

# Extreme Exploration and Outreach: Taking the World on a Voyage to Pluto and Arrokoth

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## ABSTRACT

*New Horizons' historic flyby of Pluto in July 2015 generated headlines worldwide and set records for both the farthest planet ever explored and, arguably, the largest public engagement of any NASA science mission in history. From live road shows and innovative social media campaigns to documentaries and live television broadcasts, the mission brought the public along on this great voyage of exploration. The engagement and communications program began long before the spacecraft was even launched, and it had to include plans to generate awareness and maintain excitement through a decade-long cruise to Pluto. The excitement and outreach continued as New Horizons achieved another historic flyby—of the Kuiper Belt object 2014 MU69 (since named Arrokoth) on January 1, 2019. As more records fell—this time, for the farthest world ever explored, more than 6.5 billion kilometers from Earth—the team applied its best practices and lessons learned from the Pluto flyby.*

## OVERVIEW: NASA'S NEW HORIZONS MISSION

New Horizons is the first mission to Pluto and the Kuiper Belt, the region of ancient, icy, rocky bodies beyond the orbit of Neptune. NASA authorized the mission after it was ranked at the top of the 2003 planetary decadal survey queue for medium-scale missions. The New Horizons spacecraft was launched on January 19, 2006, passed Jupiter for a gravity boost and a successful test of its science instruments in February 2007, and made a historic flight through the Pluto system on July 14, 2015—returning data that immediately transformed our view of the intriguing worlds at the edge of our planetary system.

New Horizons opened the door to our solar system's next frontier, an entire realm of small planets and bodies we are still just beginning to understand. We once thought that Pluto marked the “end” of the planetary system; it turns out that Pluto is only the beginning—a harbinger of a new zone of icy dwarf planets that outnumber any other objects in the solar system, and likely hold the keys to understanding fundamental aspects of planet formation.

With Pluto in the rearview mirror, New Horizons embarked on the Kuiper Belt Extended Mission (KEM).

Updated from a manuscript presented at the 70th International Astronautical Congress (IAC-19), Washington, DC, October 2019. Copyright by IAF.<sup>1</sup>

Speeding deeper into the Kuiper Belt, it began observing distant Kuiper Belt objects (KBOs) and sampling the heliosphere. But the centerpiece of the KEM was a flyby of 2014 MU69—an ancient KBO and a building block of the solar system—on January 1, 2019. (MU69 was officially named Arrokoth, a Native American term meaning “sky” in the Powhatan/Algonquian language, in November 2019.<sup>3</sup>)

New Horizons flew 1.6 billion kilometers (1 billion miles) beyond Pluto for its rendezvous with Arrokoth. Mission team members identified the object in 2014 using the powerful Hubble Space Telescope. The first extended mission before and after the flyby also included distant studies of other KBOs and heliospheric dust and plasma science as far out as 50 astronomical units from the Sun.

New Horizons is the first mission under NASA’s New Frontiers Program, managed by NASA Marshall Space Flight Center in Huntsville, Alabama. New Horizons is a principal investigator (PI)-led mission; the Southwest Research Institute (SwRI) of San Antonio is the PI institution, and Alan Stern, of SwRI’s office in Boulder, Colorado, leads the mission as PI. APL manages the mission for NASA’s Science Mission Directorate. APL built and operates the New Horizons spacecraft, while SwRI led development of the New Horizons science payload comprising instruments principally built and operated by APL, Ball Aerospace, the Laboratory for Atmospheric and Space Physics (LASP), Stanford, and SwRI. SwRI also leads science operations and data processing, which take place at the Tombaugh Science Operations Center at SwRI in Boulder.

## ENGAGEMENT AND COMMUNICATIONS

With its long duration and unprecedented path to the outer solar system, the New Horizons mission provides unique opportunities to engage the public on

science, technology, engineering, and math (STEM) topics. STEM audiences, communication channels, and methods include traditional and social media; web and multimedia; NASA TV and streaming outlets; public outreach venues; conferences and events; speakers bureaus; exhibits and displays; visitor centers; the scientific research community; public engagement partners; academia; and industry partners. Programs engaged the public throughout the history-making New Horizons flybys and inspired the next generation of explorers. The mission also had a robust media engagement campaign.

### Mission Messages and Themes

The team tells the New Horizons “story” through multiple themes and messages. Examples of the messaging for both Pluto and Arrokoth flybys include:

- **Farthest, Fastest, First:** New Horizons traveled the farthest distance to reach its primary target; was the fastest space mission ever launched; and remains the first mission to Pluto and the Kuiper Belt. It was also the first mission since 1989 to an unexplored planet; the first mission to explore a double planet; the first to explore an ice dwarf; the first planetary mission to carry a student-built instrument; and the first PI-led outer planets mission.
- **Exploration Bookends:** We first explored Mars (with Mariner IV) exactly 50 years, to the day, before New Horizons flew past Pluto. New Horizons completed the first reconnaissance of the solar system’s classical planets.
- **Farthest Exploration—“The Last Stop before the Stars”:** The New Horizons flyby of Arrokoth remains the farthest planetary encounter ever, taking us 1.6 billion kilometers (1 billion miles) beyond Pluto and beyond the familiar solar system into a barely explored realm called the Kuiper Belt. The flyby was



Figure 1. Flyby event backdrops. Left, a backdrop for the Pluto flyby. Right, a backdrop for the Arrokoth flyby.

the gateway to even more remarkable exploration, perhaps sending humankind on our way toward still more distant planets and even planets around other stars. Figure 1 shows a backdrop the team developed for the Arrokoth flyby events, as well as one created for the Pluto flyby.

- **The Next Giant Leap:** The Arrokoth flyby ushered in the 50th anniversary year of the Apollo 11 Moon landing, a bookend to one of humankind's greatest explorations. A thread of inspiration runs from the Apollo astronauts to the New Horizons team, linking these explorers and connecting generations who will remember where they were when they saw brand-new worlds, up close, for the first time.
  - **The Triumph of Arriving:** Simply reaching Pluto and Arrokoth, and seeing them as actual worlds, was a heroic exploration achievement. Akin to reaching the South Pole, meeting the challenge of getting there equaled success. Every New Horizons activity, from the most distant flyby to the most distant trajectory adjustments to the most distant imaging, sets a deep-space exploration record not likely to be broken in our lifetime.
  - **Delivering from Daunting Distances:** New Horizons is a miniaturized, low-power breakthrough in robotic exploration, and it delivered at Pluto from mind-boggling distances. At Arrokoth, the spacecraft faced an even tougher test: it had to deliver the goods from more than 6.5 billion kilometers away—more than 40 times the distance between the Sun and Earth—through radio signals that needed 6 h to reach home at the speed of light.
  - **Into the Unknown:** New Horizons remains at constant risk of impact from space debris. Although the mission team had to search for it near both Pluto and Arrokoth and was prepared to react if needed, it still couldn't know every danger awaiting the lone, plucky spacecraft. The analysis of hazards potentially facing New Horizons and the decision to send it on an alternative path (or not) were all part of the run-up to both flybys. (See the article by Holdridge et al., in this issue, for more on hazard analysis and trajectory planning.)
  - **Shedding Light on Frontier Worlds:** The Pluto system contains many high-priority exploration targets; as mentioned, the little planet and its moons topped the National Academies' decadal survey priority list in 2003,<sup>2</sup> underscoring the need for New Horizons. The chilly expanse of the Kuiper Belt holds hundreds of thousands of objects—all remnants of early solar system formation. New Horizons conducted humankind's first-ever close flyby of Pluto and a small KBO; this is exploration at its greatest,
- an opportunity to unravel the origins of scientifically valuable worlds on our planetary system's frontier.
- **Exploring the Third Zone:** A generation ago we didn't even know there was a "third" zone beyond the rocky inner planets and outer gas giants, yet that zone, the Kuiper Belt, is larger and more populous than the solar system we already "knew." New Horizons' continued exploration of the Kuiper Belt marks the frontier of both human exploration and human knowledge, and another first for NASA and the United States.
  - **Examining Our Origins:** Always frozen, Arrokoth is the most primitive body ever visited by a spacecraft, a 4.6-billion-year old relic from our solar system's earliest days. Scientists believe the deep freeze of the Kuiper Belt may have kept Arrokoth largely pristine, giving us a better look at the "true" Kuiper Belt—and a glimpse into the origins of our solar system—even more than Pluto did. The close approach also revealed new things about how small planets like Pluto were built.
  - **The Everest of Planetary Exploration:** In terms of its distance from home and its historic completion of the reconnaissance of the classical planets, its frontier-busting exploration of the Kuiper Belt at the edge of our planetary system, and its low-cost access to the outer solar system, New Horizons' visits to Pluto and Arrokoth represented the pinnacle—the Everest—of planetary exploration.
  - **Practice, Practice, Practice:** Like world-class athletes or musicians, the New Horizons team worked hard to prepare for its historic moment at Pluto—flawlessly conducting a flight past Jupiter a year after launch; putting the spacecraft through annual checkouts; and plotting out each step of the Pluto flyby and practicing that entire encounter in real time. And like great Olympians, the New Horizons team was ready for its one shot at excellence.
  - **New Year, New Worlds, New Hope:** More than symbolism, New Horizons' flight past a "new" world on New Year's Day 2019 conveyed a message of hope and optimism, a demonstration of how people, through education, creativity, persistence, and hard work, can truly accomplish the extraordinary.
  - **The Next Generation:** After capping the reconnaissance of the classical solar system at Pluto, New Horizons headed into an entirely new realm, a voyage into the true "destination next." The mission team embodied this spirit with a new generation of committed and dedicated explorers ready to pick up the trail their mentors blazed to Pluto. Figure 2 shows some members of that team.





**Figure 2.** Some of the women on the New Horizons Pluto flyby team. Women make up ~25% of the team, a fact included in a NASA feature story released during the Pluto flyby campaign. This group was photographed at APL on July 11, 2015, just 3 days before the spacecraft's closest approach to Pluto. (Credit: NASA/APL/Michael Soluri.)

### Engagement and Communications Products and Programs

The New Horizons engagement and communications program (then known as education and public outreach, or E&PO) began long before the spacecraft was even launched and had to include plans to generate awareness and maintain excitement through a decade-long cruise to Pluto, all leading up to the historic flyby on July 14, 2015. Aside from engaging the public directly throughout the Pluto flyby and inspiring the next generation of explorers (Figure 3), the communications team planned and carried out a robust media engagement campaign including many products.



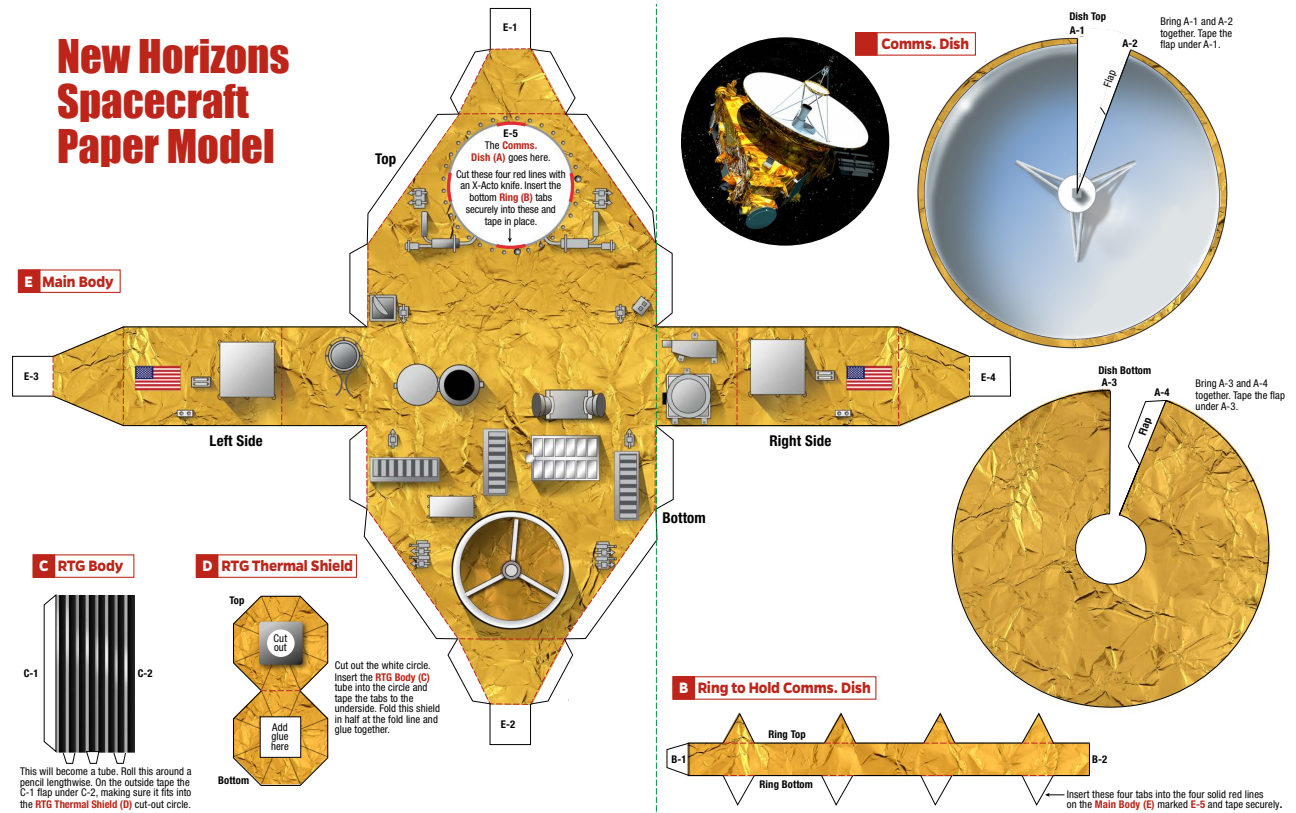
**Figure 3.** Inspiring the next generation of explorers. Young people, possibly future space scientists, enjoying the 2019 New Year's Eve celebration of the Arrokoth flyby alongside the mission team, including PI Alan Stern (shown waving a flag at the center). To Stern's right are APL director Ralph Semmel (holding flag) and SwRI president Adam Hamilton.

**Fact sheets, infographics, and lithographs:** These products (and other collateral) are available in print and posted on mission website, <http://pluto.jhuapl.edu/Learn/Get-Involved.php#Toolkit>.

**Demonstrations and activities:** The team created “make it/take it” types of demonstrations and activities (such as the paper model shown in Figure 4), posting them to the mission website for use in museums, science centers, and libraries. NASA networks such as the Museum & Informal Education Alliance and Solar System Ambassadors were also trained to use these demonstrations and activities.

**Road shows:** The team conducted a number of New Horizons road shows—called Plutopaloozas—at targeted museums and science centers. These multiday, multigenerational events created mission awareness and allowed the public to meet and interact directly with the people conducting this historic exploration.

**Events at museums, science centers, and planetariums:** The New Horizons team educated members of the NASA Museum & Informal Education Alliance on the mission and trained them in using mission materials at their own facilities. Partners for this effort include more than 1,000 professionals at 550 museums, science centers, planetariums, NASA visitor centers, Challenger Centers, observatories, parks, nature centers, zoos, and aquariums across the



**Figure 4.** One of the “make it/take it” demonstrations and activities. This paper model was one of the many activities created as part of the New Horizons engagement and communications program.

United States. In addition to sending kits of handouts to partners hosting events, the New Horizons team provided “virtual” kits that allowed the partners to produce their own events and exhibits. For the Pluto flyby, for example, the mission teamed with the NASA Solar System Ambassadors and NASA Museum & Informal Education Alliance programs. Through July 2015, Solar System Ambassadors conducted more than 545 events around the country, engaging 5,281,404 people. The NASA Museum & Informal Education Alliance tracked 690 events through July 29, 2015; this included 93 US organizations in 36 states and the District of Columbia, as well as 9 international events in countries such as Argentina, Brazil, Canada, Colombia, Iceland, the Netherlands, and Tasmania.

**Displays, exhibits, and planetarium shows:** The team supported national requests for displays and exhibit graphics and supplied planetarium-quality animations and videos for members of the NASA Museum & Informal Education Alliance and other NASA partners so that they could showcase New Horizons at their own facilities.

**Special events:** The New Horizons team managed many regional and national special events, including those surrounding both the Pluto and Arrokoth flybys. For these events, the communications team created mission- and event-specific materials and displays, staffed

exhibit booths, made science and engineering team members available for media interviews, and produced more than a dozen live NASA TV broadcasts (with accompanying videos and animations). The New Horizons team also participated in high-profile NASA events and exhibits such as Earth Day on the National Mall, the USA Science & Engineering Festival, and other events that included the large (and popular) NASA booth.

**Animation and graphics:** APL designers and graphic artists produced animation segments depicting New Horizons and its science operations at Pluto, Arrokoth, and other locations in the Kuiper Belt. These files were posted to the mission website—making them widely available to news media and documentary producers—and used in other video products.

**Video:** The mission communications team created a video series, mini-documentaries, and full documentaries (see Box 1) that covered the science and engineering of the Pluto and Arrokoth flybys and the results of the remaining KEM efforts. These videos were made available via the mission website as well as iTunes, YouTube, and other video sharing/podcasting sites for outreach partners and the public to download. One example, the *Pluto Explored* series of cartoons (Figure 5), brings the excitement of the mission to students in a fun and innovative way. The series includes episodes such as “How Are Pluto and Earth Alike and Different?,” “How Did



### BOX 1. SUMMITTING THE SOLAR SYSTEM

*Summitting the Solar System*<sup>4</sup> is a story of exploration at its most ambitious. Produced through the New Horizons engagement and communications program, the feature-length documentary debuted in December 2018, just before New Horizons flew by Arrokoth. But *Summitting* is much more than the story of a sophisticated, plutonium-fueled robotic spacecraft exploring far from the Sun. The New Horizons mission is powered as much by the passions of a small team of humans for whom pushing the frontiers of the known, climbing the very peaks of the possible, has been the dream of many decades.

The documentary goes behind the scenes of the most ambitious occultation campaigns ever mounted, as scientists deployed telescopes to Senegal and Colombia in 2018, and Argentina, South Africa, and New Zealand in 2017, to glimpse Arrokoth as it passed in front of a star and gather data on the object's size and orbit that have been essential to planning the flyby. Mission scientists recall the astonishing scientific success of flying through the Pluto system in 2015 and use comparative planetology to show how Earth and Pluto are both amazingly different and—with glaciers, tall mountains, volcanoes, and blue skies—awesomely similar.

Appealing to space junkies and adrenaline junkies alike, *Summitting* brings viewers along for the ride of a lifetime as New Horizons pushes past Pluto and braves an even more hazardous unknown.

As with climbing Everest, this mission braved dangers that could have ended in failure. A serious computer glitch just 10 days before the Pluto flyby required heroics from a dedicated team of mission operations engineers at APL; having little time to figure out what happened, then develop, test, and upload new commands, they succeeded . . . with just 4 hours to spare. This dramatic story is told in *Summitting* for the first time, through emotional interviews with the people who recovered from the anomaly. (See the article by Bowman et al., in this issue, for more on this anomaly and the team's response.) *Summitting* anticipates the new discoveries of the New Year, as New Horizons explores the new frontier of our solar system's third zone—the Kuiper Belt. However, the perseverance, pluck, drive, and ambition of those who made New Horizons' long journey possible are the stuff of the epic, age-old human drive to climb the highest mountains, explore the most distant lands, and reach every peak and pole.

Pluto Gets its Name?," "How Far? How Fast?," and "How Many Planets Are in the Solar System?" In another example, actor Chris Pratt recorded a promotional video, played on NASA websites and social media, to generate excitement for the Arrokoth flyby. The mission team developed the concept for the video, which also allowed Pratt to promote his upcoming space-themed movie, *The Lego Movie 2: The Second Part*.

**Eyes on the Solar System:** The mission team worked with NASA's Jet Propulsion Laboratory (JPL) to create special Eyes on the Solar System modules (Figure 6)—using real trajectory and operations data—that allowed users to fly along with the spacecraft as it journeyed past Pluto and Arrokoth. These simulations were essential elements of the live NASA TV coverage of each flyby.

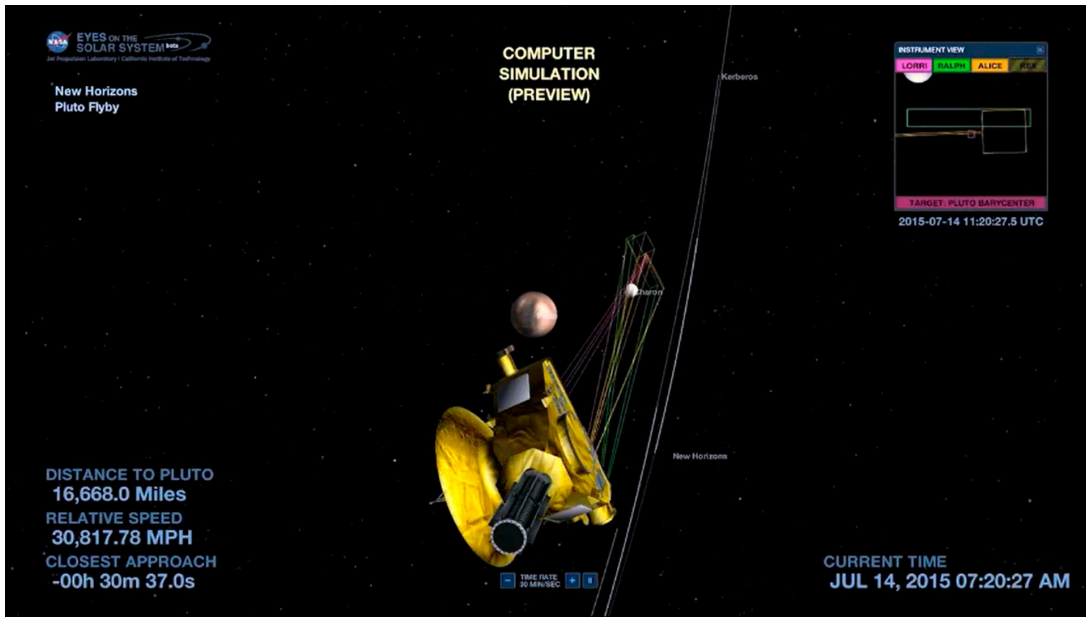


**Figure 5.** *Pluto Explored.* This series of cartoons brings the excitement of the mission to students in a fun and innovative way. Episodes cover topics such as how Pluto and Earth are alike and different and how Pluto and Arrokoth got their names.

**Pluto Time:** Just how dim is the sunlight on Pluto, some 4.8 billion kilometers away? While sunlight is much weaker than it is here on Earth, it isn't as dark as you might expect. In fact, for just a moment during dawn and dusk each day, the illumination on Earth matches that of high noon on Pluto. We call this Pluto Time. The mission team worked with colleagues at JPL to coordinate a full campaign that included a web application that provided that approximate time, based on user location. The public was encouraged to take a photo during their Pluto Time—preferably with a local landmark—and share it on social media with the hashtag #PlutoTime. During the live NASA TV flyby broadcasts, the New Horizons team highlighted some of the most interesting shots from around the world. JPL also combined the photos into an image of Pluto and its moons that NASA released to the public. More than 5,000 images from around the world were shared on social media, and the program was featured in the *New York Times*, the *Guardian*, *Mashable*, *Daily Telegraph*, *Time*, *Slate*, *NBC News*, *Gizmodo*, *Universe Today*, *CNET*, and *Discovery*, among other websites and publications. Figure 7 is a representation of this global response.

### Live NASA TV Programming

NASA covered the flybys of both Pluto and Arrokoth on its television channel (NASA TV), website, and social media accounts. The programming was developed, managed, and led by the New Horizons engagement and communications teams at APL. On July 14, 2015, the live Pluto flyby program generated more than 1.3 million



**Figure 6.** Eyes on the Solar System. These modules, created in collaboration with JPL, gave the public a real-time simulated view of the Pluto flyby on July 14, 2015.

views on the NASA TV page. The team also produced recorded and live NASA TV and web updates on June 9, 16, 23, and 30 and July 9, 10, 11, 12, 13, and 14. NASA TV also broadcast the flyby of Arrokoth on January 1, 2019 (Figure 8). A peak of about 23,100 viewers watched the NASA TV web stream of signal acquisition; 19,500 watched streams of the flyby; and the January 2 briefing with the first close-up images peaked at about 14,500 viewers. According to NASA, the viewer numbers compared to an audience for space station crew and cargo launches—and this was without a full “push” by the NASA communications team (which, with the rest of the federal government, was sidelined by a shutdown in January 2019).

### A Royal Outreach Partner

The Arrokoth flyby outreach effort received a huge boost from an unlikely partner: legendary Queen guitarist Brian May (Figure 9), who holds a PhD in astrophysics and serves as a New Horizons participating scientist. Dr. May posted several New



**Figure 7.** The #PlutoTime social media campaign. This mosaic includes hundreds of images shared during the campaign. A photo of Clyde Tombaugh, the American who discovered Pluto in 1930, is embedded in the mosaic. The image is available at <https://www.nasa.gov/image-feature/pluto-time-mosaic>; zoom in on the inset in the image to reveal a photo of Tombaugh and his homemade 9-in. telescope in the region of Pluto’s “heart,” informally named Tombaugh Regio. (Credit: NASA/JPL.)





**Figure 8.** New Horizons project scientist Hal Weaver takes part in a live Arrokoth flyby preview program on NASA TV. A peak of ~23,100 viewers watched the signal acquisition, and 19,500 watched the flyby. A January 2 news briefing with the first close-up images saw a high of ~14,500 viewers. According to NASA, these viewer numbers compared to those for space station crew and cargo launches, even without a full “push” by the NASA communications team, which was sidelined by a federal government shutdown in January 2019.

Horizons images on his popular Instagram account; he also participated in two live televised events, recorded a promotional video with the New Horizons operations team, and debuted a song and video written just for the mission—called, naturally, “New Horizons”—as part of the live flyby program on New Year’s Eve 2019. The connections boosted social media accounts across the board. The @NASANewHorizons Twitter account, for example, increased by 40,000 followers; Dr. May’s Instagram account (@Brianmayforreal) jumped by 200,000 followers, to more than 1 million total.

### Media Relations Products and Programs

In addition to the robust public engagement activities, the New Horizons team crafted and executed an

extensive media outreach campaign. That campaign included several elements, described below.

**Media kit:** For each flyby, the team produced a media kit for news media, a document of several dozen pages that includes detailed background information on the New Horizons mission, science objectives, and flyby activities.

**News releases:** The mission’s public affairs team, led by APL, NASA, and SwRI, issued news releases for key mission events and discoveries. In addition to writing news releases on mission milestones, the team worked together on feature releases covering scientific plans and results, human interest, business, technology, education, and other topics related to the mission. The team also created status reports covering events that were notable but not necessarily major news. Like news releases, the status reports were posted on mis-

sion websites and NASA social media accounts, as well as sent to the 5,000-plus subscribers to the New Horizons “E-News” email list.

**Video B-roll package:** Packages including animation segments, background footage, and interview clips were distributed to news media to enable outlets to edit and air news stories on the mission. These packages were distributed to media via NASA TV and the mission websites—the first large-file transfer opportunities on an APL space mission website—and posted to social media sites such as YouTube. To maintain shared distribution and easy access across the project, APL maintains an online database with all available video and animation.

**Live shots:** Live satellite interviews allow television and radio stations around the world to speak with team members about mission milestones, discoveries, or other



**Figure 9.** An unlikely partner. Left, New Horizons team members discuss the Arrokoth flyby with Brian May, the legendary Queen guitarist and imaging expert who holds a PhD in astrophysics. Middle, a New Horizons participating scientist, May released a song and video on New Year’s 2019 to commemorate the flyby. Right, May also engaged with media assembled at APL to cover the Arrokoth encounter.



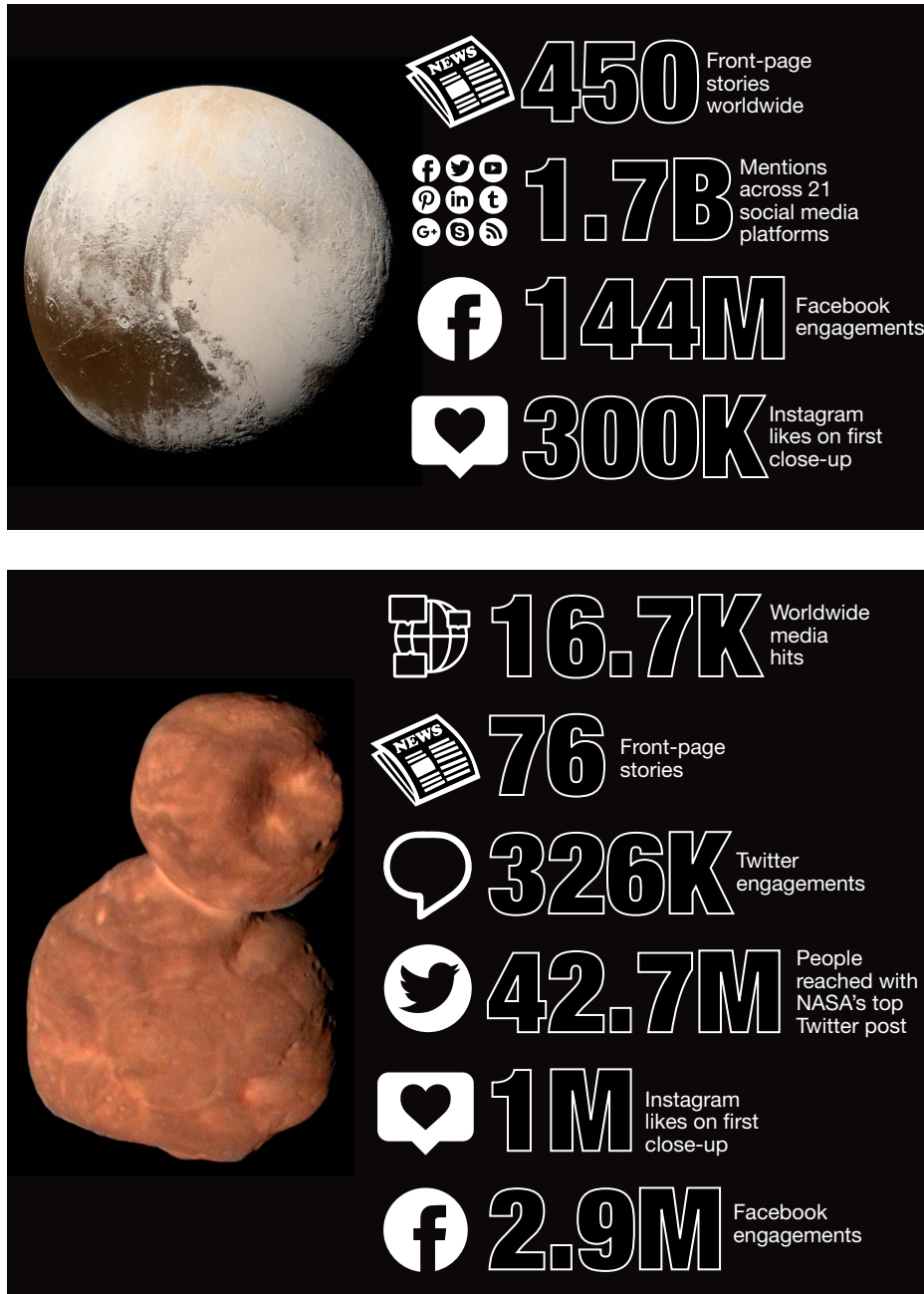
stories of interest as they occur. The mission team coordinated three of these dedicated interview sessions with NASA Communications and NASA TV.

### Managing Expectations

The New Horizons team still works hard to set reasonable public expectations of mission events and the amount, duration, and quality of data. The Pluto and Arrokoth encounters were not typical planetary flybys with a flurry of immediate data collection and transmission. Owing to the low transmission rates from Pluto,

the spacecraft sent data back to Earth up to 16 months after it had finished collecting it; as a result, many of the mission’s major discoveries resulted from examining data that arrived late in 2015 or during 2016, well after New Horizons flew through the Pluto system.

At Arrokoth, even the spacecraft’s most powerful camera was unable to resolve the KBO (beyond a few pixels) until the day of the flyby. Unlike the landing of a rover on Mars that operations teams can witness in near real time and confirm by a set of images, New Horizons was out of contact with Earth during most of the Pluto



**Figure 10.** Highlights from the public outreach campaigns for the Pluto (top) and Arrokoth (bottom) flybys.

and Arrokoth flybys. With the signal from New Horizons needing about 6 h to reach Earth from the Kuiper Belt, real-time operations coverage was limited.

## SUCCESS!

The New Horizons team introduced Pluto and one of its largest, most mysterious Kuiper Belt companions to the world. From the hundreds of events held around the country, to the millions of STEM students and members of the general public we inspired, to the billions of people who responded to our unprecedented public engagement and outreach campaign (Figure 10) on live NASA TV, social media, and through the press, we shared an amazing, thrilling story about the excitement and importance of space exploration.



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Michael R. Buckley is the senior communications manager in APL's Communications Department. He has a BA in journalism from the University of Maryland, College Park. Mike is a strategic, creative communications leader, drawing from extensive and progressive experience in public relations, news reporting, storytelling, editing, interviewing, photography, public speaking, publications, and crisis communications to craft products ranging from news articles, press releases, websites, and newsletters to annual reports, marketing materials, videos, presentations, and strategic communications plans. He has led national and international public and media relations for APL programs, including those for NASA's New Horizons mission to Pluto, its Parker Solar Probe mission to the Sun, and its Dragonfly mission to Titan. His email address is michael.buckley@jhuapl.edu.



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aeronautical science, with a concentration in space studies, from Embry Riddle Aeronautical University. She managed education, communications, and public outreach for the following missions and instruments: NEAR (Near Earth Asteroid Rendezvous), TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics), New Horizons, CRISM (Compact Reconnaissance Imaging Spectrometer), the Interstellar Innovative Explorer, and the STEREO (Solar TERrestrial Relations Observatory) twin observatories.



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