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NASA Case Study

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ST5: Miniaturized Space Technology

Doug McLennan, the Space Technology 5 (ST5) Project Manager, looked up from his desk to see Ed Rogers, the Goddard Space Flight Center's Chief Knowledge Officer (CKO), standing in his doorway. Doug had postponed several meetings with Ed already--he was up to his eyeballs trying to keep his ST5 team on track. Without waiting for an invitation, Ed took a chair. He explained a new Center process called Pause and Learn (PaL) that his office had developed:

> *The PaL process is designed to simply give people a time to reflect on what they've experienced [in their work projects], and to really learn from it both individually and as a team. It was designed to be a simple yet compelling 1-2 hour discussion about what happened and what was learned. Furthermore, a PaL should be a "safe spot" with no attribution, no action items required, and is informal in nature. It is a facilitated learning discussion for the team. However, holding a PaL is not currently a project requirement, so getting it on the schedule can be a challenge.*

Doug listened, but didn't really see how this PaL process would help his team, especially right now in the midst of all the challenges they were facing. Being as straight-forward as he could, he responded to Ed's offer to hold a PaL with the ST5 team:

> *I hear what you are saying about learning and developing people—I agree those are good things—but tell me how taking my whole team off-line for two hours to hold a PaL is going to help me deliver on performance, schedule, or cost? It seems like you want me to invest my limited project dollars in these people for the benefit of their next project.*

The ST5 mission was initiated in the summer of 1999 and baselined for launch in 2003. Soon after starting up, however, it was clear that the schedule would be stretched regardless of the technology

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development of the project. This was because the mission lacked a launch vehicle (LV). By 2004, ST5 was still waiting for a ride into space.

For years, project managers had faced the daily challenge of keeping the team focused on a mission whose fate was uncertain. It was well known that cancellation was a constant threat for a mission without a LV. The doubts could easily ripple through a team, threatening incentive and morale—a problem that had plagued other missions. On a project populated with high-performers eager to get things done, there was the ever-present danger of people thinking, "I'm going to find something else to work on if the mission is going to be canceled."

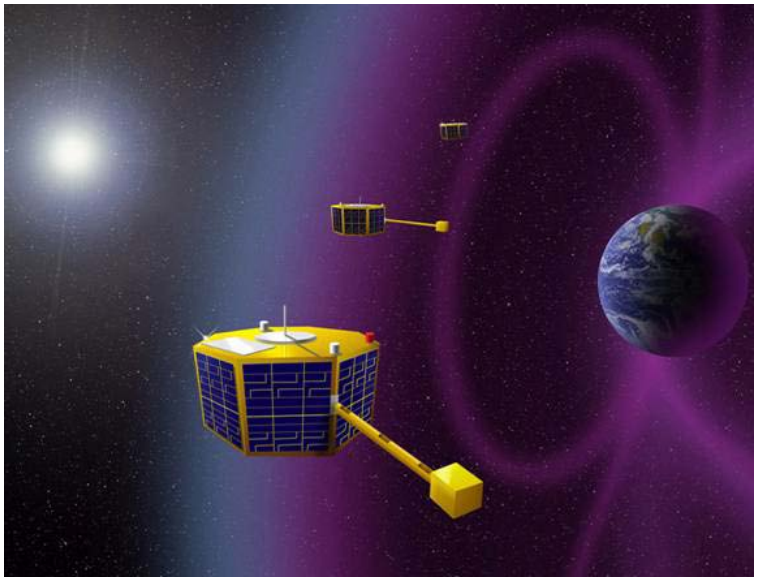

Figure 1 - The Space Technology 5 (ST5) mission consists of three birthday cake-sized micro-satellites exploring the Earth's magnetic fields. Credit: NASA.

Now, months after the original launch date had passed, the project manager (PM) reflected on the status of ST5—and his team. Even without the LV concerns, ST5 had some challenges as a technology development project. The focus of ST-5 was on making everything smaller, so the team had had to work within the boundaries of low power, low volume, and low weight.

The ST5 team had responded to the challenge. It was breaking new development ground with every major subsystem. Technology development was largely on track, even with the uncertainty over LV interfaces. Now, it was a matter of keeping all eyes on the finish line while waiting for a LV.

ST5: Pathfinder for Micro-Sats

ST5 was conceived as part of NASA's New Millennium Program (NMP). NMP was set up to develop and test high-payoff technologies for science missions at reduced cost albeit with higher risk. ST5 was a pathfinder mission: it aimed to show that its miniature technologies could not only function in the harsh conditions of the magnetosphere, but conduct research-quality scientific measurements. A successful flight and ST5 mission would pave the way for future micro-sat missions. ST5 was led by Goddard Space Flight Center, partnered with the University of California-Los Angeles, the Kennedy Space Center, the University of New Mexico, and several commercial technology providers.

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Big Technology in a Small Package

ST5 consisted of three micro-sats. Each micro-sats would weigh about 25 kilograms (55 pounds) when fully fueled. Each would measure 53 centimeters (20.7 inches) across and 48 centimeters (18.7 inches) high—about the size of a 13-inch TV set. The micro-sats would perform many of the same functions as larger satellites: guidance, navigation and control, attitude control, propulsion, and high-bandwidth communication. They were being designed to function and record measurements in the magnetosphere--that particle-charged region of the upper atmosphere responsible for the "space weather" that disrupts communication and navigation systems and causes power blackouts on Earth.

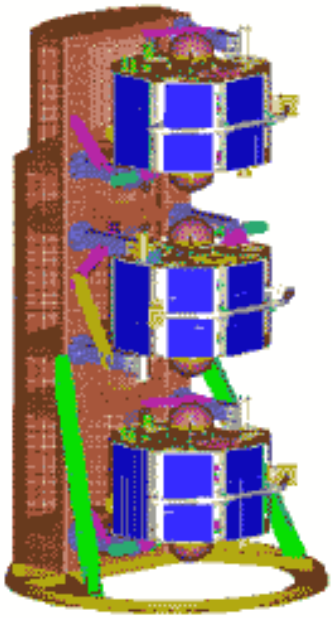

Figure 2 - Space Technology 5 satellites stacked for launch. Credit: NASA

ST5's goal was to demonstrate "nanosat technology": for communications (using tiny transponders for space-to-ground communications and tracking), power (with lithium ion batteries), and other systems. Specifically, the mission's goal was to validate a range of NMP technologies, including the cold gas micro-thruster, X-band transponder communication system, and CMOS ultra-low power radiation tolerant (CULPRiT) logic.

The miniaturized size and low weight of the micro-sats made it possible to launch them from a single rocket. In addition to designing and building the spacecraft bus, the ST5 team fabricated and tested an innovative launch rack that supported the satellites in a stacked configuration. The multi-rack design allowed each micro-sat to be spun like discs into a near-Earth polar orbit of approximately 2,796 miles altitude. Such motion was necessary to stabilize the satellites and to optimize the use of sunlight by the solar array panels that lined their sides.

Managing Uncertainty: Staying Focused

Exacerbating the developmental challenges was the ongoing uncertainty over what type of vehicle would carry the micro-sats into space. The approach at the beginning of the project was that ST5 was destined as a secondary payload. In other words, it would "hitchhike" a ride on a launch vehicle along with another satellite thereby reducing launch costs. The challenge was to find a launch vehicle that had sufficient mass and volume to accommodate the three ST5 satellites. It soon became clear that hitchhiking with another mission would be less than ideal—in fact, the management of most space missions did not welcome another project along for the ride.

There were organizational challenges as well. ST5 was a highly distributed project, consisting of focused development teams spread across Goddard. This "isolation" among the teams threatened to hinder communication and, if not managed properly, foster an "us versus them" mentality. These distributed teams might easily lose sight of their relationships to each other and to the project at large.

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In addition, there were many new people on the project, and so considerable on-the-job training would be required. Without a clear focus on project goals in the face of uncertainty, interest might wane quickly.

A Puff in the Thermal-Vac Chamber

A few weeks after the visit to PM Doug McLennan by Ed Rogers, the CKO, the ST5 team had an incident during integration and test. One of the microsats was in the thermal vacuum (T-V) test chamber. During a test, a thruster was actually fired—and it puffed some inert gas into the T-V chamber. The test procedure had been red-lined [changed by hand] yet somehow it was not caught that the thruster was to be signaled for firing but should not have been live inside the chamber. Fortunately, there was no damage done. However, given the potential seriousness of a T-V chamber accident, the team was asked for safety reasons to stand down for a day. During the test, the Integration and Testing (I&T) team had been at a table within earshot of the project team. Somehow this procedure had not been noticed by those running the test. The project was directed to hold a safety stand-down day.

Doug pondered his next move:

> *What other risks were there lurking in the fast pace, distributed locations, and strained communication channels? How should the ST5 team conduct a stand-down day to reflect on what was clearly a near-miss accident?*

Doug decided to call Ed back and see if this PaL process would be of use.

Together Doug and Ed put together a plan that would include a discussion of the case study on GENESIS, the mission to study the solar wind, led by Mike Ryschkewitsch, then Goddard's Director of Engineering. Mike had headed up the Mishap Board for GENESIS, and was intimately familiar with how problems with communications and test validation had crept into GENESIS mission and doomed its return entry to earth.

On the day of the team stand-down, the I&T team came in and sat down in one area. The ST5 project personnel sat in a different area. It was rather symptomatic of why both groups were sitting in that room in the first place. One participant volunteered:

> *I don't see why we're here. No harm, no foul. We don't have any technical problems. This is all just programmatic stuff.*

As Ed got up to introduce the agenda, a technician pulled out a newspaper and opened it up to read. Others crossed their arms in defiant body language. It looked like a tough crowd.

1. How would Doug keep his team focused on the goal of mission success?

2. How do you get a team to practice reflective learning short of an incident or accident?

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