientists to explore the interstellar medium. Proposals typically come from teams of three researchers, including someone from the Caltech campus, someone from JPL, and someone from the external community. These team members go on to lead the workshop if the proposal is selected. Over the course of the year, the co-leads then schedule one or two multiple-day workshops in which experts in the field come together for intense brainstorming sessions focused on the proposed topic. That's the *think* part of the model. Following the workshop phase, participants are then given the opportunity to propose two years of technical follow-up work to pursue any great ideas that came out of the workshop brainstorming. That's the *do*.

"KISS allows us to look beyond what is being done to what is possible," says planetary scientist Dave Stevenson. "It enables us to look at innovative approaches to planetary science—especially those things that we're not going to be able to do immediately or even may not be able to do at all. It goes beyond the current mission set."

In 2010, Stevenson led a workshop in which the group fleshed out novel ideas for using a seismometer to study the interior of a planet like Venus or Mars. At the time, there was no immediate need for the work. But now NASA has selected a mission for its next Mars lander, called InSight, which is to be launched in 2016 and will use some of the seismology techniques that were initially discussed at the workshop. The mission's principal investigator, Bruce Banerdt of JPL, attended the KISS workshop and says he believes it helped pave the way for the mission's selection. "The workshop…helped a lot in my approach to writing the science section of the proposal," Banerdt explains. "I also believe, without any direct evidence, that the higher profile for planetary seismology that came from the activities that were initiated through the contacts and discussions at the workshop helped us in the evaluation."

To try to enhance opportunities for close interaction, KISS asks that no more than 24 researchers and an additional six students or postdocs attend each workshop. They also ask leaders to allot at least half of a workshop's time for unstructured conversation.

To help get that conversation flowing, a robotic helium-filled shark sometimes "swims" around the large meeting room known as the Think Tank, where KISS now holds its workshops; it's a great ice-breaker. And during one recent workshop, a well-known senior scientist volunteered to serve as the target of a Koosh ball attack by other attendees, as a way to remove any existing barriers between junior and senior researchers.

"Workshops should be all about interaction," says Prince. "In our workshops, talks are only a vehicle for getting people to interact, which is very different from what you see at most conferences. The people who speak are discussion leaders, not lecturers. There needs to be a free flow of information."

The approach seems to be paying off. Astronomer Tony Readhead co-led KISS's very first workshop—one focused on designing and building new array receivers for cosmology and astrophysics—because he was interested in the science the devices might enable. But during one of the workshop's breakout sessions, he got to talking with other attendees, and it became clear that Caltech needed a lab to develop these receivers. Even though he had never been a device instrumentalist, Readhead eventually took on the task of running such a lab, which is now known as the Cahill Radio Astronomy Lab (CRAL).

Until the advent of these new receivers, called monolithic microwave integrated circuits (MMICs), nearly all radio telescopes were single-pixel devices, meaning they had just one beam on the sky at any one time. The new, highly integrated circuits make it possible for telescopes to employ arrays of detectors. "They're doing for radio astronomy what CCDs did for optical astronomy 30 or 40 years ago, allowing us to use multiple detectors to go after very, very faint signals," says Readhead. He and his colleagues have already produced a 90-pixel array for the QU Imaging ExperimenT (QUIET) in Chile, are building a 16-pixel array for the Greenbank Telescope in West Virginia, and have provided MMICs to other observatories around the world, including the National Radio Astronomy Observatory. The devices have already improved the sensitivity of ground-based measurements of the cosmic microwave background, and Readhead expects them to be real game changers in studies of star formation. "I'm quite sure that a decade from now, most radio telescopes will have arrays of receivers," says Readhead. "And that was completely enabled by the work that KISS supported."

Planetary scientist Bethany Ehlmann (bottom of previous page) participates in a workshop discussion. John Brophy (above), a principal engineer at JPL, is "Kooshed" by participants at a KISS workshop on an asteroid redirect mission.

In 2009, when KISS provided technical development funding to start the CRAL, researchers in the field had been trying without success for about seven years to secure funding from federal agencies to develop MMICs. Add to that the fact that KISS started up right after the economic downturn and, Readhead says, "there is no way that we would be getting these devices out there now without KISS. This revolution that's coming in radio astronomy is probably arriving a decade or so earlier than it would have because of KISS's foresight."

SEEDING ADVANCES

Geochemist Ken Farley's participation in a KISS workshop led not only to new research ideas but also to a major shift in personal focus. When Farley signed up to attend a workshop about methods for studying Martian stratigraphy, or rock layers, he had never given much thought to space studies. His work had largely focused on determining the histories of rock masses on Earth. But he was intrigued by a KISS write-up about the problem of doing geochronology—rock dating—on other planetary bodies. At the workshop, he interacted with a number of people from JPL who had expertise in developing mass spectrometers, the analytical instruments used to do many geochronology experiments on Earth.

"I could imagine that some of the things that I was doing in my lab could be applied to dating elsewhere," Farley says. "As the workshop proceeded, it seemed like we might be able to do something special that would help solve this problem of dating on other bodies."

Following the workshop, Farley and his colleagues applied for and received funding for the technical development of their idea to design a new way to measure the age of rocks and soil samples on Mars.

It's this "do" part that truly sets KISS apart, says Farley. "I don't think there's anything that you could even compare it to," he says. "There are lots of venues where you can go and talk about things, but then what? Nothing. Maybe you can submit a proposal. But there's nothing more frustrating than having a great idea and realizing that it's going to take a year to get the money to even start. Here, it was pretty clear that a solid proposal would be funded quickly."

As the geochronology group started working on its dating technique for martian rocks, NASA put out a call for scientists interested in participating in the Mars Science Laboratory (MSL) mission. Realizing that the mass spectrometer onboard MSL might be able to do some of the dating work he and his colleagues had been thinking about, Farley submitted a proposal and became part of MSL's science team. He and his colleagues used Curiosity's Sample Analysis at Mars (SAM) instrument to make the first measurement of the age of a rock on Mars, and Farley is now serving as the project scientist for Curiosity's successor—another robotic rover called Mars 2020.

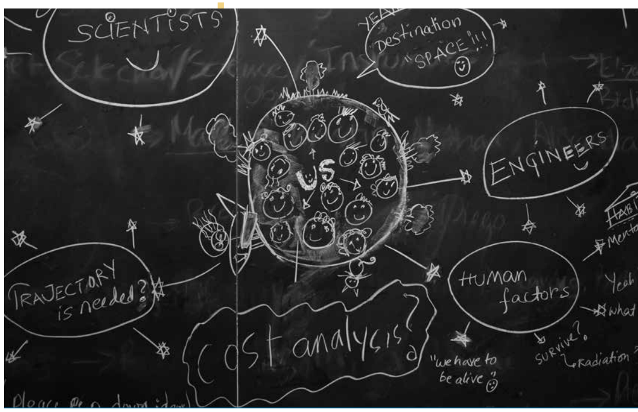
"None of that would have happened if I hadn't participated in that first workshop," Farley says. "There's no way I would have been doing science with a rover on Mars—it was totally outside of anything I had been doing." Farley is just one of many researchers whose own work has been influenced by KISS's work. So far, more than 70 Caltech faculty members have participated in KISS studies. The think and do tank has also attracted nine postdoctoral fellows, and KISS has worked to engage the broader public through open lectures, as well as Caltech students through a variety of student-led projects meant to give both undergrads and graduate students the chance to pursue their own risky space-related ideas. To date, they've funded five such projects.

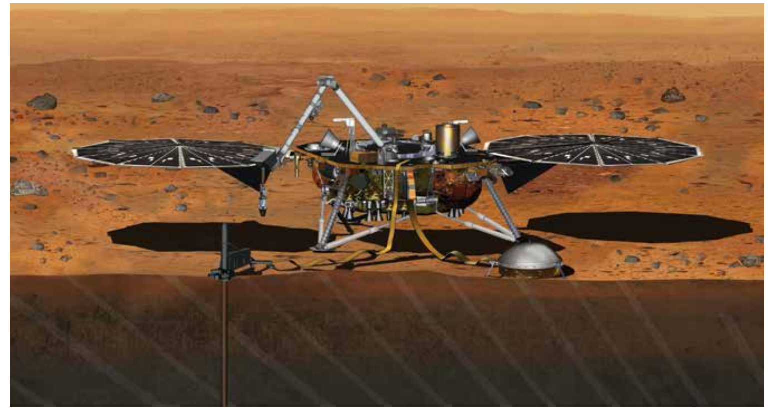
Prince says the idea for such projects began when he was walking down the Olive Walk on campus, saw the student houses on either side, and thought, "We have all of this machinery to do workshops and brainstorming. Why don't we hand it over to the students and see what they do with it?"

Notable among those student projects was the KISS Caltech Space Challenge—a project dreamed up by graduate student Prakhar Mehrotra (who received his engineer's degree in aeronautics in 2013). In 2011, 32 scholars from around the world came together for a weeklong workshop and competition on campus to design the best space mission to a near-Earth asteroid. Two years later, a new group of undergraduate and graduate students gathered to plan a mission to one of the moons of Mars. Participants attended lectures throughout the week and had mentors from JPL and elsewhere on hand to help them as they considered the myriad details of their potential missions. The Space Challenge was an overwhelming success, Prince says, and brought together leaders from academia and industry while providing the next generation of mission designers with invaluable experience and access to expertise.

Prince says at every step he has been pleasantly surprised by KISS's success.

"Little did I think that—with the asteroid redirect mission, if that goes, and the 2016 Mars lander—we'd have an impact as great and as quickly as we have," he says. "It just shows how powerful it can be to get two dozen people from different backgrounds together to think about new ways of approaching a given subject. If you do that well and get those people really working together, it can supercharge everybody's research." E&S





Brainstorming notes (left) from one of two teams that participated in the first KISS Caltech Space Challenge in 2011. Thirty-two students from around the world, including Nathan Parrish and Kristin Nichols (both seen in photo above), competed in the week-long challenge. NASA's InSight Mars lander (top opposite) will employ techniques discussed at a KISS workshop on planetary seismology in 2010.

Jack Beauchamp is the Mary and Charles Ferkel Professor of Chemistry and sits on the KISS steering committee.

Bethany Ehlmann is an assistant professor of planetary science at Caltech and a research scientist at JPL. She is also a member of the KISS steering committee.

Ken Farley is the W. M. Keck Foundation Professor of Geochemistry and former chair of the Division of Geological and Planetary Sciences.

Thomas Prince is director of the W. M. Keck Institute for Space Studies. He is a professor of physics and the deputy executive officer for astronomy at Caltech. He is also a senior research scientist and the former chief scientist at JPL.

Tony Readhead is the Robinson Professor of Astronomy at Caltech, a senior research scientist at JPL, and director of the Owens Valley Radio Observatory.

Dave Stevenson is the Marvin L. Goldberger Professor of Planetary Science.

The Keck Institute for Space Studies was established with a $24 million grant over eight years from the W. M. Keck Foundation. It is a collaborative venture with JPL, which supports its participation in KISS programs with significant funding from its Research and Technology Development program.