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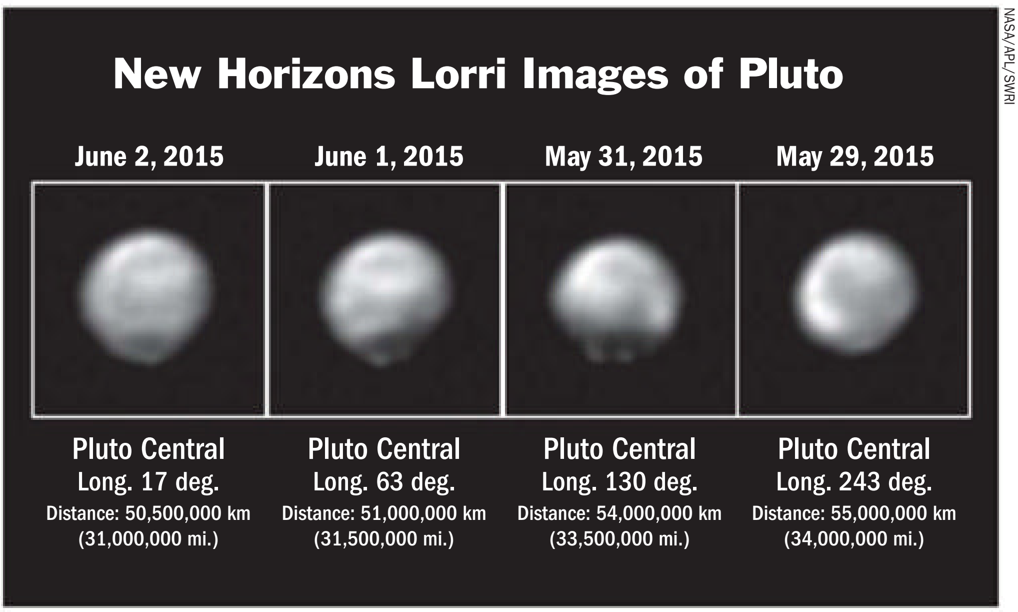
Long-Distance Data

Approaching close encounter at Pluto will initiate a long science download

Frank Morring, Jr. Washington

A nuclear-powered spacecraft the size of a baby grand piano is in final approach at Pluto, an object so distant our understanding of what it is has changed dramatically since the $700 million mission lifted off almost a decade ago on the fastest ride ever out of Earth's gravity.

When New Horizons launched from Cape Canaveral atop an Atlas V 551 at 2 p.m. EST on Jan. 19, 2006, most people—including NASA's launch commentator—believed it was leaving on a mission to the most distant "planet" orbiting the Sun. Today Pluto is no longer even classified as a planet but a "binary dwarf" instead.



It also has acquired more known moons and a new place in the structure of the Solar System. Pluto is no longer considered an outlier, but is instead probably the biggest body in a region of primordial objects that extend much deeper into the heliosphere. That zone, known as the Kuiper Belt, likely holds answers to some basic questions about how our corner of the Universe formed.

New Horizons' long-range camera has been producing better images of Pluto than the Hubble telescope since mid-May.

Today, as it nears its primary destination, it still is not clear what New Horizons will find when it hurtles through the Pluto system on July 14. Only in mid-May did the probe's Long Range Reconnaissance Imager (Lorri) begin generating images of Pluto with better resolution than the smudged blur generated by the powerful Hubble Space Telescope. And even with sophisticated processing, the Lorri data have been of more utility in seeking hazards ahead of the spacecraft than in plotting a precise ground track on Pluto's surface for the camera to follow.

"We don't know what particular parts of Pluto are what we need to go after," says Andy Cheng of the Johns Hopkins University's Applied Physics Laboratory (APL), Lorri's principal investigator. "We're going after the parts that we can, at the best resolutions that we can get."

Those resolutions will be pretty darned good—better than 100 megapixels, says Cheng. And Lorri is optimized for the low-light conditions at Pluto, which is almost 40 times farther from the Sun than Earth, and a place where high noon is comparable to the first and last hours of daylight here. Cheng and his colleagues also expect to be able to image Pluto's night side by using moonlight reflected from its large orbiting partner Charon.

Charon was discovered only in 1978, almost 50 years after astronomer Clyde Tombaugh found Pluto in 1930, as he blinked between two photographic plates exposed at the Lowell Observatory in Arizona. He was looking for moving objects at what he thought was the edge of the Solar System. The two next-largest moons—Nix and Hydra—were discovered in 2005 with Hubble as the New Horizons team prepared for the mission, and the big space telescope spotted two more—Kerberos and Styx—in 2011 and 2012, respectively.

NASA considered Pluto a flyby target for its Voyager 1 probe, which launched in September 1977, but dropped it in favor of a visit to Saturn's large moon Titan. Alan Stern, the New Horizons principal investigator, was part of NASA's first study on the feasibility of mounting a dedicated mission to Pluto.

That was in 1989, and Stern—a steady mission advocate since then—likes to point out that some of New Horizons' postdoctoral scientists were still in diapers when he started. After a generation of work, the payoff will come with a tight choreography of imaging and scientific measurements, as New Horizons zips between the Pluto/Charon binary and the outer moons at more than 30,000 mph, passing within 12,500 km (7,750 mi.)

of the larger body before hurtling deeper into the Kuiper Belt.

Because of the need to slew the spacecraft and point its instruments as needed during its closest encounter, its high-gain antenna will be temporarily out of position to send data back to Earth. Engineers and scientists gathered at APL, in Columbia, Maryland, will await an "I'm alive" signal indicating the spacecraft made it through. That is expected at 8:52 p.m. EDT on July 14.

Some compressed first-look data, including imagery, will follow starting early the next morning. Because of the low bandwidth and low power available to send it the 3 billion miles

First Reconnaissance

New Horizons probe was built for maximum data acquisition on a flyby

Frank Morring, Jr. **Washington**

It has taken 9.5 years to get there, but at more than 30,000 mph the New Horizons probe's flyby of Pluto will take only about 30 min.

Approaching at an angle set to give its instruments maximum use of the dim light from the Sun, the probe will pierce the bullseye of Pluto's system just inside the orbit of its moon Charon (see illustration, page 63).

The big moon will be on the opposite side of the dwarf planet as the spacecraft pirouettes through a preset series of slews to point its two cameras to collect imagery—some of it in stereo—at a range as close as 12,500 km (7,750 mi.) to Pluto's surface, and position its other instruments for maximum data capture.

"It's a very carefully choreographed dance, because you have a bunch of instruments, and so every last second of the encounter, almost, has been carefully thought through—what should we do when," says Andy Cheng, principal investigator on one of the cameras. "So basically every instrument is taking its turn."

Cheng is chief scientist at the Johns Hopkins University Applied Physics Laboratory (APL), where New Horizons was built and where he and his colleagues will wait anxiously for a short signal on the night of July 14 indicating that the spacecraft has made it through the Pluto system intact. The probe's 2.1-meter (6.9-ft.) high-gain antenna will be pointed away from Earth during the flyby so the instruments can point where the scientists have decided they need to, and the encounter will be conducted in radio silence.

New Horizons Principal Investigator Alan Stern of the Southwest Research Institute (SwRI) says his team decided to spend its funding on the sophisticated imagers, spectrometers and other instruments that will collect the data, and he is willing to wait for it to come home

BEN COOPER/LAUNCHPHOTOGRAPHY.COM

The New Horizons spacecraft was the fastest vehicle ever to leave Earth when it launched on an Atlas V on Jan. 19, 2006.

separating Earth and Pluto, it will take more than a year for all the data to trickle home.

As that happens, mission planners will be working out the details of a planned flyby at a Kuiper Belt Object about three more years down the road. Data from that encounter would have a similarly glacial playback, continuing to make New Horizons—three decades after work started—the scientific gift that keeps on giving.

Digital Extras *Data from New Horizons' historic encounter with Pluto—including early images and groundbreaking scientific measurements—should continue streaming back to Earth until the end of 2016. Follow our coverage on* **AviationWeek.com**

"The payload that this spacecraft carries—seven scientific instruments for remote-sensing and in-situ studies—is the most powerful payload ever sent on the first reconnaissance of a new planet in the history of space exploration," says Stern, who helped with the first NASA study of a dedicated Pluto mission in 1989.

Ultimately, it will take about a year and a half for all 70 gigabytes of data collected during the period before, during and after closest approach to trickle back to Earth. New Horizons already has been logging plenty of time on NASA's Deep Space Network (DSN) since it came out of hibernation for the flyby. While July 14 is the day of closest approach, the encounter operation began on Dec. 6, 2014, when controllers in APL's small spacecraft-control center awakened the probe from its final hibernation of the 3-billion-mile transit from Earth.

Phase 1 of the encounter science program started on Jan. 15, when Cheng's Long Range Reconnaissance Imager (Lorri) started scanning the path ahead of New Horizons for navigation data and hazards too dim to be seen from Earth. Science operations and data playback will continue until November-December 2016, as data from the flyby returns to the DSN dishes in California, Spain and Australia at 1,000-4,000 kilobytes per sec.

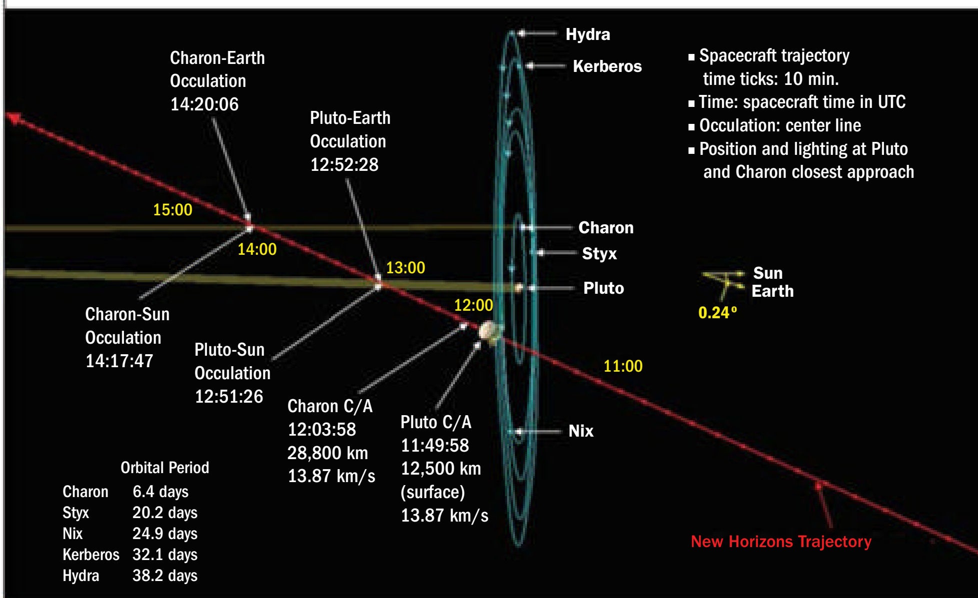
The spacecraft will take "hundreds" of observations as it approaches, passes and recedes from Pluto, says Leslie Young of SwRI, deputy project scientist and Pluto encounter planning lead.

"We only fly by Pluto once, so we need to make the most of it," she says.

That sort of time-intensity has been typical of the New Horizons mission from the beginning. Just as July 14 has been a firm deadline for the flyby since liftoff, the planetary lineup for that launch made it imperative that the mission leave the ground between Jan. 11 and Feb. 14, 2006. And to get a gravity assist from Jupiter, or face a costly delay in reaching Pluto, the spacecraft needed to lift off by Feb. 2 of that year.

NASA picked the SwRI/APL proposal in November 2001, after a head-to-head completion with the Jet Propulsion Laboratory. Work officially started the following January, giving the scientists and engineers almost exactly five years to get ready.

As with any spacecraft development, meeting that launch-window deadline was an ongoing challenge. So were the unique requirements of sending a meaningful mission to Pluto,



NASA/APL/SWRI

starting with the need for a radioisotope thermoelectric generator (RTG) to provide electricity out where there is not enough solar energy for power. But the engineers designing New Horizons soon found that bureaucracy could be as strong a force as gravity.

"The biggest challenge was not technical, although the technical challenges were there," says Glen Fountain, the New Horizons project manager at APL. "The biggest challenge was getting approval for launching the RTG with 11 kg of plutonium."

The earlier Cassini mission to Saturn also had carried an RTG, and safety concerns over possible accidental release of its Plutonium-238 fuel had triggered a public outcry before it was launched on Oct. 15, 1997. Ultimately, New Horizons may have been spared the same kind of public opposition because, unlike Cassini, its trajectory did not require an Earth flyby that could have dispersed Pu-238 in the upper atmosphere with an accidental reentry.

For engineering simplicity, the only radioactive material New Horizons carries is in the RTG. Designers chose a system of heat ducts instead of isotope heaters, and wrapped the spacecraft with advanced thermal blankets, to keep its electronics at room temperature. But there were problems procuring enough Pu-238, as well as production slowdowns caused by security and safety issues at the Energy Department's Los Alamos National Laboratory, where the RTG fuel pellets were processed. Ultimately, "everything kind of fell into place," says Fountain, and the RTG was ready to go on time.

Because of the problems, the RTG wasn't able to deliver as much power as initially planned—201 Watts at Pluto instead of 220—which underscored the value of keeping margin in the spacecraft's design, according to Chris Hersman of APL, who led the spacecraft design group. With only enough onboard power to light a good reading lamp, Hersman's team had to do everything it could to minimize power consumption, including designing a digital radio that pushed the state of the art at the time.

"Now, 10 years later, digital receivers may not seem so rare, but at the time we couldn't get one," he says. "We had to build it ourselves, you know, a space-qualified digital receiver. Now we're using it in a lot of other missions as well, but it enabled the mission because there are two receivers on board, and you usually want to power them both all the time for redundancy and to make sure you can get commands into the spacecraft. Typically, those might take 10 or more Watts each, and this one . . . essentially saved us about 14 Watts of power, when we compared what an analog receiver might use."

Building the high-gain antenna to hold its shape in the cold vacuum of space, with one side getting a heat load from the RTG, required careful attention to detail but no new technology. However, the 2.1-meter dish caused a few gray hairs when it was placed in a thermal vacuum chamber at Goddard Space Flight Center. Inside the chamber, as the temperature plunged under vacuum, the readouts went haywire and the engineers feared the antenna had cracked in the cold.

"They pumped back up to room atmosphere and opened the chamber, and [found] all the dots [used as targets for the instrumentation] had popped off and were collecting in the bottom of the chamber," Hersman says. "It had nothing to do with the antenna. It was just the adhesive that we used to stick them on."

Because of the long trip to Pluto, the design team built a spacecraft that had only a few moving parts. Although now it is in 3-axis control to point its fixed instruments, it has been spin-stabilized for most of the mission. That feature required a fine balance so the spacecraft would spin around the axis of the high-gain antenna, and getting it right was difficult because APL couldn't use the hot—and heavy—actual flight RTG for balance testing.

"You have to dummy up a simulated RTG that has its mass properties, and you spin-balance it with that, and if those mass properties are not quite right you can be off," says Fountain. "So that was another one of our risks, and we found after launch that we had a slight misalignment. It was very small, a little bit more than we wanted, and we believe that was due to a slight error in our estimation of the mass properties of the RTG and how we placed it on the spacecraft."

The problem shows that it can be as challenging to execute a spacecraft

Into the Third Zone

Frank Morring, Jr. Washington

Today scientists believe Pluto is the largest object in the Kuiper Belt, a distant zone of primordial objects left over from the formation of the Solar System more than 4 billion years ago.

New Horizons will pass near Pluto and its five known moons on July 14, and then plunge deeper into that little-understood region that constitutes a third zone of the Solar System, in addition to the rocky inner planets and the gas giants beyond the asteroid belt.

It has taken 9.5 years for the probe to get this far. Here is the route it has taken and where it hopes to go after it passes Pluto:

LAUNCH

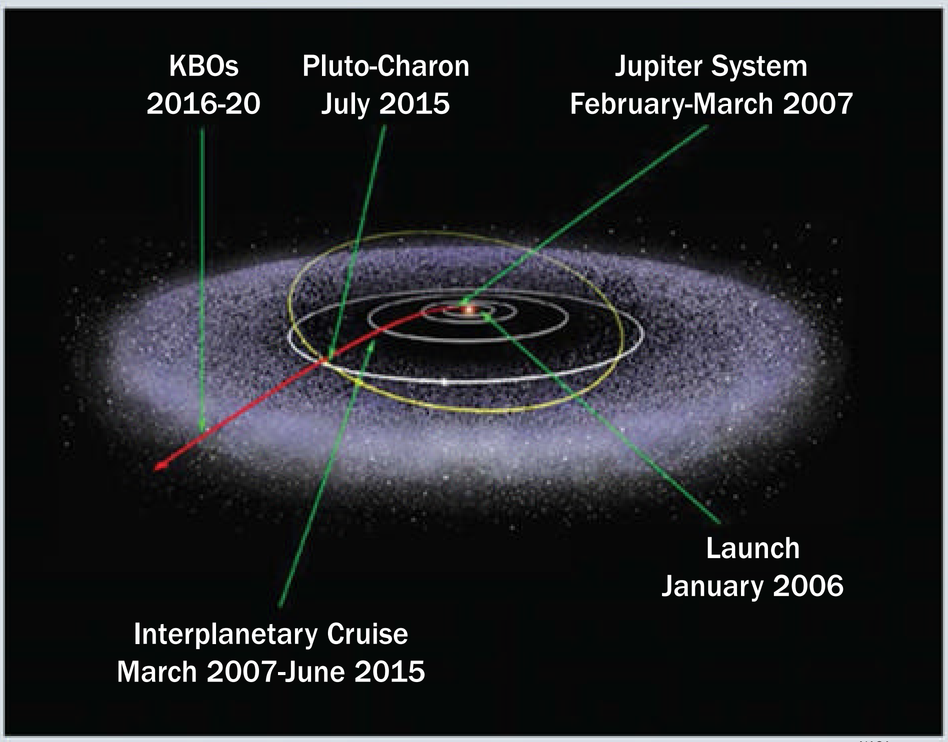
New Horizons leaves Earth on Jan. 19, 2006, atop an Atlas V 551, with a Centaur second stage and a solid-fuel Star 48B third stage. The fastest vehicle ever to leave Earth orbit, it achieved a velocity of 58,536 kph (36,373 mph) on its direct escape trajectory from the Sun's gravity well.

JUPITER

On Feb. 28, 2007, the spacecraft pulled a gravity assist from the gas giant that shaved three years from its flight time to Pluto. Engineers and scientists also took the opportunity to practice flying New Horizons, exercising its instruments and control software to collect "significant" data from as close as 2.3 million km to the planet, at a speed of about 23 km/sec. (51,000 mph).

CRUISE

From March 2007 until this June, the spacecraft was in hibernation mode most of the time, spinning about the



NASA

design as it is to create it in the first place. Fortunately, the balance overall "was within the parameters we needed," says Fountain.

The spacecraft trajectory took it outside the heaviest radiation belts around Jupiter when it picked up a gravity assist there in February 2007, but its hardened electronics have still experienced more single-event upsets than predicted—about one per year instead of one for the whole mission. That, and the uncertain debris environment around Pluto, makes the careful planning that went into programming the spacecraft for autonomous operations during the closest encounter particularly important. Basically, if there is an upset during autonomous operations, the clock keeps ticking until the flight computers reset themselves.

"If you were in the middle of an observation, you might lose that observation, but the next observation is designed to pick up from the same place, and the autonomy is designed to leave the spacecraft in a known state, ready to take observations," says Hersman. "So that way, if you had the problem during an observation, you might lose that one, but we built the encounter sequence to be redundant, so there are multiple observations with the same scientific goal."

New Horizons left Earth faster than any vehicle before or since, launched on a direct trajectory to its Jupiter gravity assist. That required its Atlas V to use five solid-fuel boosters, and crews at Cape Canaveral AFS were mounting them in October 2005 when a late-season hurricane named Wilma blew across Florida from the Gulf of Mexico. The storm damaged the 280-ft.-tall folding fabric doors on the assembly building at Launch Complex 41 and dinged one of the boosters already installed on the rocket.

Fortunately, there was a spare onsite for the damaged booster, and the approaching storm had halted work before the final unit could be attached, so it wasn't harmed. Had it been, the mission couldn't have hit its launch window, Fountain says, joking that "I'd rather be lucky than good," and praising the "fabulous" personnel at Kennedy Space Center for getting the launch off on time. He and his teammates have the same regard for the DSN team and for the experts at Los Alamos and the Energy Department who scraped together enough plutonium dioxide for the mission to go forward.

"The moral of this story is twofold, I believe," Fountain says of the latter instance. "One is you need to design systems with margin. That's a good engineering practice, and that's something that we did. And two, when you're faced with a problem across boundaries, work together to find a solution."

axis of the high-gain antenna for propellant-saving stability and sending a health-check signal once a week. Controllers activated New Horizons for about 30 days a year for more detailed hardware checkouts and navigation updates. The mission team also used the time to rehearse the encounter at Pluto. Milestones were the orbits of Saturn (June 8, 2008), Uranus (March 18, 2011), and Neptune (Aug. 25, 2014).

PLUTO

The closest approach to the dwarf planet will come at about 7:50 a.m. EDT on July 14, but the science operation started in mid-January and will continue for at least 170 days after the flyby. During the approach and flyby the spacecraft has shifted to 3-axis control. The flyby itself will be controlled autonomously by onboard computers to point the seven fixed instruments at carefully planned scientific targets, which will shift New Horizons' high-gain antenna away from Earth.

KUIPER BELT OBJECTS

Plans call for New Horizons to proceed into the Kuiper Belt to study one of the small, ancient Kuiper Belt Objects (KBO) there. The science team is using data generated by the Hubble Space Telescope to identify and characterize a target that is within reach with the fuel remaining on board.

For the Textbooks

New Horizons ready to open a new page

Frank Morring, Jr. Washington

Planetary scientist Alan Stern has spent his whole career getting ready for Tuesday, July 14, 2015.

Now 57, the New Horizons principal investigator started working on a dedicated mission to explore Pluto in the 1980s, when he was still in graduate school. But his inspiration for New Horizons goes further back.

"This is a mission plucked out of the sixties or seventies, when NASA was going first to everywhere—first to Mars, first to Venus, first to Jupiter, first to Mercury," says Stern, who is based at the Southwest Research Institute (SwRI) in Boulder, Colorado. "This is one of those, from your childhood, but with 21st-century technology."

The spacecraft is in the midst of taking "hundreds" of images and science measurements, "about half" of them programmed for the day that surrounds closest approach to Pluto at 7:49:57 a.m. EDT, according to Leslie Young, the deputy project scientist and Pluto-encounter planning lead.

Data from the approach has already answered one question about Pluto and its big moon Charon—what color are they? In the first color images collected on approach, Stern sees Pluto as "beige-orange," while Charon is gray.

"Exactly why they are so different is the subject of debate," he says.

Like all good science missions, New Horizons is designed to raise such questions, as well as to provide answers. To that end, the spacecraft will be autonomously following a set of priorities hammered out by the planetary-science community years before Stern and his team were picked to meet them in November 2001.

"We set our priorities up in a fairly straightforward way," says Young, also of SwRI. "We have our science goals, and they're ranked. The Group 1 goals are required, and those come with specific quantitative subgoals, like what resolution. That very specifically says when you have to take those observations, given our instruments and our flyby distances."

At a "required" Group 1 minimum, New Horizon is expected to characterize the global geology and morphology of Pluto and Charon; map the surface composition of the two bodies, and

If New Horizons flew past Earth, this is how it would resolve the New York City area.

ALAN STERN/SWRI

characterize Pluto's atmosphere and its escape rate.

Since those goals were set in the 1990s, Pluto has been downgraded from a "planet" to a "dwarf planet" and, as its close connection with Charon has become better understood, as part of a "binary dwarf." A "highly desired" objective from Group 2 should be met during radio and ultraviolet occultation measurements after closest approach, when New Horizons is set to determine if Charon has an atmosphere.

Other Group 2 objectives include characterizing the time variability of Pluto's surface and of its atmosphere, which may precipitate out in the coldest stretches of its 250-year orbit. Also on the Group 2 list are collecting stereo images of Pluto and Charon; mapping surface temperatures of the two bodies; mapping the surface compositions of some areas on both in high resolution; characterizing Pluto's ionosphere and its interaction with the solar wind; and identifying as much of the neutral atmospheric chemistry as possible.

The "desirable" Group 3 list is short: characterize the energetic particle environment of Pluto and Charon; refine measurements of the two bodies' radii, masses, densities and orbits; and look for rings and additional moons.

"For our Group 1s, we make sure that every goal has a prime observation, a backup which was almost as good as the prime, and then, in the case of a failure of an instrument, how we could address that Group 1 [objective] at all," says Young.

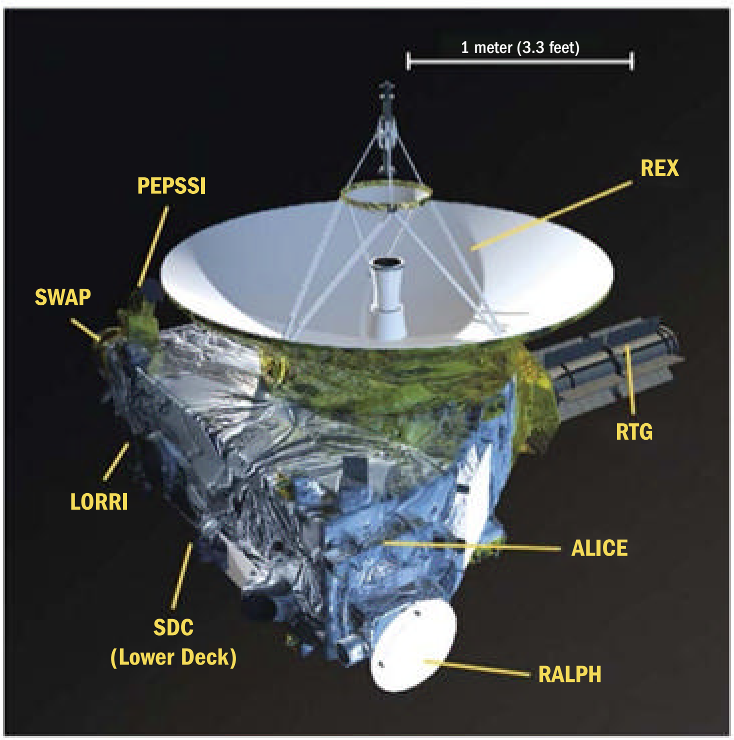
As an example, if the main mapping camera isn't working, backup maps can be made from mosaics collected with the other imager. But there won't be a second chance on some measurements, particularly those taken with the unprecedented 80,000-Watt "uplink" occultation signal beamed through Pluto's atmosphere from the Deep Space Network on Earth (see page 67).

Even so, the spacecraft designers have backups in other wavelengths to measure the atmosphere of Pluto and of Charon—if there is one. In case the Radio Experiment (REX) incorporated in the probe's redundant digital radios doesn't work, the instrument dubbed Alice can pick up some of the slack with ultraviolet (UV) light from the Sun.

"Simultaneous to what we're doing at X-band, the Alice instrument is doing in the UV at the exact same time," says SwRI's Michael Vincent, the REX and payload system engineer and the deputy radio frequency engineer on the mission, describing the nominal instrument handoff. "So you can combine those data sets and determine . . . what's happening further out from the planet with Alice and then, as you get close, REX picks up the ball there and you can figure out what the atmosphere is actually made of."

If REX doesn't work, scientists still will have the Alice data. The encounter plan was worked out after the spacecraft flew past Jupiter for a gravity assist in February 2007 and was "essentially on the shelf" and ready to go by the summer of 2009, according to Young. Some updates were added to accommodate new discoveries, she says, including a "color sweep across the entire system" to make color observations of the four smaller moons outside Charon's orbit, and of any others that may be discovered.

The team rehearsed the closest 24 hr. in 2012, but since then the observation sequence has been left alone. "The bar was extremely high" to get an observation into the sequence, and it will play out as programmed unless a diversion is deemed necessary to avoid hazards spotted at the last minute. Four "safe haven by other trajectory" routes were



The seven instruments wiil draw power from the nuclear RTG to collect 70 GB of data at Pluto.

NASA/APL/SWRI

planned, with a diversion possible as late as June 30.

Bill McKinnon, a member of the New Horizons science team who has chaired NASA's Outer Planets Assessment Group, says Pluto is "an archetype for all the large dwarf planets in trans-Neptunian space," the unexplored region beyond the orbit of the gas giant Neptune that is better known as the Kuiper Belt. Exploring Pluto and its moons will give scientists their first look at this third zone of the Solar System—outside the rocky inner planets and gas giants beyond the asteroid belt.

"The Kuiper Belt is littered with small planets," says Stern. "We didn't know it, but our Solar System, and probably others, [is] very good at making small planets. No longer [is] Pluto a misfit. It [is] part of the dominant planet class in our Solar System. It's not the terrestrials that are normal. It's not the giant planets that are normal. It's the little ones, and it's completely unexpected."

Stern has been much in demand for talks and media interviews in the runup to the flyby, and he says he finds that he gets a lot of questions that he can't answer because "it's been so long since we've had raw exploration.

"You're used to the 16th mission to Mars, the ninth mission to Jupiter, where you have really detailed questions," he says. "In this case it's really eyes wide open. What is this place? How does it look? What is it made of? How does its atmosphere work? What are the characteristics of its moons? How many are there?"

A former associate NASA administrator for science who has tickets and the training to fly research missions on two of the commercial suborbital human vehicles now in development, Stern brings missionary zeal to his work. He is not shy about how he sees its significance.

"Just like Voyager or Apollo, I think New Horizons is the capstone event in the reconnaissance of the Solar System," Stern says. "We'll be in textbooks. When you read that paragraph about Pluto in grade school in the year 2115, the picture will be from New Horizons."

Digital Extra *See images and more about the seven instruments on the $700 million New Horixons mission:* **AviationWeek.com/NewHorizons**

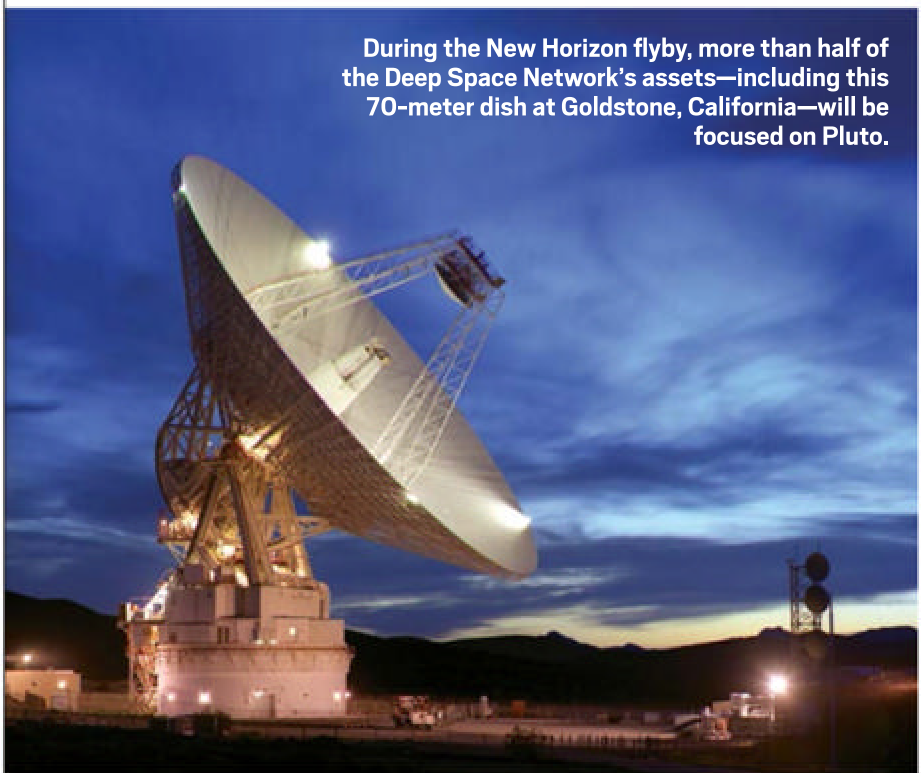
Long Link

Guiding New Horizons probe to Pluto and retrieving its data is a challenge

Frank Morring, Jr. Washington

New Horizons will maintain radio silence when it flies through the Pluto system, but more than half of the huge antennas operated by the Deep Space Network (DSN) will be listening.

The probe's seven instruments are fixed. As the spacecraft slews through a closely timed series of maneuvers to point them, the 2.1-meter (6-ft.) high-gain antenna that sends and receives signals across the 3 billion mi.—a 4.5-hr. round trip—to Earth won't be pointed there.



During the New Horizon flyby, more than half of the Deep Space Network's assets—including this 70-meter dish at Goldstone, California—will be focused on Pluto.

NASA

But right after closest approach, as New Horizons flies behind Pluto and its largest moon Charon, the DSN will light up to blast the spacecraft with a a high-power uplink for radio-occultation atmospheric measurements. It will use three dishes at each of the two ground stations that will be facing Pluto, plus another to send bistatic radar signals.

"We have bookkept seven [dishes] simultaneously for that number of hours, seven of the 13 that the DSN has," says Chris DeBoy of the Johns Hopkins University Applied Physics Laboratory (APL), lead radio-frequency communications engineer on the mission. "Obviously [the DSN station at] Madrid is facing in the wrong direction. Otherwise, we would have taken them, too."

The Radio Experiment (REX) circuitry built into the spacecraft's state-of-the-art digital radios are set to analyze how the atmosphere of Pluto— and that of Charon, if it has one—bends radio waves as they pass through. The occultation technique is a standard tool for planetary scientists, but because of the low onboard power and long distance home, REX is the first that will operate on an uplink signal to the spacecraft instead of the probe sending signals back through a planetary atmosphere to Earth.

"The real lion's share of the antennas' time is for the Pluto and Charon occultations," says Mark Holdridge, the Pluto encounter mission manager at APL. "We have a large number of DSN assets that will be transmitting to New Horizons simultaneously for REX, and that's a one-shot deal. We fly through the shadow and we point the spacecraft back at the Earth during those occultations, and if we don't have those uplinks at those times then it's lost."

After guiding New Horizons to Pluto for 9.5 years, Holdridge and his team have done everything they can to avoid coming up empty-handed. The heavy DSN use on flyby day includes 34-meter X-band dishes at the two stations that will be facing Pluto—Goldstone in California and Canberra in Australia—to back up the main 70-meter units there, plus 34-meter "cold spares" just in case. The seventh antenna will be blasting Pluto with 80,000 Watts for bistatic-radar mapping of the surface with REX.

New Horizons has performed very well during its interplanetary voyage, but it is literally a journey into the unknown. Two small moons were discovered after launch in 2006, raising fears there might be undetected space debris along the trajectory through the Pluto system that could prove fatal to the fast-moving spacecraft.

To obtain at least some scientific data, the mission plan includes five "failsafe downlinks" on July 13—the last only 13 hr. before closest approach.

"They're really there as a risk mitigation in case we were to have a particle impact," says Holdridge. "Basically these would be the goods that we would have to show for our efforts. There's a very select amount of data. They're short downlinks, but they're kind of a representative smattering of science that at least we'll have down on the ground before we fly through the satellite plane."

The team has calculated there is less than a 1% chance debris will be in the way, largely because Charon's gravity has acted as a kind of debris-magnet over the eons to clear the space where New Horizons will fly.

The spacecraft's Long-Range Reconnaissance Imager (Lorri) has been checking for hazards during approach. While the final trajectory is set, data

SPACE

Cost Avoidance

Sbirs satellite redesign stabilizes cost, a step forward after a history of overruns

Amy Butler Washington

The U.S. Air Force is touting more than $1 billion of cost avoidance through a redesign of the Space-Based Infrared System (Sbirs) early missile warning satellite built by Lockheed Martin.

Program leaders in the company and the service negotiated a modification to the June 2014 contract award for Sbirs geosynchronous (GEO) satellites 5, 6, to introduce a "technology refresh" at no additional cost to the government, Col. Mike Guetlein, Sbirs program manager for the Air Force, tells Aviation Week.

The refresh addresses obsolescence and simplifies the design to incorporate a more open architecture. The deal also provides data rights to the Air Force so future upgrades can be managed in-house. Sbirs GEOs 5, 6 are estimated to cost $2.3 billion total, including launch and nonrecurring engineering funds. This is only slightly lower than Sbirs GEO 3, 4, which cost about $2.5 billion total in the same year's dollars.

The $1 billion of cost avoidance is a comparison to the Pentagon's estimate of the GEO 5, 6 price based on the old design.

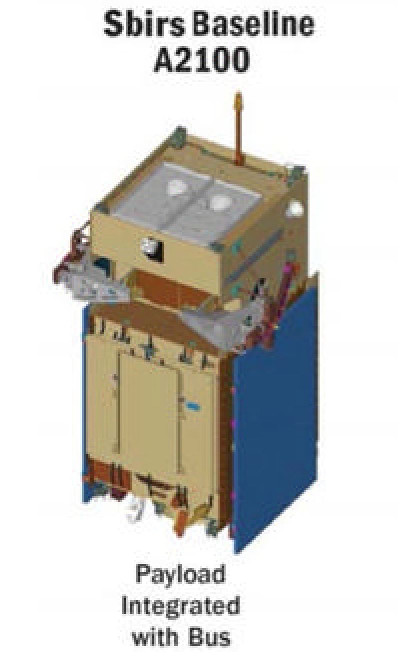
But the refresh design allows for more flexibility, Guetlein says.

These satellites, designed with infrared (IR) scanners and staring sensors to detect ballistic missiles as they launch, are slated to be deployed in 2020 and 2021, says Dave Sheridan, Lockheed Martin's Sbirs program director.

Air Force and Lockheed Martin officials are keen to crow about savings in Sbirs, owing largely to its notorious history of multibillion-dollar overruns and late deliveries. In March 2014, the Government Accountability Office (GAO) reported the total Sbirs program cost—including six GEO satellites and four sensors on classified host satellites in highly elliptical orbit—was $18.9 billion, $14.1 billion over the original program cost (which included only five GEO satellites). The program is also nine years late, the GAO says.

Despite the high cost, commanders have praised Sbirs for its performance in orbit. Because of its classified nature, little detail has been provided.

Lockheed Martin infused elements of its A2100 refresh into the Sbirs design, which is built on the A2100 bus. The old design had a highly integrated bus and payload, fused into one single module. The new design decouples the payload module from the propulsion system.



Lockheed Martin's redesign of the Sbirs satellite decouples the missile warning sensor payload from the A2100 bus.

The new design is also configured to mate with any Evolved Expendable Launch Vehicle; the earlier design was suited only to the Atlas V. But the refreshed model will be able to operate with the Delta IV and Falcon 9 if needed, Guetlein says.

This, together with improved software and command-and-control systems, allows for ease in adding new payloads, Guetlein says. Sheridan says from a final look-ahead received on July 1 could drive a last-minute decision to alter the command sequence at Pluto to swing the high-gain antenna forward into the ram direction for some protection from any debris.

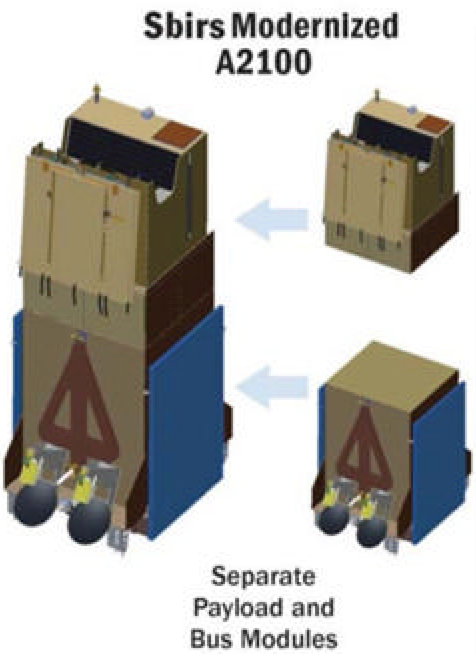
Communications have been picking up steadily since New Horizons emerged from its final hibernation period in December. The instruments were checked out, and Lorri has been used for optical navigation to ensure the spacecraft hits its imaginary target in space—a box measuring 60 X 90 mi. —within ± 150 sec.

Two independent navigation teams have been using their own software to calculate position and course, feeding the results to the mission operations team for final trajectory-correction maneuvers (TCM). A June 14 TCM used a 45-sec. thruster-firing to change the spacecraft's velocity by 52 cm/sec. (1.7 fps.), which moved the spacecraft's projected trajectory 755 km (470 mi.) back to the center of the target. The adjustments are necessary because the navigators are not certain exactly where the planet is.

"We don't know that much about Pluto," says Michael Vincent of Southwest Research Institute, the REX and payload system engineer and the deputy radio-frequency engineer on the mission. "That's why we're going there. And we only have 70 years of an orbit, out of a 250-year orbit. I'm rounding, largely, but we actually don't know its orbit very well, so it's possible it could be further away than we think it is."

Despite the long distance and low power, the communications equipment can maintain signal stability at the levels necessary for REX, thanks to ultra-stable crystal oscillators built at APL for the Pluto mission and also used on the Cassini Saturn probe and various Mars-exploration spacecraft.

"Without the frequency stability, the radio science experiment wouldn't be able to do what it's trying to do, which is measure the neutral atmosphere by looking at the radio signal as it's transmitted from the ground to the spacecraft," says Vincent. "As the phase of that signal walks around in very small amounts as the spacecraft passes behind the planet, you get the information about what the neutral atmosphere of Pluto is actually made of." ⊗



LOCKHEED MARTIN CONCEPT

the company sharpened its pencil on the redesign after the government requested a 30% cost savings for future satellites. He notes the payload is the same system that is provided by Northrop Grumman, and is only shifted in location on the satellite. It will also provide the same performance.

The technology refresh includes the transfer of data rights for key parts of the system to USAF. Because of this, a follow-on to Sbirs will cost roughly 30% less, Guetlein says. "We have interface data rights to the spacecraft, we have data rights to the payload software and to the interface between the ground and the spacecraft.

"The [Sbirs] 3, 4 architecture is very Sbirs-unique and very inflexible to new ideas. The [technology refresh] is now based on an open architecture where we own all the interfaces and we can add or subtract capability easier."

The Air Force is expecting to finish a long-awaited analysis of alternatives for the future early missile warning mission in August. Since Sbirs was designed, technological advances indicate that simpler designs based on staring focal plane arrays could be used. The service experimented with the concept with its Commercially Hosted Infrared Payload program.

In that project, an IR telescope developed by Science Applications International Corp. was lofted into orbit on a commercial communications satellite owned by SES. The sensor included a 2,000 X 2,000-pixel focal plane array and provided input on how such a sensor could be used in the future for early missile warning.

The results of the analysis of alternatives will likely be borne out in the forthcoming fiscal 2017 budget being crafted this summer at the Pentagon, to be sent to Congress in February 2016. This could lead to an altered future design, or full competition for a new constellation.

Meanwhile, Guetlein says there is progress in the Real Time Transfer service, a collaborative new "cloud" of overhead IR data hosted by the National Geospatial Intelligence Agency. It will include IR data collected by the intelligence community, Air Force and other government agencies. The service is intended to provide time-sensitive IR data to users worldwide more quickly.

Guetlein says it should be operating by this summer, and the plan is to incrementally grow the number of users who can access the data. The goal is for Sbirs and other data not only to be used for ballistic missile detection but to help as well with other missions.

The Sbirs staring sensor—the newest technology between the scanner and starer—is slated to make its official operational debut this summer as well. Though scanning sensors have been working on both Sbirs GEO satellites lofted since 2011, they were not certified to pass the most critical warning information to the national command authority, which would then react with the use of missile defenses.

The starer has been on a long path for checkout and validation because it was new compared to the Sbirs scanner and the Defense Support System's scanning sensor before it. Guetlein says it will be finally certified in the coming months for relaying messages in the Integrated Threat Warning and Attack Assessment system, which is used by the president and senior commanders to warn of ballistic missile attack and to pinpoint possible impact zones.

The scanning sensor—which uses older technology to sweep over the globe looking for missile plumes—was certified in 2013. The starer does not require revisit time like the scanner does. ⊗