APOLLO F-1 ENGINE RECOVERY PROJECT FLAG REPORT TO THE EXPLORERS CLUB

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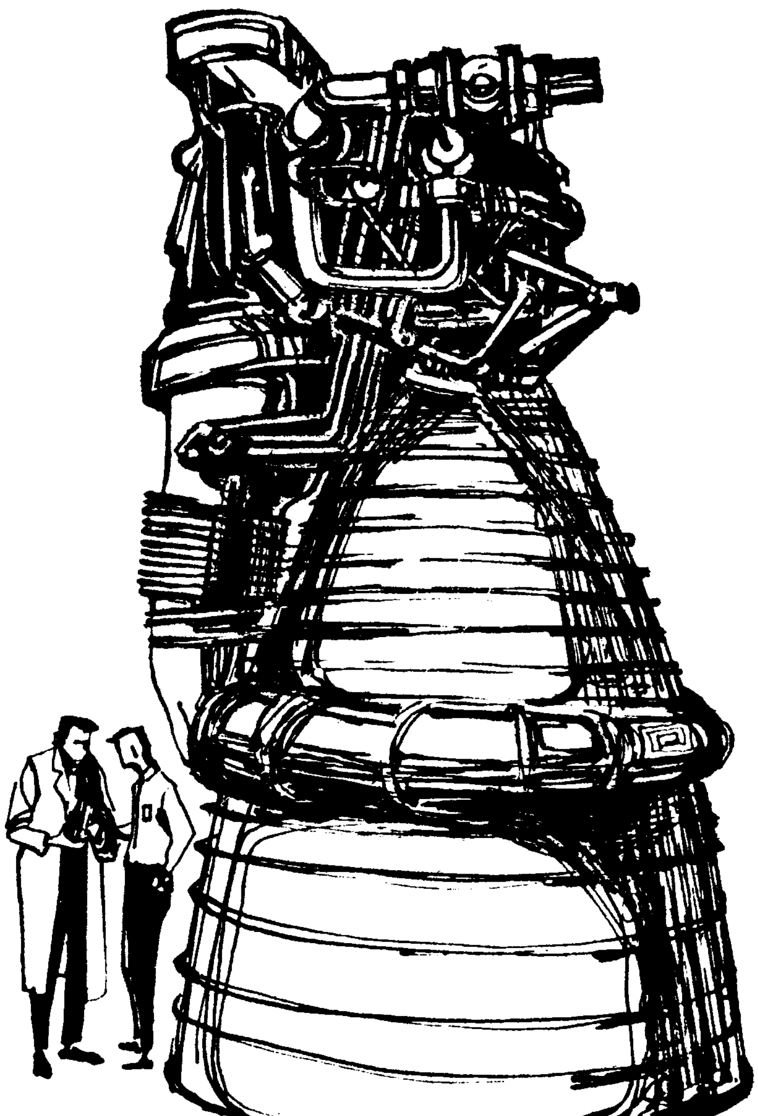
OCTOBER 12, 2017



Flag Report to The Explorers Club
Apollo F-1 Search & Recovery Project

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I. Project Overview

Purpose: To find and recover the Apollo F-1 rocket engines that launched men to the Moon, to conserve these historic artifacts and put them on public display, for the purpose of encouraging a new generation of young people to invent and explore.

Background: Encouraging exploration is vital to the human spirit. The Apollo space program represents the epitome of innovation and cooperation combining to meet an audacious challenge put forward by President John F. Kennedy on May 25, 1961, to put a man on the Moon and return him safely to Earth before the decade was over. At that time, the technology did not exist to meet this challenge, only one American had flown in space – for 15 minutes – and America's rocket launches had only a 40% success rate. Nevertheless, Americans from all fields came together to develop new technologies to explore space, first in near Earth orbit in the Mercury and Gemini programs, and then on the Moon with the Apollo program.

Very little of the flown equipment used to launch men to the Moon is visible to the public. With few exceptions, everything on public display is either excess hardware or pre and post-flight mockups. By finding, recovering, conserving and displaying the remnants of the flown Apollo F-1 engines, it is hoped that these artifacts can encourage young people to pursue innovation and exploration.

Results: The Apollo F-1 Project required the development of various new technologies to achieve success, including an advanced deep water sonar imaging technology known as synthetic aperture sonar ("SAS"), ultra high resolution imaging systems, and remotely-operated vehicles ("ROVs") capable of working and recovering objects at depths to 16,400 feet of sea water ("fsw") (5,000 meters or "m").

The search and recovery phases involved two deep-water expeditions in 2011 and 2013. The first expedition used tried and true methodology to search 180 square miles ("m^2") (300 square kilometers or "km^2") of the sea floor, at depths ranging from 12,500 fsw (3,810 m) to 14,500 fsw (4,420 m), to find the S-IC first stages and F-1 engines from eight Apollo missions (*Apollo 4, 8, 9, 10, 11, 12, 13* and *16*). The second expedition used sophisticated new technology to image these objects and recover enough major components to rebuild two complete flown F-1 engines, as well as several additional components, including thrust chambers, gas generators, injectors, heat exchangers, turbines, fuel manifolds and dozens of other artifacts – all a striking testament to the Apollo program.

After their return to Port Canaveral, Florida, the 25,000 pounds (11,340 kg) of artifacts were transported to the SpaceWorks conservation facility at the Cosmosphere International SciEd Center and Space Museum (formerly known as the Kansas Cosmosphere and Space Center) in Hutchinson, Kansas for more than two years of painstaking conservation and stabilization. This process took place in full view of the public, and those that were unable to make the trip to Kansas could follow the process on a dedicated web site, www.f1engineconservation.org.

In addition to stabilizing the engine parts, the preservation also uncovered some of their history. The Cosmosphere's team discovered markings that tied the parts to flights on *Apollo 11* and *Apollo 12* in 1969 and to *Apollo 16* in 1972.

Thereafter, the artifacts went through a disposition process whereby the National Aeronautics and Space Administration ("NASA") agreed to give the F-1 engines to the Smithsonian's National Air & Space Museum and the Seattle Museum of Flight, among others, for public display. As of this writing, the thrust chamber and thrust chamber injector of the number 3 engine from the *Apollo 12* mission, as well as a gas generator from an engine that powered the *Apollo 16* flight, are on display in Seattle; an injector plate from *Apollo 11* is on tour with the command module from *Apollo 11*; and a thrust chamber from *Apollo 11* and other artifacts are on temporary display at the Cosmosphere. The Smithsonian plans to exhibit the engine parts from *Apollo 11* in a new gallery, "Destination Moon," set to open in 2020.

News about the Apollo F-1 Project has generated hundreds of thousands, if not millions, of media impressions around the world. The project has generated published scientific papers in the fields of deep-sea exploration, marine archaeology and conservation of historic artifacts (attached hereto).

More than 100 people worked on the Apollo F-1 Project to guaranty its success. In 2014, the entire Apollo F-1 Project Team was awarded The Explorers Club Citation of Merit for "an outstanding feat of exploration."

II. Project Explanation

<u>The F-1 Engine & Apollo</u>: The F-1 engine – the most powerful single-nozzle, liquid-fueled rocket engine ever developed – boosted the Saturn V rocket off the launch pad and on to the moon during NASA's Apollo program during the 1960s and 1970s.

Five F-1 engines were used in the 138-foot-tall (42 m) S-IC, or first stage, of each Saturn V rocket. Each F-1 engine stands 19 feet (5.8 m) tall by 12 feet (3.7 m) wide and weighs over 18,500 pounds (8,400 kg). The F-1 was developed by engineers at NASA's Marshall Space Flight Center ("MSFC") in Huntsville, Alabama, and an industry team from Rocketdyne.

The five-engine cluster developed more than 7.5 million pounds of thrust to lift the rocket from the launch pad. The five F-1 engines burned a mixture of liquid oxygen and kerosene fuel at more than 15 metric tons per second during its two-and-one-half-minutes of operation. Each F-1 engine had more thrust than three space shuttle main engines combined to lift the vehicle to a height of about 36 miles and to a speed of about 6,000 mph. In the words of *Apollo 11* astronaut Buzz Aldrin, MED '76, "the Saturn V rose with the power of 100,000 locomotives, burning 5,000,000 pounds of fuel in 150 seconds, getting a full five inches to the gallon."

From November 9, 1967 until May 14, 1973, 13 Saturn V rockets launched 12 Apollo and one Skylab mission into space. Our mission was principally concerned with recovering the five F-1 engines from *Apollo 11*, so our research focused here.

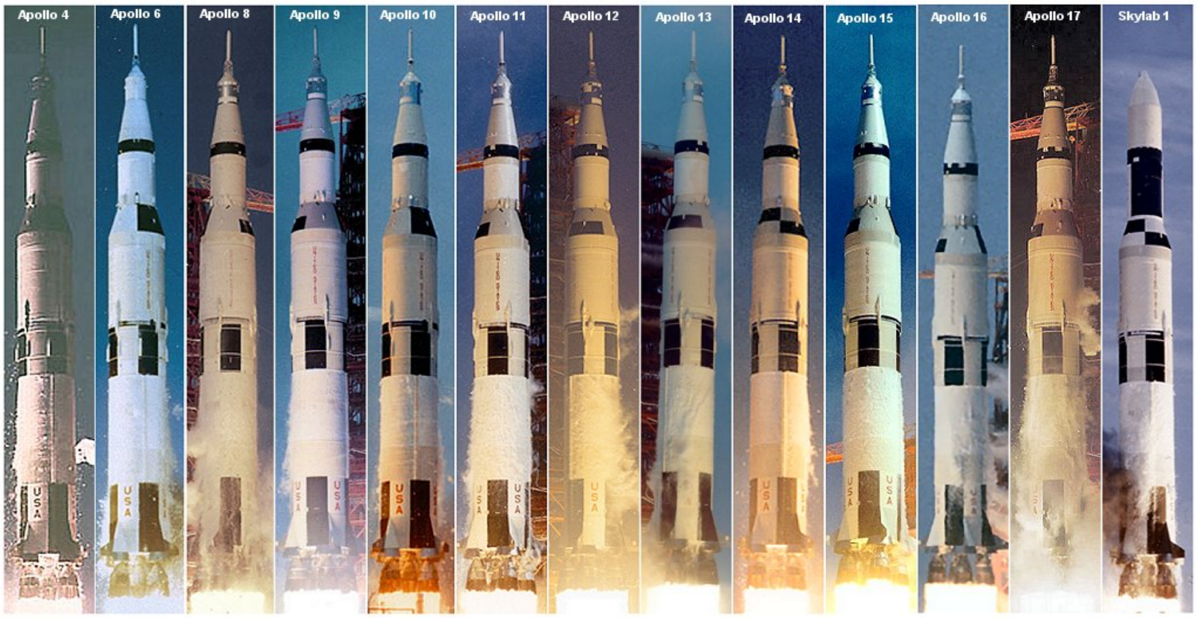

Figure 1 – 13 launches of the Saturn V rocket (NASA)

At 9:31:51.1 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. Two minutes and forty-two seconds later, after propelling *Apollo 11* to an altitude of 42 miles (67 km) at a speed of more than 9,100 feet per second (2,773 meters per second), the quincunx of F-1 engines and 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 71.5 miles (115 km) before plummeting into the waters of the Atlantic Ocean some 350 nautical miles ("nm") (650 km) east of Florida.

Compared to the *Titanic*, which was 883 ft. (269 m) long and weighed 52,310 tons (47,455 metric tons or "mt"), the F-1 engines were seemingly minute, being a mere 19 ft. (6 m) tall and weighing less than 10 tons (9 mt). 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 14,500 fsw (3,800 m) 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 prior expeditions had spent at least 100 days searching more than 995 square miles (1,600 km^2) of sea floor in the vicinity of the sinking by the time Dr. Robert D. Ballard and Jean-Louis Michel led that now famous 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 bottom of the ocean.

Finally, a total of eight S-ICs from various Apollo missions had landed in the same general area, on the western and eastern slopes of the Blake Ridge. It was anybody's guess if the individual F-1s had separated from their S-IC, how far each of their 40 F-1 engines may have drifted as they sank some 14,000 feet (4,300 m) to the seafloor, or whether they would be hidden in deep sea furrows of this little-explored area of the Atlantic Ocean (Att. 1). To find any of the F-1 engines from *Apollo 11*, we would be looking for the proverbial needle in a haystack.

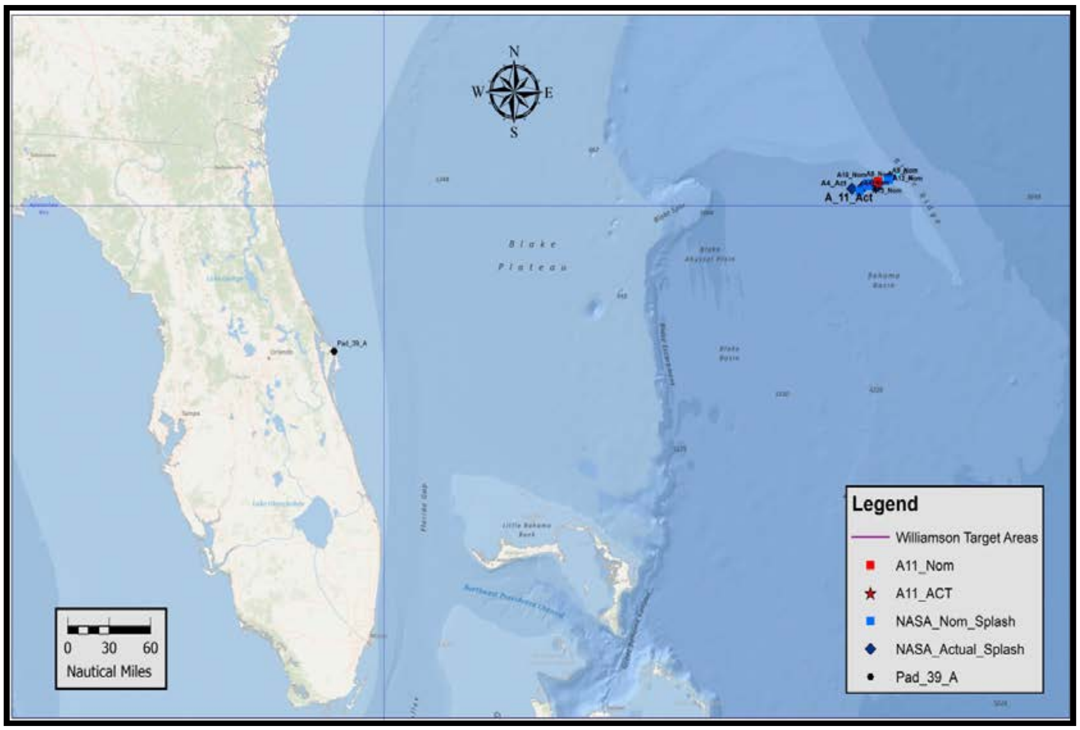

Figure 2 – Seafloor Map from Florida to the Search Area (Bezos Expeditions)

<u>Project Summary</u>: The Apollo F-1 Project had five phases: (1) research and preparation; (2) the search expedition; (3) the reconnaissance and recovery expedition; (4) conservation and stabilization; and (5) public display and education.

1. <u>Research and preparation</u>: This phase of the project started in August 2010, initially with just five people: Jeff Bezos, MN '13, the initiator of the project; David Concannon, FN '96, Project Leader and Expedition Leader; Don Walsh, Ph.D., HON, deep-sea consultant; Matthew Charles, Assistant Project Manager; and Vincent Capone, MN '89, Head of Operations. A comprehensive feasibility study was conducted in the fall of 2010, with options for moving forward presented to Bezos by the end of the year.

Preparation for the search expedition proceeded throughout 2011. Stabbert Maritime/Ocean Services of Seattle, Washington was selected to provide the expedition support vessel, the 224 ft. (68.27 m) *RV Ocean Stalwart* (Att. 2); and Williamson & Associates, also of Seattle, and HL Hydrospheric, LLC of Whitefish, Montana, were selected to provide sidescan sonar equipment to perform the search (Att. 3). During the summer of 2011, the *Ocean Stalwart* was refitted in Newport News, Virginia, while the PROSAS SLH PS-60 Surveyor SAS system underwent refinement and testing in Puget Sound, Washington and the Pacific Ocean off the coast of California (Att. 4).

The SLH PS-60 is a high-frequency sidescan sonar system with a center frequency of 60 kHz that is capable of operating at depths up to 6,000 meters. The SLH PS-60 platform provides seafloor imagery at 3.9 inch x 3.9 inch (10cm x 10cm) resolution up to 4,921 ft. (1,500 m) on each side of the towfish, providing a detailed view of the seafloor that is almost two miles wide. Interferometric bathymetry is available at up to 80% of the image range. Older low-frequency, long-range sidescan sonar systems are capable of covering up to 3,937 ft. (1,200 m) per side; however, with significantly less resolution that degrades with distance. We would bring both systems on the search expedition, and both systems were put to use.

2. <u>The Search Expedition</u>: This phase began on September 24, 2011, as the *Ocean Stalwart* set off from Newport News, Virginia, reaching the target area 1,000 nm (1,852 km) due south approximately four days later. Between September 28, 2011 and October 5, 2011, the survey team searched an area approximately 180 square miles (164 square nautical miles or 300 square kilometers) of ocean bottom, at depths ranging from 13,000 fsw (3,962 m) to 14,300 fsw (4,360 m) – and we discovered the impact sites of the S-IC first stages from eight Apollo missions, including Apollo 11 (Fig. 3). The search expedition concluded in Jacksonville, Florida on October 7, 2011.

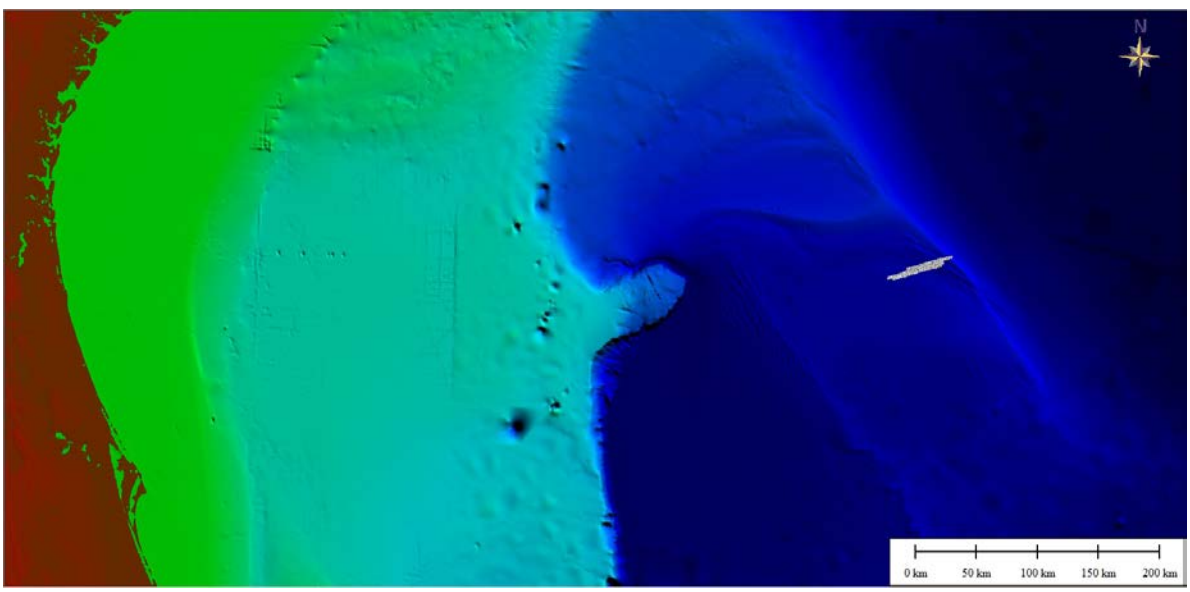

Figure 3 - F-1 Project Area, High Level Overview with Bottom Topography (Bezos Expeditions)

The first survey line was over 30 nautical miles long, and the search pattern consisted of three overlapping survey lines with the sonar array towed nearly five miles behind the boat, often just 15 ft. (4.6 m) above the bottom. After the entire 180 m^2 (300 km^2) search area was covered once to obtain blanket coverage, it was covered again to obtain higher resolution imagery of key target areas (Fig. 4).

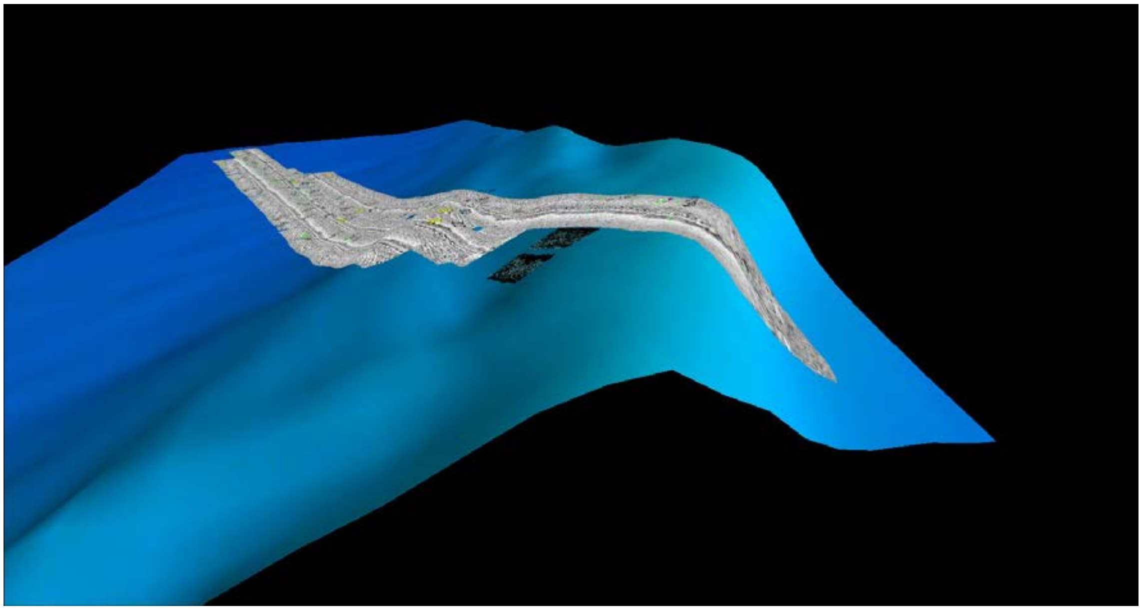

Figure 4 - F-1 Project Search Area, 3,000m Depth View with Bottom Topography (Bezos Expeditions)

The search continued night and day, stopping for only one day as Hurricane Ophelia approached the search area. Every target position was plotted and matched with flight trajectories of multiple Apollo missions. The team located 18 concentrations of debris with hundreds of pieces of debris scattered in between, discovering thousands of manmade targets and 300 "high value targets." The greatest concentrations of targets were clustered in 18 distinct target areas, none of which were located near where NASA had predicted the S-ICs had splashed down. Within these target areas, the team was able to identify parts of at least 30 F-1 engines.

Although successful, the search expedition was not without setbacks, mostly due to adverse weather. The SAS system returning detailed imagery of debris on the bottom and set two world records (Att. 5). On November 7, 2011, the *Ocean Stalwart* made port in Jacksonville, Florida, pushed by tropical force winds preceding Hurricane Philippe.

Post-expedition analysis of the sonar data began immediately in a double-blind review of the data performed by Kelly and Capone during the winter of 2011-2012. Although the 18 target areas were dispersed randomly around the search area, post-expedition research indicated that the first debris field discovered by the search team, on the first full day of the sonar search, contained the F-1 engines from *Apollo 11*.

Principal members of the search expedition team included: David Concannon, FN '96, Expedition Leader; Matthew Charles, Assistant Project Manager; John Anderson, Director of Photography; Colin Stewart, Sonar Team Leader; Jay Larsen, Sonar Team Leader; Michael Kelly, Navigator & Sonar Interpretation Expert; and Andy Wilby, Chief Engineer, Raytheon Applied Signal Technology Inc. The search area and methodology were developed by Vince Capone, MN '89, who unfortunately was not able to participate in the expedition due to a scheduling conflict. The team carried the "unnumbered" Explorers Club Flag first (and last) carried on the 1985 Expedition that discovered the wreck of the *R.M.S. Titanic* (Fig. 5).

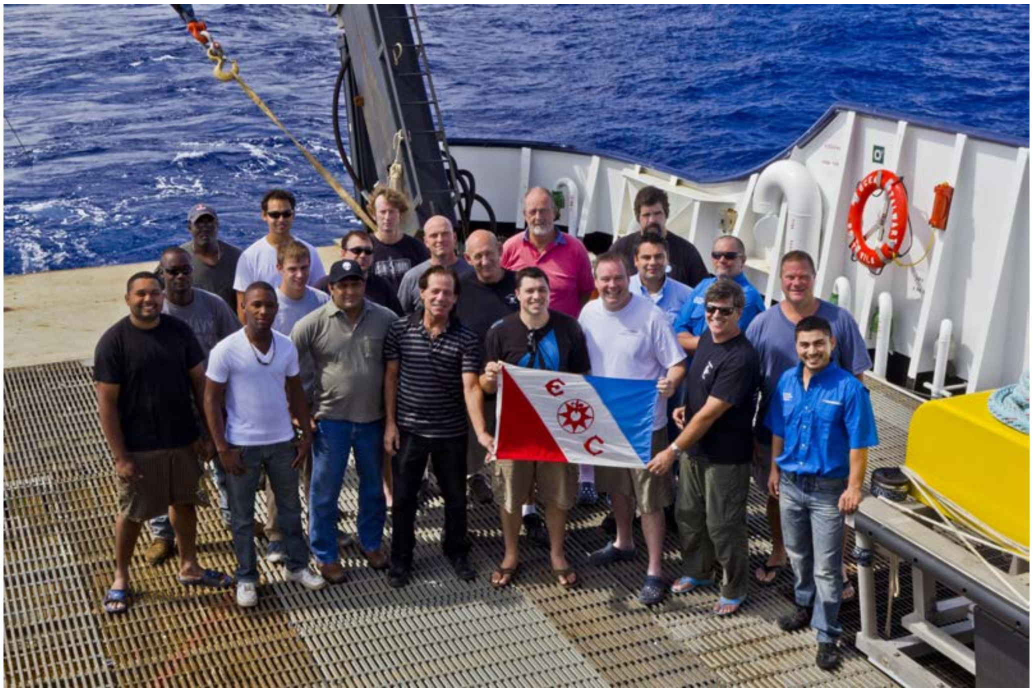

Figure 5 – 2011 Search Expedition Members with The Explorers Club Flag (Bezos Expeditions)

3. Reconnaissance and Recovery: The team initially explored the possibility of conducting a short reconnaissance expedition in the summer of 2012 to assess the condition of the engines and determine lifting solutions. However, 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 2012, Tropical Storm Debby bore down on the Gulf of Mexico, wreaking havoc on ship schedules. A summer departure would be impossible. Consequently, we decided to postpone a return to sea to the winter, when the seas should have been calmer.

The weather delay turned out to be a blessing in disguise. On July 18, 2012, news broke that 48 tons of silver had been recovered from the wreck of the *SS Gairsoppa*, a British merchant vessel resting in 15,420 fsw (4,700 m) off the coast of Ireland, having been torpedoed by a German U-boat in February 1941. The most interesting aspect of the *Gairsoppa* project was the asset used to perform the recovery: the specially-designed Norwegian salvage vessel *Seabed Worker* outfitted with a Schilling HD 150hp Heavy Work Class ROV capable of operating at depths up to 16,404 fsw (5,000 m) (Att. 6 and 7).

An inspection of the ship during an August 2012 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 5,000 meter-capable 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 gingerly 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 (Fig. 6).

Figure 6 – *Seabed Worker* deploying ROV, Jan. 2013 (Bezos Expeditions)

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 it way 500 nm (926 km) southwest to the Apollo site. However, the seas were calm on March 2, 2013, when the ship arrived on site and the first ROV was deployed.

The sophisticated 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 one nautical mile line along the flight path of *Apollo 11*. At that point, the team had narrowed its list of high value targets to just 130 objects, which were now marked with red dots on a large map of 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 sea floor. Within minutes, the ROV came upon 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, the team found what was undeniably an F-1 engine (Fig. 7). 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 the ROV continued to search to the west, it returned images of significant parts of two more engines, before gathering seas forced the crew to retrieve the ROV and bring it back to the surface.

Figure 7 - F-1 Engine Thrust Chamber "2050" and ROV "HD 23" (Bezos Expeditions)

The team 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.

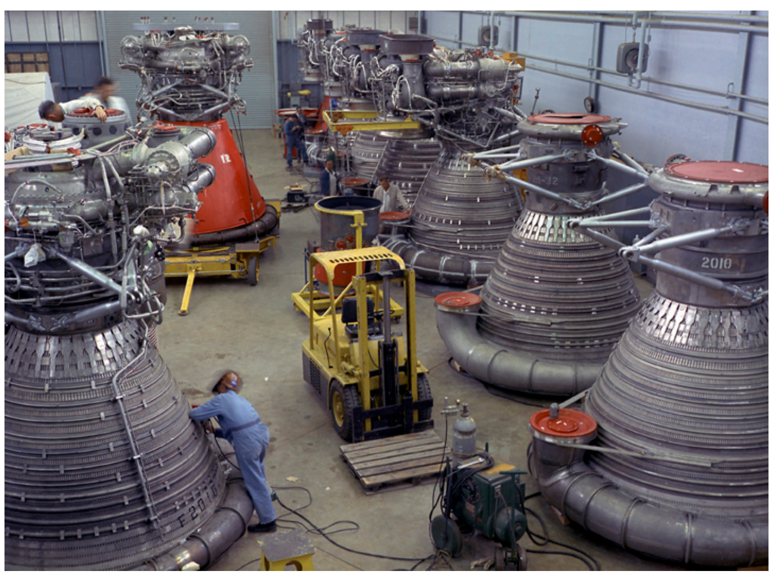

Figure 8 – Numbered F-1 engines in the F-1 Engine Preparation Shop (NASA/MSFC)

Rocketdyne reportedly 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 to the thrust chamber. To confirm that an engine was from *Apollo 11*, the team simply had to find a serial number and match it to the numbers assigned to a particular mission. This would not be easy.

This is where state-of the-art technology was nearly defeated by simple chemistry. In most cases, the F-1 engine identification plates had dissolved or they were inaccessible. The mud on the sea floor 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*, which often proved to be impossible. With the weather worsening, the team was not able to conclusively identify which Apollo mission the engines had come from while the engines were on the bottom. To positively identify an engine, the team would have to bring one up.

On March 5, 2013, the "imaging" ROV, "HD23," was redeployed to the bottom, where it completed a pre-disturbance survey of Area 17 and performed the delicate job of rigging a thrust chamber for a gentle 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. Careful examination of the thrust chamber revealed a serial number: "2050." This number seemingly corresponded with *Apollo 12*, which was supposed to be located 8 miles (13 km) away. The mystery of how this thrust chamber came to be located in a debris field that almost certainly contained the remnants of *Apollo 11* would not be solved while the team was at sea.

As "2050" was on its way to the surface, the weather turned ugly, as the ironically named Winter Storm Saturn parked itself off the east coast of the U.S. For the next six days, the expedition was engulfed by the storm and our operations were completely shut down as the team rode out the storm. During that week, the *Seabed Worker* was battered by gale-force, 50-knot winds and 50-foot seas (Fig. 9).

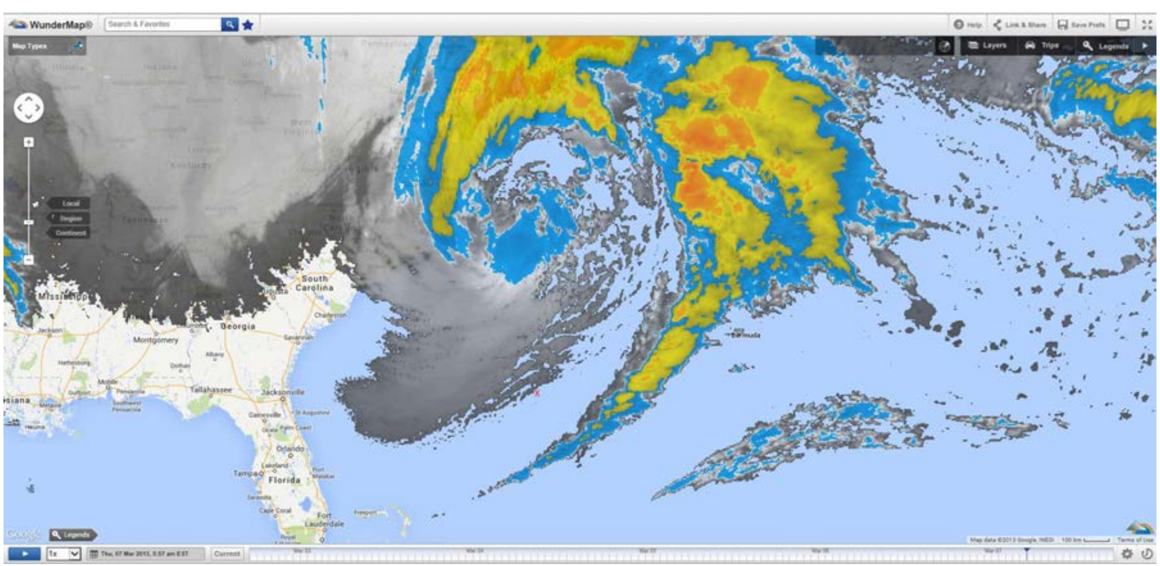

Figure 9 – Winter Storm Saturn, March 7, 2013. "X" indicates F-1 Recovery Area (NOAA)

The team used this weather delay to refine its search methodology and recovery plan. Over the next two weeks, the recovery team used the ROVs to systematically explore 124 of the

130 “high value targets” identified with red dots on the map from the 2011 survey expedition. In the process, the team discovered 15 thrust chambers and dozens of F-1 engine components. Only five of the thrust chambers had visible serial numbers underwater, and none were from *Apollo 11*.

After thoroughly surveying the site with the ROVs, the team decided to recover the best preserved and most complete engine components it had found for conservation and public display. One nearly intact engine was selected as a primary target for recovery (Fig. 10). 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.

Figure 10 – F-1 Engine “2044” prior to recovery (Bezos Expeditions)

The engine and its surrounding components were recovered, along with enough major components to rebuild two complete flown F-1 engines. The team brought back thrust chambers, gas generators, injectors, heat exchangers, turbines, fuel manifolds and dozens of other artifacts – all simply gorgeous and a striking testament to the Apollo program.

Each artifact was recovered using a delicately choreographed procedure that showcased the advanced skills of the *Seabed Worker* crew and ROV pilots. Once the ship was moved back over the location of an artifact resting nearly three miles beneath the ship, the ROVs were deployed and slowly made their way to the bottom. The ROVs were accompanied by a recovery basket, which would be gently guided to a location near an artifact by the “worker” ROV, HD28, as the second “imaging” ROV, HD23, observed with its high resolution camera and lights.

Once the equipment was safely on the bottom, HD28 removed a lifting sling and any tools required from the “skuff,” a small hydraulically-operated compartment under the manipulator arms which opened and closed like a drawer, and moved these over to the artifact. Next, the ROV pilots would use the precision manipulator arms to thread the sling either through or around the open thrust chamber and cinch it tight. HD23 would retrieve the lift line from the recovery basket and transport the hook on the end of the line to HD28, where the pilots would use the manipulator arms to carefully hook the sling into the free loop.   After this, the motion of the ship gently rocking on the sea surface three miles above would slowly break the suction holding the artifact in the mud on the sea floor. Once free of the sea bottom, the surface winch raised the thrust chamber and, guided by the ROV, maneuvered the artifact over and into the recovery basket. After a collective sigh of relief, the lifting line was disconnected from the engine sling, reattached to the basket, and the artifact was brought to the surface (Fig. 11).   This delicate interplay of six different teams – navigation, ship's crew, HD23 crew, HD28 crew, crane operators and deck crew – in six different areas of the ship was repeated every time an artifact was recovered.

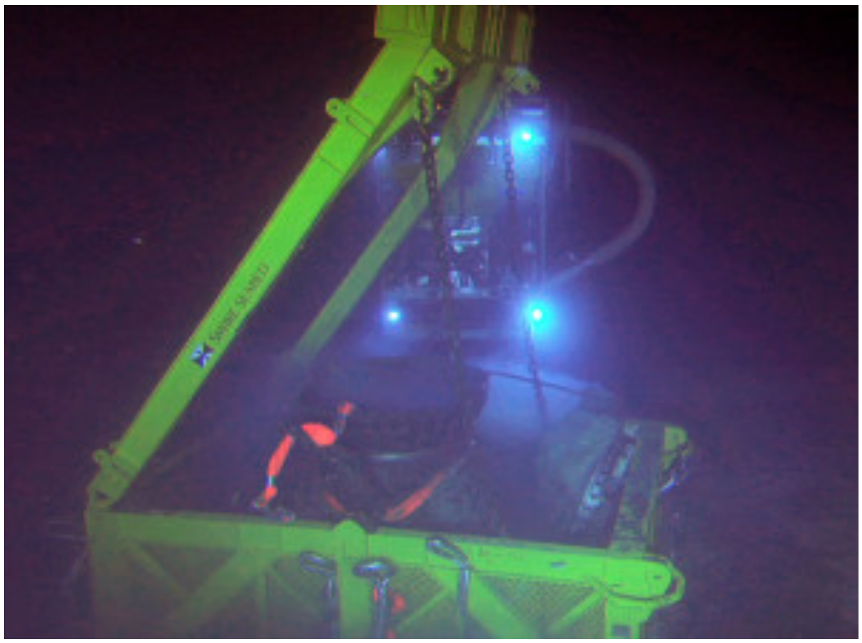

Figure 11 – F-1 Engine rigged for recovery with HD28 (Bezos Expeditions)

Once the artifacts were safely on deck, they were cleaned, cataloged, photographed and bathed in a constant spray of fresh water day and night. Each item was carefully examined for serial numbers that would provide clues to the Apollo mission it had flown. Only two thrust chambers had four-digit Rocketdyne serial numbers visibly stenciled on them, although two other thrust chambers had two digit numbers stenciled on their side. The mostly complete engine had no visible serial numbers. Mission identification was one secret that the ocean would not give up easily.

After three weeks at sea, the *Seabed Worker* brought the flown F-1 engines home to Cape Canaveral, Florida on March 21, 2013, and the team disembarked.

Principal members of the team on the recovery expedition included: Jeff Bezos, MN '14; David Concannon, FN '96, Expedition Leader; Vince Capone, MN '89, Operations Director; John Anderson, Director of Photography; Michael Kelly, Navigator & Sonar Interpretation Expert; Evan Kovacs, MN '15, Director of Underwater Photography; Kenneth Kamler, M.D., Expedition Physician; John Broadwater, Ph.D., Marine Archaeologist; Bill Mills, MN '14, Cinematographer; Troy Launay, Head of ROV Operations; Doug Scott, MI '15, Swire Seabed Project Manager; Rory Golden, MI '14, Artifact Identification & Conservation; Josh Bernstein, FN '04, Photographer; and Mark Bezos, MR '16, Artifact Conservation (Fig. 12).

Figure 12 – 2013 Recovery Expedition Members with recovered artifacts (Bezos Expeditions)

After returning home to Cape Canaveral, NASA Administrator Charles Bolden released a statement congratulating Jeff Bezos and the team on the recovery:

> *Nearly one year ago, Jeff Bezos shared with us his plans to recover F-1 engines that helped power Apollo astronauts to the moon in the late 1960s and early 1970s. We share the excitement expressed by Jeff and his team in announcing the recovery of two of the powerful Saturn V first-stage engines from the bottom of the Atlantic Ocean. This is a historic find and I congratulate the team for its determination and perseverance in the recovery of these important artifacts of our first efforts to send humans beyond Earth orbit. We look forward to the restoration of these engines by the Bezos team and applaud Jeff's desire to make these historic artifacts available for public display.*

4. <u>Conservation</u>: The Apollo F-1 engine components were transported by truck to SpaceWorks, the conservation, restoration and fabrication facility at the Kansas Cosmosphere in Hutchinson, Kansas. Once there, the engine components were placed in specially designed tanks for the painstaking conservation and stabilization process that took more than two years (Fig. 13).

After more than 40 years on the floor of the Atlantic Ocean, the engines had suffered extreme levels of deterioration and corrosion. Treatment was accomplished by taking a deliberate, archaeological object–based treatment approach for these composite objects that are both modern technological marvels and marine archaeological artifacts. The attached article by the conservators describes the archaeological treatment approach they adopted and the results of selected analytical work undertaken to understand the materials of construction and the deterioration processes (Att. 8 and 9).

Figure 13 – F-1 Engine components in treatment at SpaceWorks in Kansas (Bezos Expeditions)

Months into the conservation process, one of the conservators working at the Kansas Cosmosphere, 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*. Similar discoveries in subsequent months conclusively identified engine parts from *Apollo 11*, *Apollo 12* and *Apollo 16*.

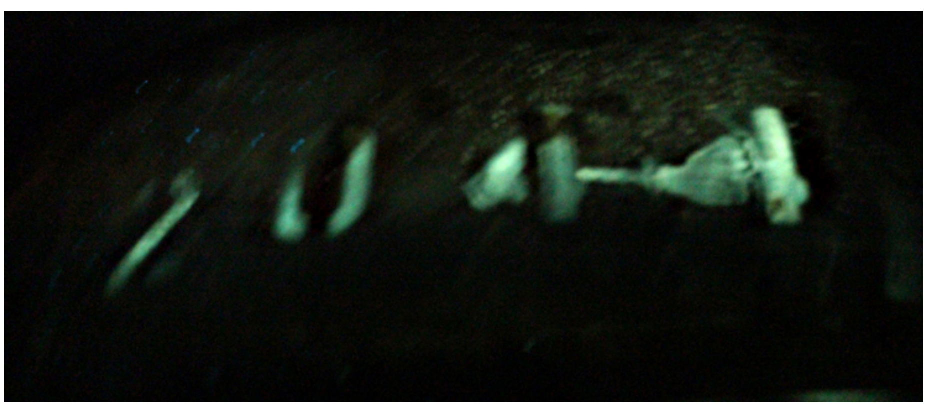

Figure 14 – “2044” serial number under black light (Bezos Expeditions)

Consistent with the objective of the Apollo F-1 Project to display the artifacts and inspire the public, visitors and schoolchildren were able to watch the conservation and stabilization process in real time by visiting a public viewing area set up in the conservation facility at the Cosmosphere, and those that were unable to make the trip to Kansas could follow the process on a dedicated web site, www.f1engineconservation.org.

Principal members of the conservation team included Paul Mardikian and Claudia Chemello, Terra Mare Conservation LLC; Jerrad Alexander, Jim Remar and Dick Hollowell, Kansas Cosmosphere and Space Center; Larry Goodwin, Dale Capps and Don Aich, Space Works; John Broadwater, Ph.D.; and Tim Foecke and Adam Creuzinger, National Institute of Standards and Technology ("NIST").

5. Public display and education: Several museums expressed interest in acquiring objects from this collection, in agreement with NASA, who had oversight for the objects' disposition. These institutions included the Smithsonian National Air and Space Museum, who will receive the *Apollo 11* artifacts; the Museum of Flight in Seattle, Washington; the US Space and Rocket Center in Huntsville, Alabama; the Kansas Cosmosphere and Space Center; and the Space Museum in Bonne Terre, Missouri.

However, the first public display of the Apollo F-1 artifacts outside of the conservation facility in Kansas took place at The Explorers Club Annual Dinner (Fig. 15).

On March 22, 2014, the Apollo F-1 Engine Search & Recovery Team was awarded The Explorers Club Citation of Merit "for an outstanding feat of exploration." The honor was bestowed by *Apollo 11* astronaut Buzz Aldrin before an audience of 1,500 people gathered at the Waldorf-Astoria Hotel in New York City, after an 11-minute video was shown to the audience (*See* http://www.bezosexpeditions.com/updates.html to view this video). In accepting the award on behalf of his teammates, Jeff Bezos stated: "I was blown away by the skill and professionalism of the entire team."

Figure 15 – Part of the Apollo F-1 Team, ECAD 2014 (Matthew Charles)

On November 19, 2015, the anniversary of the *Apollo 12* Moon landing on November 19, 1969, Jeff Bezos unveiled a preview of the restored remains of the F-1 rocket engines used to launch NASA's *Apollo 12* and *Apollo 16* missions to the Moon at The Museum of Flight in Seattle.

Jeff Bezos was ecstatic when he unveiled the engines. "It took a lot of 21st century underwater tech and an extraordinary team of skilled professionals to find and recover these historical treasures and, thanks to them, NASA, and The Museum of Flight, now a whole new generation of young people will be able to see these amazing engines on display," said Bezos. "When I was five years old I watched Neil Armstrong step onto the moon and it imprinted me with a passion for science and exploration - it's my hope that these engines might spark a similar passion in a child who sees them today."

Finally, on May 20, 2017, the Apollo permanent exhibit opened at the Seattle Museum of Flight. The exhibit displays a full-size F-1 engine next to engine artifacts recovered in 2013, including the thrust chamber and thrust chamber injector of the number 3 engine from the *Apollo 12* mission, as well as a gas generator from an engine that powered the *Apollo 16* flight.

Figure 16 – Jeff Bezos unveiling the Apollo Exhibit to a group of schoolchildren at the Seattle Museum of Flight, May 20, 2017 (Kim Frank)

Jeff Bezos formally opened the Apollo exhibit by giving a preview to more than 100 schoolchildren and speaking to them about the importance of teamwork, perseverance and passion (Fig. 16). "You guys will find that you have passions, and having a passion is a gift. ... You don't get to choose them, they pick you. But you have to be alert to them, you have to be looking for them. And when you find a passion, it's a fantastic gift for you, because it gives you direction, it gives you purpose," Jeff said. He added that, if you get the chance to follow that passion, "all your work won't feel like work to you."

"For a long time, hundreds of years, thousands of years, the idea of going to the moon was so impossible people actually used it as a metaphor for impossibility," he said. "And then, in the 1960s, we humans did it. What I would hope you take away from that is that anything you set your mind to, you can do." Jeff concluded by recalling the words of Wernher von Braun, the architect of the Apollo-era space program when referring to the moon landings:

"I have learned to use the word 'impossible' with the greatest caution." Jeff concluded with: "I hope you guys take that attitude through your lives."

And so, at that moment, the Apollo F-1 Project, which began with an idea seven years earlier, finally came to a close. It is our sincere hope that the Apollo F-1 engines will be seen by millions as a testament to what is possible, and young people everywhere will be inspired to invent and explore.

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