Trimming the FAT for Seafloor Research in China

Constructing a Tripod to Monitor Deep-Sea Sediment Movement

By Amy West

After a piece of U.S. government equipment sat for five months far away on the seafloor of the South China Sea in roughly 1,900 meters of water, U.S Geological Survey (USGS) instrument specialist George Tate wasn't too worried whether it would return to the surface.

"The period of angst was actually the first week," Tate said.

He feared receiving an email from the new instrument, because that would signal it had risen to the surface prematurely.

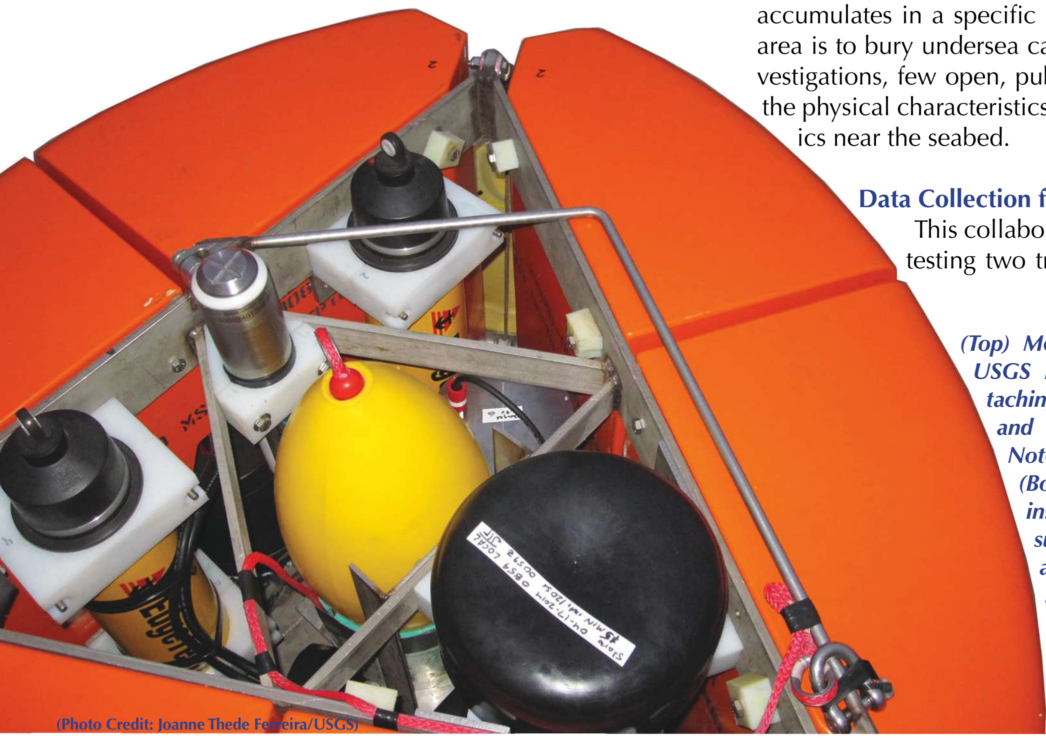
Marine technology with an acronym like FAT likely conjures images of a boxy and heavy piece of gear. But Tate's FAT (free ascending tripod) design is much more streamlined. It has to be, because its sole purpose is to sit without disturbing the very section of seafloor it was designed to monitor. Three, 13-foot stainless steel legs ensure that the water just above the seafloor—the bottom boundary layer—flows freely past it.

(Photo Credit: Joanne Thede Ferreira/USGS)

This monitored section of seafloor lies in the northeastern part of the South China Sea. This international effort started with USGS oceanographer Jingping Xu (now a USGS emeritus scientist), who collaborated with Tongji University in Shanghai, China. Xu tapped into expertise in sediment fieldwork found at the USGS Pacific Coastal and Marine Science Center to investigate what has been described as a possible "contourite," or mound of sediment deposited by bottom currents. It's not clear why mounds form in this particular spot or how circulation works in this area. Understanding how deep-sea sediment moves can help forecast how potential pollution accumulates in a specific region or where the most stable area is to bury undersea cables. Other than oil industry investigations, few open, publically available studies exist of the physical characteristics of deep-water sediment dynamics near the seabed.

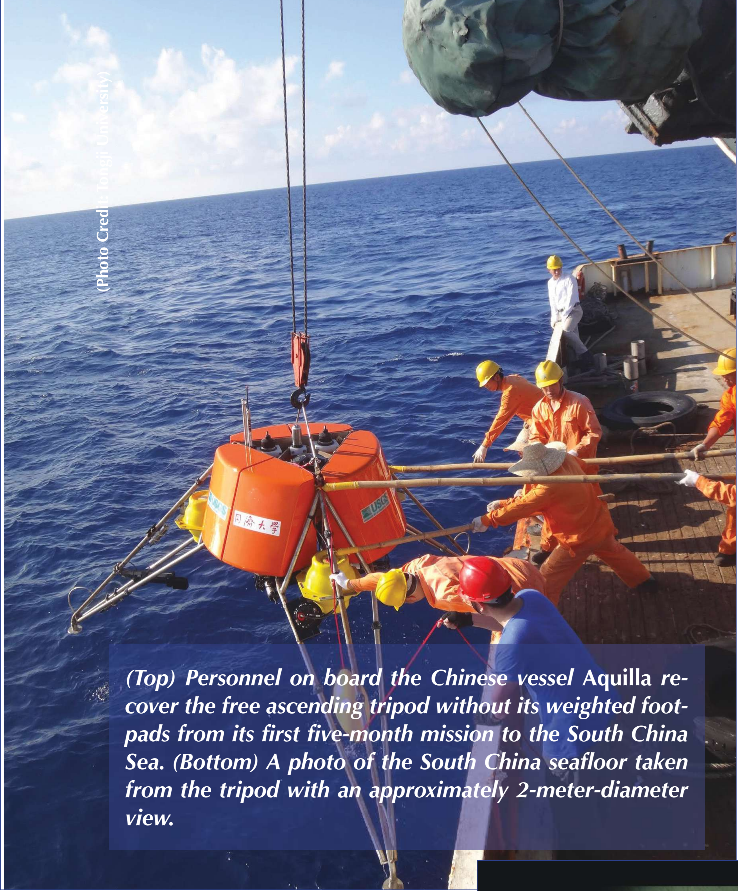
Data Collection from FAT

This collaboration consisted of designing and testing two tripods that would be jointly de-

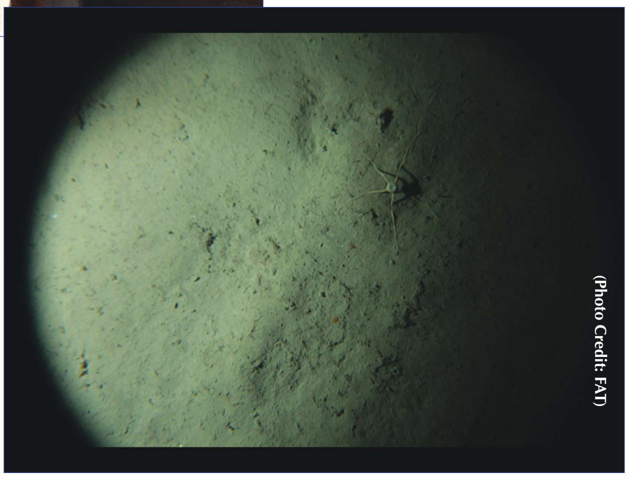


(Photo Credit: Joanne Thede Ferreira/USGS)

(Top) Members of Tongji University and USGS reassembling the tripod and attaching the oceanographic equipment and syntactic foam (orange blocks). Note the square, weighted footpads. (Botom) A bird's eye view of FAT's instrumentation showing the yellow surface recovery float in the middle and two EdgeTech (West Wareham, Massachusetts) acoustic transponding releases on the left, with a XEOS (Dartmouth, Canada) Sable satellite Iridium beacon mounted between them.



(Top) Personnel on board the Chinese vessel Aquilla *recover the free ascending tripod without its weighted footpads from its first five-month mission to the South China Sea. (Bottom) A photo of the South China seafloor taken from the tripod with an approximately 2-meter-diameter view.*



(Photo Credit: FAT)

veloped by the USGS and Tongji University, and deploying them throughout the course of three years. During previous work for the Office of Naval Research, Tate designed a similar tripod for use in deepwater (1,000 meters). Using his 40-plus years of design experience, Tate modified that design to meet Xu's requirements. Initially Xu asked if it was possible to collect bottom boundary layer data in 2,000 meters of water and take measurements of a focused point on the seabed, without obstructing current and sediment flow. Then, he considered attaching a camera. From there, the list grew to include every piece of oceanographic equipment one could want, says Tate, which posed a challenge as weight and volume increased.

The three legs are each composed of a truss of three long, stainless-steel tubes. The entire tripod must sit without twisting or vibrating, withstand the load of gear attached to it and also tolerate a reverse load when being picked up. Keeping those factors in mind, Tate designed the tripod around how the instrumentation needed to be arranged to ensure high-quality measurements. In addition, he needed to devise a simple, but fail-safe, method to release the footpads. He developed two ideas, which were then brought to life through miniature replicas created by a 3D printer. Once they experimented with the models, he and USGS engineering technician Peter Harkins finalized the design and built two identical full-scale tripods.

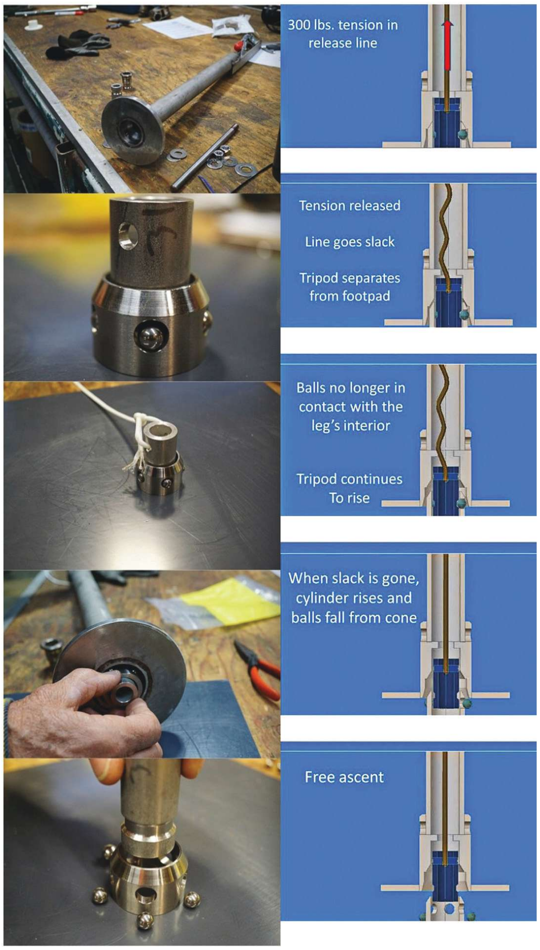
Instruments affixed to the steel triangle needed to obtain multiple and simultaneous measurements of how bottom currents affect the seafloor in the South China Sea study area. Capturing interactions at this boundary can show how particles are suspended or accumulated here and in other areas. The measurements include: a LISST-Deep laser particle sizer (laser in-situ scattering transmissometer) that calculates the size distribution of suspended particles; acoustic altimeter, which measures fine-scale changes in seafloor elevation; and a Teledyne RD Instruments (Poway, California) 300-kilohertz ADCP. This upward-looking current sensor measures current velocities over a range of depth, and in this case, from its position to 100 meters above the tripod. In conjunction with the altimeter, it helps determine the shape of the bottom boundary layer.

Also attached were a Nortek (Rud, Norway) Aquadopp current profiler, which faces downward to measure current velocities between the gear and the bottom, and a Nortek Vector velocimeter (single-point current meter) that makes very precise measurements at one point to give a 3D view of flow direction and velocity. In addition to these instruments were several RBR (Kanata, Canada) data loggers: pressure and temperature sensors and a transmissometer to measure light attenuation of a 25-centimeter-long, 650-nanometer LED light beam as it passes through a defined volume of water to determine suspended-sediment concentration, as well as an optical backscatter sensor to measure turbidity by calculating how much light bounces back as a result of turbulence and particles suspended in the water. Finally for imaging purposes, a digital Canon EOS 7D camera was mounted to take 10 still images with an approximate 3-square-meter field of view every six hours with 10 seconds between each frame, controlled by a customized intervalometer (remote interval timer), which combined an off-the-shelf Canon TC-80N3 timer and custom micro-controller.

Retrieval Without Line

The most distinctive feature is the release technique for retrieving the tripod, which is vital in sites too deep for hauling it to the surface with a long line. The technique did not require a heavy anchor, which normally hangs below the tripod and disturbs the flow of bottom currents. Instead, lead and steel footpads serve as weights to hold the tripod in place so as not to disturb the monitored area. Footpads are then released simultaneously from a single release mechanism. When the FAT's bottom time is up, an acoustic pulse sent from a boat signals the release of tension from a high-strength fiber line that helps lock the footpads to the legs.

To better understand the novel approach to anchoring the FAT, here is a description of the weighting system: Initially when the footpad is locked onto the legs, five 3/8-inch stainless steel balls sit inside small holes in a blunt-nosed cone welded to the footpad. Inside this cone fits a short cylinder with a horizontal groove around its base into which the inner sides of the five balls also fit. A high-strength fiber line runs through each leg to this cylinder, keeping it under tension by connecting it to the acoustic release at the top



(Photo Credit: Amy West/USGS. Drawings courtesy of George Tate/USGS)

An image sequence illustrates the release mechanism of a tripod foot. Photos from top to bottom: a) a view of the tripod leg from the bottom shows the opening where the release mechanism fits; b) the release mechanism consists of a blunt-nosed cone with holes that hold five balls in place, which is welded to the footpad (grey square), and a short cylinder that sits inside the cone; c) a long fiber line links the acoustic release at the top of the tripod to the cylinder to keep the cylinder from moving; d) looking inside the recreated tripod leg shows the release mechanism (cone and cylinder) seated inside the leg, wedging the balls firmly between the leg's interior and cylinder; e) when the cylinder sinks after the acoustic release is triggered, the balls are no longer jammed between the tripod leg and the groove of the cylinder, so they fall out of the cone. The cylinder freely slides up past the cone once the slack in the line disappears, and the legs are free of the footpads.

of the tripod. Each tripod leg fits over the entire cone, ball and cylinder assembly to sit flush against the footpad. The interior of each leg does not have a constant diameter and is wider at the base. The line's tension keeps the cylinder wedged against the narrower part of the tripod leg, trapping the balls against the tripod leg, cone and cylinder. The balls are the critical elements, keeping the tripod attached to the footpads. Until the tension is released, this locking ball mechanism essentially keeps the 200-pound footpads, which want to sink, from separating from the legs, which naturally want to rise because of the buoyant syntactic foam encasing the tripod head. It's similar to the coupling that keeps a hydraulic air hose attached to its high-pressure nozzle fitting. Once an acoustic signal triggers the release of tension on the rope, the slack allows the small cylinder to stay on the footpad, while the buoyant tripod leg rises a very short distance above the footpad. With the balls no longer jammed against the slanted leg wall, they fall out when the leg has risen above the cone. Once the leg is high enough, the line is no longer slack and pulls the cylinder up from the footpad cone as the entire structure floats to the surface. Moreover, the tripod will still rise even if only one footpad releases, albeit more slowly.

Seafloor Research

This regional study is the largest one on deep-sea sediment in the South China Sea. Aside from understanding how these mini-seamounts, or contourites, form, the objective is to characterize how bottom currents circulate over space and time. The data can also be used to describe the nepheloid layer, or sediment-laden bottom layer of water, and how sediment stays suspended in this layer or returns to the seafloor. The data can also depict turbidity currents and what releases them, as well as reveal the source(s) of sediment accumulation.

To gather more data, four other sites at the bottom along the 1,900-meter contour host arrays of equipment, such as sediment traps, current meters, transmissometers and temperature/salinity/dissolved oxygen sensors.

But the data are only valuable to the scientists if the FAT, which essentially relies on five tiny metal balls and a little more than half an inch of movement, arrives at the retrieval boat. Though the team had conducted trials of the footpad release off the coast in Santa Cruz, California, they had not conducted test deployments in very deep water, over a long period of time, or with the actual footpads. Safe to say, not everyone was sure the design would work. Yet, the 2,000-pound tripod rose to the surface on September 26, 2014, Beijing time.

"When we got confirmation, it was like, okay, I can retire now," said Tate.

When discussing the next study site for the second tripod, the thought was that this innovative technology may be valuable for deep-sea coral restoration in the Gulf of Mexico in the aftermath of the *Deepwater Horizon* oil spill. USGS's Nancy Prouty already conducts studies in the region, and in-situ sediment measurements along with imaging capabilities could be a real benefit to assessing the coral's recovery.

The tripod in the South China Sea was immediately serviced and redeployed again for another six months. Future plans may include deploying it at the head of a nearby submarine canyon. More time on the bottom will help resolve sedimentary movement over a longer period, since an initial assessment of the data seemed to show that the bottom water below the FAT was pretty "clean" and didn't reveal much sediment movement. Xu presented preliminary results at the December 2014 American Geophysical Union conference in San Francisco.

While it's not certain why this particular spot accumulates sediment, it is most certain that the relationships forged from this international collaboration will grow, much like the mounds at the bottom of the South China Sea. **ST**

Amy West is a science outreach consultant for the USGS Pacific Coastal and Marine Science Center in Santa Cruz, California. Her many years as a marine scientist lend a hand in her current freelance science-writing career that takes her throughout the world and to great ocean depths.