TECHNICAL NOTE

Revisiting the Challenger Deep using the ROV *Kaiko*

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After the remotely operated vehicle *Kaiko* (Figure 1) was launched from the deck of its support ship, the research vessel *Kairei*, it descended for more than 3 h through nearly 11 km from the surface of the calm seas ~320 km SW of Guam to the seabed at the bottom of the Challenger Deep in the Marianas Trench. Even watching the *Kaiko* system in operation, it is difficult to imagine just how deep 11 km is until you put it in the context of normal human experience—it is the same distance as the altitude of a commercial transcontinental or transoceanic flight. Although sitting in the ROV control room (Figure 2) aboard the *Kairei* in 1998 could not have equaled the intensity of a descent inside the cramped sphere of the *Trieste* 38 years earlier, watching as the display of *Kaiko*'s depth sensor in the ROV control room counted past 5,000, 7,000, and 10,000 m was captivating, to say the least. When the seabed finally appeared through the darkness as the ROV reached 10,924 m, we knew we had witnessed something very special.

FIGURE 1

ROV *Kaiko* during recovery from the Challenger Deep. The launcher (top half) and vehicle (lower half) are both visible.

FIGURE 2

ROV control room on the R/V *Kairei* during descent of the *Kaiko* in the Challenger Deep. Two primary pilots operate the *Kaiko* thrusters and manipulators while other support personnel and researchers watch.

JAMSTEC, the Japan Agency for Marine-Earth Science and Technology, developed the ROV *Kaiko* in 1995 to enable scientific research in the deepest trenches of the oceans. The *Kaiko* is a two-body system with a smaller mobile *vehicle* latched to the *launcher* during descent. The *launcher*, about 5.2 m in length, 2.6 m wide, and 3.2 m high, acts as a heavy weight (5.8 tons in air) to help the *Kaiko* system to sink rapidly to depth. It has limited capabilities for operation near the seabed, but can be used without the *vehicle* as a towed system equipped with side-scan sonar, a sub-bottom profiling system, and a sensor package (CTD). For use with the *Kaiko vehicle*, the two are mated through a 250 m long tether that unreels from a spool mounted in the *launcher*, allowing the *vehicle* a relatively short but unconstrained ambit. The *vehicle* is the heart of the *Kaiko* system, and once released from the *launcher*, it can use its four horizontal and three vertical thrusters (~5 kW each) to maneuver freely near the *launcher*, exploring and sampling the seabed. It is smaller (3.0 m long × 2.0 m wide, and 2.1 m long) and lighter (3.9 tons in air) than the *launcher* and is equipped with several CCD and wide angle color video cameras, a digital still camera, several high-intensity lights, and several sensors (forward looking sonar, altimeter, depth, compass, GPS). Two highly dexterous manipulator arms (six axes and seven axes of motion) enable operators to deploy and recover samples or gear from the front-mounted sample basket.

Deployment, positioning, and recovery of a massive system like the *Kaiko* are complicated operations. At 106 m length and 4500 tons displacement, the R/V *Kairei* is a very capable support ship, with berthing for 22 researchers, and is outfitted with a large multipurpose A-frame and winch system. The *Kaiko* is protected in a hanger when aboard the *Kairei* (Figure 3). Before each dive, it is rolled to the aft deck deployment station on rails. Upon deployment, the A-frame lifts the nearly 10-ton mated *Kaiko* system over the stern. The primary tether, ~4.5 cm diameter with optical and copper conductors, is then paid out at ~1 m/s from a single massive (>7 m in diameter) steel spool (Figure 4) holding 12,000 m of cable, through a cable-tensioning system, across the aft deck to the A-frame pulley, and over the side. Very accurate navigation of the *Kaiko* is accomplished using a set of three acoustic transponders arranged as a long-baseline system that can be pinged from the *launcher* and *vehicle*. Once the *Kaiko* system is within 100 m of the seabed, the *vehicle* is unlatched from the *launcher* and the secondary cable (~3 cm diameter) is paid out to allow the *vehicle* to wander the nearby seabed. Transiting long distances (several hundred m or more) while the *Kaiko* is deployed is difficult but possible by towing the *launcher* using the *Kairei*. Recovery of the *Kaiko* first requires re-reeling the primary cable on the *launcher* and re-mating the *vehicle*, then rewinding the primary cable until the *Kaiko* can be reattached to the A-frame and lifted aboard the *Kairei*. The *Kaiko* made numerous dives in various trench systems until 2003, when the *vehicle* was lost near the surface when the secondary tether was severed during a storm. Unfortunately, a power failure on the *vehicle* had prevented re-mating it with the *launcher* prior to ascent. The *Kaiko* was returned to service in 2004 as the *Kaiko 7000 II* (rated to 7,000 m) after adapting a 7,000 m rated ROV as a *vehicle* compatible with the original *launcher*.

FIGURE 3

Aft hanger for ROV *Kaiko* maintenance, looking toward the stern A-frame. The primary tether is visible above the coarse net.

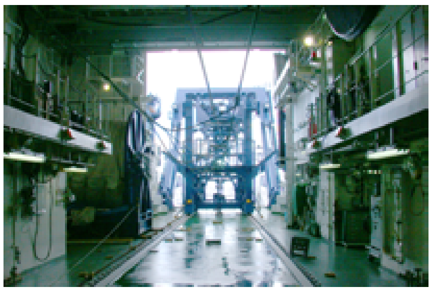
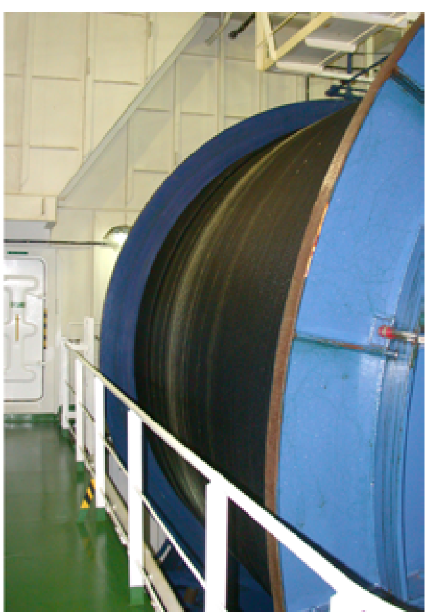


FIGURE 4

Primary tether spool for ROV *Kaiko*.



The ROV *Kaiko* completed a series of dives at the Challenger Deep in 1998 and succeeding years during which researchers saw very sparse life on the seabed (Figure 5). Two major factors—great ocean pressure and potentially severe food limitation—make the Challenger Deep one of the most extreme environments on Earth. The weight of seawater reaching nearly 1,100 atmospheres affects protein stability and membrane permeability in all organisms, such that any capable of inhabiting hadal depths must have proteins, enzymes, and membranes tuned to extreme pressures. Food is another problem. Deep-sea ecosystems depend on the rain of organic debris derived from surface production, which in the oligotrophic waters over the Challenger Deep is typically quite low. In addition, consumption and recycling of organic material as it sinks toward hadal depths burn much of its nutritional value through each kilometer of depth, resulting in well less than 1% of surface levels expected to reach ~11 km. Consequently, little food is available for any life tolerant of the high pressures in the Challenger Deep. Future visits to the Challenger Deep using new deep-diving vehicles will allow researchers to test hypotheses related to the role of extreme pressure, food limitation, or perhaps other factors in defining the boundaries of life in this extreme environment.

FIGURE 5

Collection of sediment core samples at 10,924 m in the Challenger Deep.