RELICS OF APOLLO

high-tech recovery on the high seas

by DAVID G. CONCANNON

THE FIRST STAGE OF THE SATURN V SEPARATES FROM *APOLLO 11* TWO MINUTES FORTY TWO SECONDS AFTER LIFTOFF ON JULY 16, 1969. IMAGE COURTESY NASA.

A fellow of The Explorers Club since 1996, David G. Concannon is a veteran of several deepwater search and recovery expeditions, including three expeditions to the R.M.S. *Titanic*. He has deep roots in space exploration, having served as general counsel to the X-Prize Foundation. He organizes major expeditions and advises clients on exploration-related issues through his company, Explorer Consulting, LLC.

At 9:31:51.1 A.M. EDT on July 16, 1969, as *Apollo 11* sat poised atop the mighty Saturn V on launch pad 39A at the Kennedy Space Center, the ignition sequence began for what would become a defining moment in the history of exploration. At exactly 8.9 seconds later, the multi-stage rocket lifted off, propelled toward the heavens by five F-1 engines, each generating more than 1.5 million pounds of thrust and burning 6,000 pounds of rocket-grade kerosene and liquid oxygen per second. In the words of *Apollo 11* astronaut Buzz Aldrin, "the Saturn V rose with the power of 100,000 locomotives, burning 5,000,000 pounds of fuel in 150 seconds, getting a full 5 inches to the gallon."

Two minutes and forty-two seconds later, having lifted *Apollo 11* to an altitude of 67 kilometers (42 mi.), at a speed of more than 2,773 meters per second (9,100 ft/s), the quincunx of engines known as the S-IC–the first of the Saturn V's three stages–separated from the rocket and continued to climb to an altitude of more than 115 kilometers (71.5 miles) before plummeting into the waters of the Atlantic Ocean some 350 nautical miles east of Florida.

Like so many children of the Apollo age, I was mesmerized by the events that unfolded over the ensuing days: our technological ability to build a craft that could reach the 40,320 km/h (25,000 mph) escape velocity necessary to get to the Moon, 384,400 km (238,900 mi.) away; the astronauts' heroic landing on the lunar surface on July 20; and their triumphant return to Earth on July 24. *Apollo 11* was to have a profound impact on my life, fostering in me a passion for science and exploration. And, I am not alone.

Amazon.com founder Jeff Bezos credits the Moon landings with inspiring his endeavors in the realm of technological innovation and wondered if it just might be possible to find and recover the F-1 engines that propelled *Apollo 11* to the Moon. If successful, he reasoned, the endeavor had the potential to inspire a new generation of young people to invent and explore.

In August 2010, I was contacted by a member of his team to see if such an objective could be achieved. My answer was yes, but I cautioned that the project would be difficult and nearly unprecedented in the field of deep-ocean exploration. At that time, the only expeditions that had successfully searched for and recovered historic objects from such great depth were those to the R.M.S. *Titanic,* which sank off the coast of Newfoundland during her maiden voyage in April 1912, a project with which I had been deeply involved.

Compared to *Titanic*, which was 269 meters (883 ft.) long and weighed 52,310 tons, the F-1 engines were seemingly minute, being a mere 6 meters (19 ft.) tall and weighing 10 tons. Moreover, the *Titanic*'s location on the surface prior to her sinking was reported with some precision. Its drift after the collision was uncertain, as was the location of the wreck site 3,800 meters (14,500 ft.) down, but at least the joint American-French expedition that discovered the *Titanic* knew approximately where to look. They also had the benefit of being the fifth expedition to search for the *Titanic*; four previous expeditions had spent more than 100 days searching 1,600 square kilometers (995 sq. mi.) of seafloor in the vicinity of the sinking by the time Robert D. Ballard led his successful expedition in late summer 1985.

Conversely, little was known about the actual location of the F-1 engines. NASA did not track the S-IC's trajectory on radar after it separated from the body of the Saturn V. Instead, NASA predicted where each S-IC would "splash down" in the Atlantic based on a handful of data points, including the Saturn V's flight path; the time the first stage separated from the Saturn V; the S-IC's location at the time of separation; the rocket's speed at separation; and whether the S-IC may have fallen horizontally, vertically, or it tumbled. NASA made no effort to actually track the S-IC's apogee on radar, determine whether the S-IC came apart as it fell to Earth, measure winds aloft, calculate a precise point of impact, or even issue a Notice to Mariners passing through the impact zone (which lies in a major shipping lane) that rocket debris could be falling from the sky. After their job was done, *Apollo 11*'s F-1 engines simply fell from the sky, slammed into the ocean's surface at great speed, and sank to the ocean bottom.

Finally, eight S-ICs from various Apollo missions had landed in the same general area. And it was anybody's guess if the individual F-1s had separated from their S-IC, or how far each of their 40 F-1 engines may have drifted as they sank some 4,300 meters down to the seafloor. To find any of the F-1 engines from *Apollo 11*, we would be looking for the proverbial needle in a haystack.

Never one to be dissuaded by long odds, Bezos was up for the challenge and so we began to work with him on a comprehensive plan to make it happen.

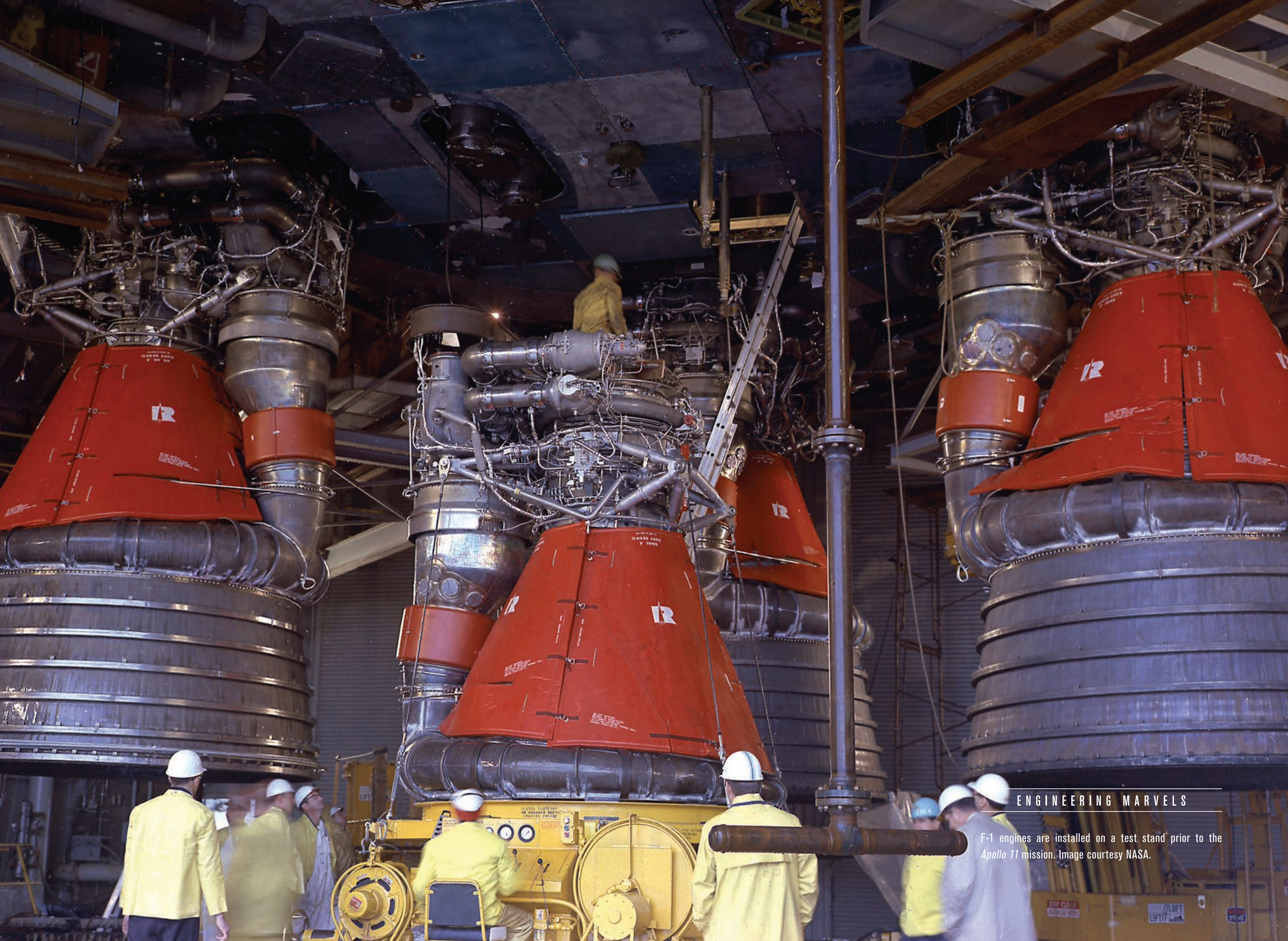
To carry out the project, we brought together a core team of undersea pros–mostly members of The Explorers Club–chosen for their vast experience and, more important, their discretion. In time, we would expand our team to include more than 100 people–experts in deep-sea search and recovery, marine archaeology, conservation, aviation, and space exploration, as well as retired astronauts and NASA and Rocketdyne engineers. In addition, we would need to identify and secure the necessary ships, remote sensing technologies, submersibles, and remotely operated vehicles.

Throughout the spring and summer of 2011, we overhauled the *Ocean Stalwart*, a former U.S. Navy spy ship that would serve as our base of operations, and finalized the development of a new high-resolution synthetic aperture sonar (SAS) system known as the SLH ProSAS-60, which could provide 10-square-centimeter resolution at ranges up to 1,500 meters per side. Our efforts were hampered by nine tropical storms and hurricanes that swept through the search area and mobilization site in Virginia between July and September.

On September 24, 2011, we set off from Newport News, Virginia, reaching our target area four days later. Over the course of two weeks, we surveyed some 300 square kilometers (180 sq. mi.) of ocean bottom, at depths ranging from 4,000 to 4,425 meters (13,123 to 14,517 ft.), discovering thousands of man-made targets and more than 300 "high value targets." The greatest concentrations of targets were clustered in 18 distinct target areas, none of which were located anywhere near where NASA had predicted the S-ICs had splashed down. Within these target areas, we were able to identify parts of at least 30 F-1 engines.

With the verification process complete, Bezos announced the discovery to the world on March 28, 2012, and his intention to recover the engines and turn them over to NASA. "We don't know yet what condition these engines might be in–they hit the ocean at high velocity and have been in salt water for more than 40 years. On the other hand, they're made of tough stuff, so we'll see."

With his pronouncement, preparations for the recovery phase began in earnest.



F-1 engines are installed on a test stand prior to the *Apollo 11* mission. Image courtesy NASA.

While finding the targets was difficult, safely recovering them in potentially stormy seas could be impossible. We initially explored the possibility of a short reconnaissance expedition in the summer of 2012 to assess the condition of the engines and determine lifting solutions. However, much to our chagrin, the 2012 Atlantic Hurricane Season began unusually early. Tropical storms Alberto and Beryl, and Hurricane Chris all swept over the search area in one four-week period from mid-May to mid-June. At the end of June, Tropical Storm Debby bore down on the Gulf of Mexico, wreaking havoc on ship schedules. A summer departure would be impossible. A decision was made to postpone a return to sea until the winter, when the seas should have been calmer.

The weather delay turned out to be a blessing in disguise. On July 18, news broke that 48 tons of silver had been recovered from the wreck of the SS *Gairsoppa*, a British merchant vessel resting in 4,700 meters (15,420 ft.) of water off the coast of Ireland, having been torpedoed by a German U-boat in February 1941. Although the silver recovery was impressive, the most interesting aspect of the *Gairsoppa* project from our standpoint was the asset used to perform the recovery: the Norwegian salvage vessel *Seabed Worker* outfitted with a Schilling HD 150hp Heavy Work Class ROV capable of operating at depths up to 5,000 meters (16,404 ft.) and a second 150hp ROV capable of working at depths up to 4,000 meters (13,123 ft.).

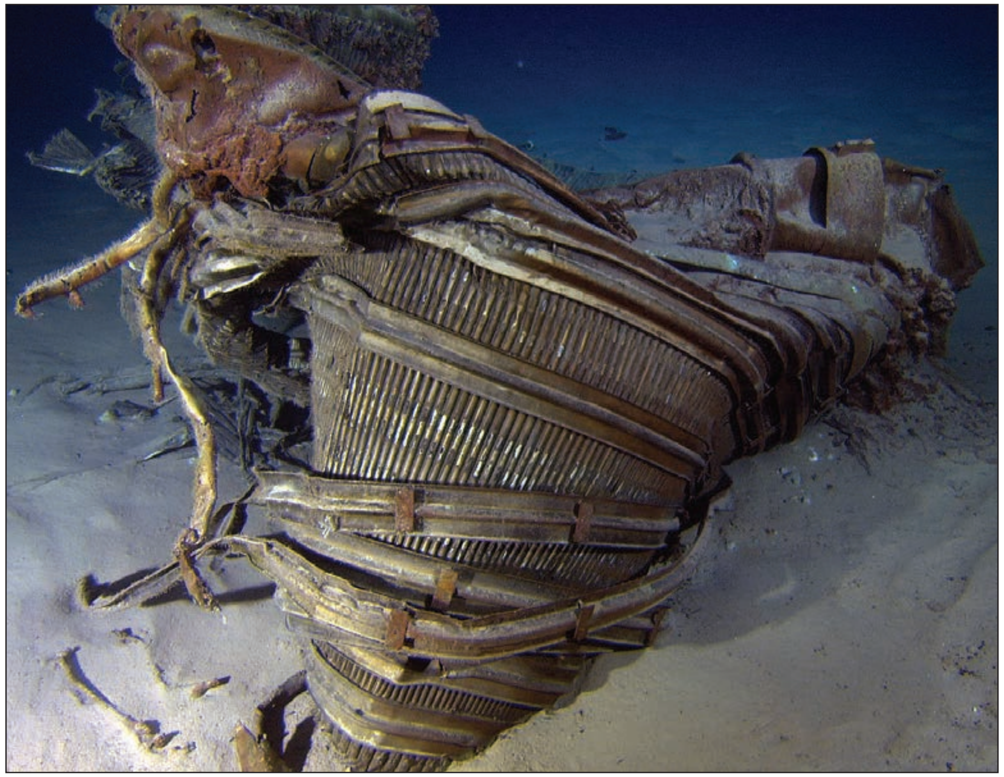
An inspection of the ship during an August port-of-call in Ireland confirmed that its capabilities were unmatched, and the ship was secured for an expedition to begin in February 2013. This would allow ample time for the ship's owner, Swire Seabed, to acquire a second 5,000-meter-capable Schilling ROV outfitted with a sophisticated high-definition underwater imaging and lighting system designed and built by Marine Imaging Technologies. Because the *Seabed Worker* was able to conduct a survey and recovery operation with two ROVs working in tandem, the team decided to consolidate the reconnaissance and recovery expeditions into one long but comprehensive mission.

Members of the team met in Bergen, Norway, in late January 2013 to install specially designed lifting cradles to bring the F-1 engines to the surface, plus install the underwater imaging system and mobilize for the recovery expedition. The *Seabed Worker* could accommodate 65 people, including the ship's crew, ROV crew, and the F-1 project team.

The ship set sail from Norway on February 9, 2013, and, after crossing the stormy Atlantic, was met by the full crew in Bermuda two weeks later. More rough weather accompanied the *Seabed Worker* as it made its way 500 nautical miles southwest to the Apollo site. However, the seas were calm on March 2, when the ship arrived on site and the first ROV was deployed.

The deep-sea robot sank to the ocean bottom, tasked with finding and exploring what was now called "Area 17," the furthest east of three small debris fields extending in a 1 nautical-mile line along the flight path of *Apollo 11*. At that point, we had narrowed our list of high-value targets to just 130 objects, which were now marked with red dots on a large map of the search area. Area 17, with Areas 16 and 15 to the west, held the most promise.

As the ROV reached the bottom, it began returning ghostly images of the seafloor. Within minutes, we found an F-1 engine part, confirming that an engine was close by and it had broken apart on impact. Within the first hour of the first day spent exploring the bottom, we found what was undeniably an F-1 engine. Although the engine was in pieces and debris was strewn about, its thrust chamber, turbo pump, heat exchanger, and fuel valves were all resting in close proximity to one another. As we continued to search to the west, we found significant parts of two more engines, before gathering seas forced us to retrieve the ROV.



We had planned to inspect small areas of the engines in fine detail, as well as surrounding debris from the S-IC, to search for serial numbers identifying the engines and rocket parts as coming from *Apollo 11*. Each F-1 engine was given a four-digit serial number beginning with the number "2" by Rocketdyne, the manufacturer, and NASA had renumbered each engine with a newer serial number beginning with the number "6" for missions that were intended to land on the Moon. Rocketdyne had assigned serial numbers 2043, 2044, 2046, 2051, and 2054 to the F-1 engines flown on *Apollo 11*; and NASA had renumbered them F-6043, F-6044, F-6046, F-6051, and F-6054. The serial number was placed on the engine in several locations, including on engine identification plates on the thrust chamber, gas generator, and nozzle extension; and on stencil markings painted on the thrust chamber.

All the team had to do to confirm that an engine was from *Apollo 11* was find a serial number and match it to the numbers assigned to a particular mission.

Unfortunately, this is where state-of the-art technology was nearly defeated by simple chemistry. In most cases, the identification plates had dissolved or they were inaccessible. The mud on the seafloor was caustic and ate away parts of the engines that it touched like acid. The most reliable way to identify an engine was to look for the Rocketdyne serial number that was sometimes painted on a particular area of the thrust chamber, if we could see it in situ. With the weather worsening, we were not able to conclusively identify which Apollo mission the engines had come from before leaving the bottom. To positively identify an engine, we would have to bring it up.

On March 5, we were able to put the

THE NOZZLE OF AN F-1 FROM *APOLLO 12* LIES 4,300 METERS DOWN ON THE SEAFLOOR. © BEZOS EXPEDITIONS.

VIOLENT AND FIERY END

ON DECK, THE TWISTED REMNANTS OF AN F-1 ENGINE ATTEST THE STRENGTH OF THE APOLLO PROGRAM. PHOTOGRAPH BY JOSH BERNSTEIN, © BEZOS EXPEDITIONS.

ROV back on the bottom, complete a pre-disturbance survey of Area 17 and perform the delicate job of rigging a thrust chamber for a nerve-racking lift to the surface. The thrust chamber broke the surface at dawn the following day, just as the waves and wind were rising again as heavy weather was approaching. Nevertheless, we were excited as a careful examination of the thrust chamber revealed a serial number: 2050. It was from *Apollo 12*, which was supposed to be 13 kilometers (8 mi.) away.

Subsequently, the weather turned ugly, as the ironically named Winter Storm Saturn parked itself off the Eastern Seaboard and shut down our operations below the surface. We were battered by gale-force, 50-knot winds and 50-foot seas for six days. Nevertheless, the team persevered and used the time to evaluate all of its research and conclusions against our findings below. We spent the next two weeks exploring all but six of the red dots on the large map. In the process, we discovered 15 thrust chambers and dozens of engine components.

The team decided to recover the best preserved and most complete engine components for conservation and public display. Although the thrust chamber was torn open, the top of the engine and all of its major components were still attached to a section of the heat shield and thrust structure of the S-IC. The engine and its surrounding components were recovered, along with enough components to rebuild two complete F-1 engines. Only two Rocketdyne serial numbers were visible on these thrust chambers, although two other thrust chambers had two digit numbers stenciled on them. The mostly complete engine had no visible serial numbers. Mission identification was one secret that the ocean would not give up easily.

After returning home to Cape Canaveral on March 21, the Apollo F-1 engines traveled by truck to the Kansas Cosmosphere and Space Center in Hutchinson, Kansas, for conservation. The engine components were placed in specially designed tanks so that the public could witness the stabilization process, which is expected to take more than a year (www.f1engineconservation.org).

Months later, one of the conservators, using a black light, discovered the numbers “2044” stenciled in paint that was no longer visible to the naked eye on the side of the torn-open thrust chamber. Upon the removal of more corrosion at the base of the same thrust chamber, the conservator found “Unit No 2044” stamped into the metal surface. This was the Rocketdyne serial number correlated to NASA number 6044, which was assigned to the center F-1 engine on *Apollo 11*.

The juxtaposition between old and new technology was always apparent during the F-1 project. Whereas it took brute force technology from the 1960s to launch men to the Moon, it took sophisticated deep-sea robots of the modern era to perform the delicate task of returning the engines to the ocean surface. The *Apollo 11* astronauts made it to the Moon with components made of switches and circuitry that most children would laugh at today, but this team of explorers had to rely on the most modern deep-sea systems ever developed to find and recover these relics of a bygone era. Ultimately, it’s the people who make a project successful, and if it were not for the skill, passion, and determination of the explorers on the project, it never would have been successful—much like *Apollo 11*.

AFTER REMOVING CORROSION AT THE BASE OF THE F-1 THRUST CHAMBER, A CONSERVATOR FOUND “UNIT NO 2044” STAMPED INTO THE METAL SURFACE, THE SERIAL NUMBER FOR ENGINE #5 FROM *APOLLO 11*. © BEZOS EXPEDITIONS.