BACK TO THE FUTURE:

KSC SWAMP WORKS

BY KERRY ELLIS

After the retirement of the Space Shuttle and completion of the International Space Station, NASA has been looking toward what's next in human space exploration. Several centers have begun working on projects that could pave the way for the new ambitious goals of exploring asteroids and launching missions beyond low-Earth orbit. But such a shift in goals also requires a shift in culture. Taking a cue from NASA's Apollo days, Kennedy Space Center (KSC) has taken steps toward changing the culture to one of hands-on, lean engineering and innovation development with the KSC Swamp Works.

A panoramic view of the new KSC Swamp Works space.

Photo Credit: NASA

"KSC Swamp Works is what I call 'Back to the Future,'" said Rob Mueller, senior technologist for the Systems Surface Office. "It's an attempt to return to the early years of NASA when it was very hands-on, projects happened quickly, there were a lot of experiments, and sometimes failures happened, but we learned from the failures."

KSC Swamp Works includes the Granular Mechanics and Regolith Operations Lab and the Electrostatics and Surface Physics Lab. Both have been around for a few years as part of the Surface Systems Office but were previously located in an off-site building. When the opportunity—and budget—became available to move the labs back to Kennedy, the teams discussed their vision for an ideal environment in which to do new hands-on work.

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"I asked the team, 'What do you want?'" said Jack Fox, chief of the Systems Surface Office. "I made sure the requirements matched the building we wanted. It's a huge building because we wanted to reinvent everything into being a Swamp Works environment—cost-effective, hands-on, rapid ideas—and have both labs in the same space." The teams didn't want different codes and buildings that would inhibit joint brainstorming. Another building requirement to support this goal was to include an "innovation space."

With café seating and white boards, and walls and tables painted with whiteboard paint as well, the innovation space is located in a small, open loft. "It's completely flexible, reconfigurable. The whole dynamic of the room can change," said Mueller. "It's not designed to be a room to have meetings. It's designed to be a room where people can interact spontaneously and informally to come up with new ideas and innovative ways of working."

To further encourage openness and collaboration, the team also included a flexible work space as part of the building requirements. Meant to operate as a technology incubator, it allows anybody with a good idea to come in and have real estate available to try out a new technology. "They can't stay there forever," Mueller explained, "since it's an incubator, but at least there's a place for new ideas to get started."

The labs have a mix of primarily engineers, physicists, and chemists—both senior and fresh-outs—to help encourage innovative thinking and problem solving. But that diversity is part of the challenge of running a Swamp Works operation. "How do you get people together from different disciplines?" asked Mueller. "Usually we do this by creating a multidisciplinary team for a project, but we don't always have all the disciplines we need." To fill the gaps, the Surface Systems Office takes advantage of Kennedy's matrix organization and asks the Engineering and Technology Directorate for the help they need.

Sometimes they find that expertise through more informal means. Every other week the teams have innovator get-togethers during lunch. "We talked about having after-work activities, but people kind of want to go home," said Fox. "We learned that lunchtimes every other Friday work well. And what I've noticed is innovators from different groups will have great conversations about what they're working on and asking, 'Have you thought of this? Have you thought of that?' It's worked out very well."

With an abundance of knowledge and ideas flying about, KSC Swamp Works has taken steps to formally capture lessons learned in the midst of their fast-paced efforts.

Capturing Lessons Learned

Using a "make it, test it, and improve it" model of work, projects in the KSC Swamp Works labs often undergo several generations of builds, each an inexpensive attempt to improve on the one before. With so much excitement generated by doing hands-on work, it can be a challenge to get the teams to slow down and capture what they've learned from their efforts.

Mueller reminds his teams of the incentives for taking the time to document that knowledge. "We try to tie things together

with positive outcomes—like a conference or a new technology report or a patent application," he explained. "In order to get credit for the work we've done, we write conference papers, which require us to document things well. We also write new technology reports, which could get published in NASA *Tech Briefs* and eventually lead to getting a patent on the work. We would like to protect intellectual property and license the new technology transfer to the public, and in order for the legal process of patenting to happen, you have to have documentation."

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Since much of KSC Swamp Works' focus is on openness and collaboration, the teams try to make their lessons learned as broadly available as possible. Currently, they use SharePoint to make formal knowledge-capture documents readily accessible. But they also use it to capture lessons in real time.

Projects traditionally complete the work, stop to document it, and then move on to the next phase. This process doesn't work as well for the faster-paced work involved in lean-engineering research and development. "We do have formal processes like design reviews, and we create documentation for those reviews, but we try to document as much as we can real time so the records are always available and you don't have to stop to generate a report," said Mueller.

The labs maintain continuity of knowledge between generations of designs by having the same team work on every successive generation together.

The collaboration among scientists and engineers, seniors and fresh-outs, is open, allowing everyone to learn from each other and ask questions along the way. One recent graduate, Rachel Cox, said the knowledge she has gained by working with senior engineers on the Regolith Advanced Surface Systems Operations Robot (RASSOR) has been invaluable.

RASSOR

The KSC Swamp Works labs currently focus on the engineering and science of dealing with regolith—or space dirt. The superfine substance has a habit of getting into places it shouldn't. Sneaking into space suits, jamming mechanical gears, and sticking to everything with strong electrostatic charge, regolith is a known nuisance. But mined effectively, it could be a valuable resource for future long-duration missions beyond low-Earth orbit.

RASSOR is a robot designed to excavate regolith on an extraterrestrial surface with very low gravity, like the moon or an asteroid. The teams are currently working on the third generation of the robot, having learned a lot from their first two efforts.

One generation ended up being too heavy. That isn't a big concern for a prototype, but weight matters to a flight-ready robot. The heavier the robot is, the larger the rocket needed to launch it, and the more expensive it becomes. A key contributor to the robot's weight was its metal tracks. In the initial planning, the team debated using tracks versus wheels for RASSOR.

"The treads you use for a track give you more traction, letting you operate in more extreme environments, on steeper hills, and very dusty soil that is fluidized," explained Mueller. "But wheels are much simpler and lighter. We did end up using tracks, but they caused a lot of problems, so now we're looking at going back to wheels. Tracks versus wheels is one good example of a problem that was designed to be addressed by rapid prototyping."

The first RASSOR used rubber-belt tracks because they're cheap, easy to obtain, and don't have to be heavily modified. But those tracks didn't hold up well during testing. The team

With a pair of drums positioned on arms, RASSOR can take on a number of different shapes to accomplish its work.

then moved on to using metal tracks. Cox, a recent mechanical engineering graduate, has been working on improving the tracks for the third-generation robot, a process she says has increased her knowledge exponentially.

"I just graduated from college, so I thought I was pretty smart and could come up with new ideas," Cox said, "but I don't have the knowledge to back it up." For a few weeks she struggled with the metal tracks, coming up with new designs that kept running into problems. "I'd fix one, and it would create

Photo Credit: NASA/Jim Grossmann

NASA Chief Knowledge Officer Ed Hoffman (left), Jack Fox (center), and Rob Mueller discuss KSC Swamp Works and techniques to enable innovation during a weeklong series called "Masters with Masters" at Kennedy Space Center.

another," she said. Then she went to one of the lead engineers for advice. He pointed out that tank tracks had been designed and created for years, and there was no need to reinvent the technology. "He said, 'Why don't you understand what's been done first before you start trying to create new ways to do it?'"

Cox found a large military textbook about tank tracks and spent a couple of weeks reading it and figuring out what applied to RASSOR. "It set me straight," she said. "I had a baseline to go off. Instead of trying to pull things out of my head, I had real-world examples and could see that this might not scale, but this is probably doable.

"So going to that engineer and asking for help, it's been really helpful. I wish I had done that sooner."

Everyone involved on RASSOR has gained invaluable knowledge by building the robot, seeing how it operates, and improving on the design. The process has allowed the team to learn not only what doesn't work, but also what might work much better than they had originally thought—or in unexpected, but advantageous, ways.

For example, after building the first generation of the robot, they learned through testing that it was capable of doing acrobatics. "We designed it so it could flip itself over again to avoid getting stuck," Mueller explained, "but then we learned just by experimenting that there were several different ways of driving it. You could drive it on its bucket drums, which it wasn't designed to do. We could also stand it up and dump regolith into a bin. So we discovered many different modes of operation just by experimenting with it. You can't get that from just white-boarding it. You need a physical prototype to try new things with."

Currently, the team foresees building RASSOR through a fourth and possibly fifth generation, each time using what they've learned from the previous build to improve the design. KSC Swamp Works aims to have each new project go through this process, benefiting NASA as well as the scientists and engineers with new knowledge and innovations.

Future Plans and Collaborations

The knowledge gained doesn't stay inside KSC Swamp Works. The labs collaborate with several NASA centers and projects, as well as commercial partners. They have worked with Project Morpheus, building the hazard field at the landing facility and building launch and landing pads for the vehicle. And they have been interacting with the Multi-Mission Space Exploration Vehicle team at Johnson Space Center and working with Desert Rats, as well as collaborating with Kennedy's Spaceport Innovators. The labs hope to do much more in the future.

"We're reinventing Kennedy to be a place where we do the high-risk, high-payoff work needed for future space exploration," said Mueller. "It's different from what we've done in the past, so there's a big culture change. KSC Swamp Works is a pile of projects designed to show how Kennedy could be a different place in the future—still very successful, but probably a different way of doing business."

SWAMP WORKS
NASA KENNEDY SPACE CENTER

KSC Swamp Works logo.

Image Credit: NASA

"Our mission is to provide government and commercial space ventures with technologies they need for working and living on the surfaces of the moon, planets, and other bodies in our solar system," added Fox. "We're the provider of technologies. We're laying the groundwork for future NASA programs and commercial ventures. We feel that's the role of a government lab." ●