The difficult birth of NASA's Pluto mission

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A history of the patronage, design, and funding of *New Horizons* offers a glimpse of how US space-science policy was formulated before and after the turn of the 21st century.

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As spectacular pictures slowly trickle back from an enormously distant *New Horizons* spacecraft, which shot through the Pluto–Charon system on 14 July 2015, it is easy to think that this mission was inevitable—the capstone to the US's pioneering exploration of the solar system. But it took 17 difficult years to get from the first proposal to launch day, 19 January 2006. On the way, there were many changes of course and three outright cancellations. Far from being inevitable, the Pluto mission was saved from oblivion several times by dogged advocacy, protests by scientists and the public, political intervention by Senator Barbara Mikulski (D-MD), and a timely endorsement by the National Academies.

The first discussions of sending a spacecraft to the then ninth planet date back to the late 1960s. Scientists at NASA's Jet Propulsion Laboratory (JPL) pointed out that in the late 1970s and 1980s, the alignment of Jupiter, Saturn, Uranus, Neptune, and Pluto, relative to Earth, would allow launching two or more spacecraft around 1977 on a "grand tour" of the outer solar system. What came of that idea was the Voyager program, which spectacularly explored the first four above-named planets between 1979 and 1989. But the opportunity to send one of the two Voyager spacecraft to Pluto was dropped in 1979 because Saturn's largest moon, Titan, the only satellite in the solar system with a substantial atmosphere, was both a higher scientific priority and a lower-risk target.

In 1978, meanwhile, US Naval Observatory astronomers had discovered a major Pluto satellite, soon dubbed Charon (pronounced "Shar-on" or "Kar-on"). From the moon's orbital characteristics, it became possible to calculate the two bodies' masses. Pluto was even tinier than expected—about 0.2% of Earth's mass. By an extraordinary stroke of astronomical luck, the system's plane was such that only seven years later, Charon, which has an orbital period of less than a week, began to pass in front of and behind Pluto as viewed from Earth—something that happens only every 124 years. Those events allowed further refinements of the masses and diameters of what amounted to a double planet, with the satellite's diameter being half the 2400 km diameter of the primary.

The transits and occultations also revealed important information about large albedo differences on Pluto's surface and about its large if very thin atmosphere. Moreover, astronomers could discern stark differences in surface composition between the two bodies; those observations led to the theory that a giant impact had knocked off a portion of Pluto's icy mantle to form Charon—analogous to the favored theory of Earth–Moon formation (see the article by Dave Stevenson, PHYSICS TODAY, November 2014, page 32). Pluto had thus turned, in the 1980s, from a little-understood planetary oddball into a scientifically important subject for research.

An opportune intervention

In 1989 that scientific context and *Voyager 2*'s Neptune encounter led NASA once again to consider a Pluto flyby. Alan Stern, shown in figure 1, initiated the project as a graduate student finishing his dissertation at the University of Colorado Boulder. He had worked on Pluto at the University of Texas at Austin in the early 1980s and remained fascinated both by the science and by the prospect of exploring new frontiers. Cognizant of the upcoming Neptune milestone, which marked the end of Voyager's primary mission, on 4 May he visited Geoffrey Briggs, head of solar-system exploration at NASA headquarters in Washington, DC. Stern told Briggs: "I want to know why we don't have a mission to Pluto. There's a bunch of us that would like to see that." Briggs replied, "No one's ever asked that question of me before. I think we should study it." During the American Geophysical Union conference in Baltimore the next week, Stern and other young colleagues organized the Pluto Underground, a group dedicated to advocating such a mission.

The Underground was scarcely alone. A flyby of Pluto would "complete the reconnaissance of the solar system," stated a June 1989 NASA planning document. But that mission conception rested on Pluto's status as the ninth planet and the end of the solar system. The Kuiper belt—a region of icy bodies beyond Neptune once proposed by Dutch American astronomer Gerard Kuiper—had yet to be confirmed. When confirmation came a few years later and astronomers discovered many objects of significant size, the news would revolutionize the concept of the outer solar system and bring Pluto's planetary status into question (see the article by Mike Brown, PHYSICS TODAY, April 2004, page 49). But in 1989 all that lay in the future, and for many, the fact that the US had explored eight planets but not the ninth was argument enough.

FIGURE 1. ALAN STERN, *NEW HORIZONS* PRINCIPAL INVESTIGATOR, celebrates a successful mission with his team in July 2015 by marking out the words "not yet" from a poster-sized print of the US Post Office's 1991 "Pluto: Not Yet Explored" stamp. The spacecraft carried the tiny stamp on its journey to Pluto. From left: Stern, Leslie Young (deputy project scientist), Ralph Semmel (Johns Hopkins University Applied Physics Laboratory director), and Annette Tombaugh (daughter of Clyde Tombaugh, who discovered Pluto in 1930), with her husband behind her. Far right is *New Horizons* coinvestigator Will Grundy. (Courtesy of NASA and Bill Ingalls.)

When *Voyager 2* flew by Neptune on 25 August, it returned some surprising data. The planet's large moon, Triton, about Pluto's size, turned out to be remarkably geologically active despite being extremely cold. Geysers spouted from an icy surface 40 degrees above absolute zero. A likely captured Kuiper belt object, Triton was thus a possible Pluto analogue, given the recent observations of the planet's dynamic atmosphere. According to JPL astronomer and Underground member Richard Terrile, the Triton encounter "had a phenomenal impact."

Another factor made Stern's overture opportune: It occurred while Briggs was trying to get a small-spacecraft initiative started. A sense of crisis prevailed in solar-system exploration at the time. No robotic planetary spacecraft had been launched between 1978 and 1989, in part because of the shuttle *Challenger* accident in 1986. Moreover, NASA was building large spacecraft so expensive that it could only afford one every half decade or longer. The Mars *Observer* orbiter mission, an attempt to lower spacecraft costs, had become mired in overruns and delays that led many to question whether cheap missions were even feasible. But helped by Stamatios "Tom" Krimigis, who energetically advocated small planetary spacecraft, Briggs was able to start the Discovery Program that fall to solicit competitive proposals from scientists. He appointed entrepreneurial orbital-mechanics expert Robert Farquhar (shown with Krimigis in figure 2) of NASA's Goddard Space Flight Center to lead it.

From Pluto-350 to Pluto Fast Flyby

Farquhar was excited by the idea of a Pluto mission. He initiated a study led by Stern and Frances Bagenal, one of the few women in the Pluto Underground. The result was a proposed spacecraft concept called Pluto-350 for its approximate unfueled mass of 350 kg. Thanks to improved technology, it had much of the multi-instrument capability of a Voyager in a package half the weight. But even under the most optimistic assumptions, the mission (not including launch) did not fit under the Discovery Program's cost cap of $150 million. It did not appeal to JPL management either, who found it too small to significantly support an institution of 5000 people.

The laboratory leadership was more interested in an elaborate spacecraft in the proposed Mariner Mark II series, even larger than Voyager. It would fly an Earth–Jupiter gravity-assist trajectory similar to Pluto-350's but would require a Titan IV-Centaur, a booster rocket that cost at least a quarter of a billion dollars. In August 1990 Wesley Huntress Jr, a distinguished former JPL scientist, took over NASA's solar system exploration division from Briggs and quickly settled on the Mariner Mark II proposal.

A working group led by Stern debated whether Pluto or Neptune should be the next target. Pluto won priority because of the forceful advocacy of Stern and others for its scientific importance. Also influential were two arguments coming out of the new science: The atmosphere might "snow out" on the surface as Pluto moved away from the Sun (computer models suggested that the atmospheric collapse might happen as early as the 2010s). And as the highly inclined north pole of the Pluto–Charon system turned toward the Sun, an increasing proportion of the southern hemispheres of Pluto and Charon would disappear into a night that would last decades. Neptune would always be there, but the longer it took to get to Pluto, the less there would be to observe.

That mission, however, quickly collided with a stagnating NASA budget. The US economic downturn that began in 1991, combined with federal budget deficits, the end of the Cold War, and several embarrassing NASA setbacks—notably the *Hubble Space Telescope* mirror problem—resulted in sudden cutbacks in the projected space-science budget. At the turn of 1991–92, Huntress was forced to reduce the scope of the Mariner Mark II program to just the *Cassini* mission to Saturn.

In early 1992 the majority of Stern's team members voted to return to the Pluto-350 concept, but they were quickly challenged by a much more radical proposal: a micro-spacecraft concept developed by Robert Staehle and his small group at JPL. Staehle's idea was to build a tiny Pluto orbiter only tens of kilograms in weight. Orbiting was soon dropped as unrealistic, but the team's early concept was for a 35 kg vehicle integrated around a spare antenna in NASA storage. Called Pluto Fast Flyby (PFF), its only science instrument would be a miniature camera.

The meager scientific return from PFF was a nonstarter in Stern's working group, but it did provoke a useful debate on what the minimum science goals should be. In early 1992 meetings the team decided only three objectives were mandatory: global mapping of Pluto's and Charon's geology and geomorphology at 1 km resolution, compositional mapping of the two bodies at 10 km resolution, and characterization of the composition and dynamics of the atmosphere of Pluto. The minimum payload would thus be a visible-light imager, UV and IR imaging spectrometers, and a radio experiment to measure the refraction of the signal through Pluto's atmosphere as the spacecraft passed behind the planet. But the tiny payload allotment meant creating a miniaturized, highly integrated UV-, visible-, and IR-sensitive instrument, rather than three separate ones. Some space scientists active in the community considered it unrealistic or at least too small.

Dan Goldin steps in

Any debate over which proposal NASA headquarters would support became moot when Staehle met the new administrator, Daniel Goldin, on 27 May 1992. The occasion was a ceremony celebrating the return of an Oscar flown on the space shuttle. Staehle received permission from his manager to present his PFF concept to Goldin at the ceremony in Beverly Hills. Goldin took office convinced that the agency's space-science directorate was ponderous, slow, and wedded to huge and expensive spacecraft. NASA needed to adopt "faster, better, cheaper" development methods and miniaturization technologies that originated in the Strategic Defense Initiative.

Goldin was excited about the junior engineer's idea and kept Staehle's Pluto materials. Staehle went back to JPL, immediately briefed higher management, and followed up with a long letter to Goldin the next day. Staehle wanted to launch a spacecraft by 1997, regardless of skepticism about getting approval to launch nuclear material in that time—like other outer-planets explorers, PFF would have to use a radioisotope thermoelectric generator fueled with plutonium-238 to supply electrical power so far from the Sun.

The drastic reduction to a miniature spacecraft did not go over well with some members of Stern's science working group. But in July they voted 3 to 1 for PFF over a revived Pluto-350 concept. The dramatically changed budget context at headquarters and Goldin's personal interest and space technology policy made it inevitable that only a small and innovative concept would be funded.

On 31 July 1992, Staehle and his team presented further studies to NASA headquarters by phone. They proposed two PFF spacecraft. Because Pluto and Charon are in locked rotation and orbit at 6.4 days, a second spacecraft would be needed to scan the hemispheres unseen by the first flyby. Two spacecraft would also reduce risk for such a daring new concept. Huntress estimated the cost at less than $400 million, as compared with almost a billion for Mariner Mark II. But both figures excluded launch-vehicle expenses, which could be significant. Huntress mentioned two possibilities—a Titan IV-Centaur with two solid-propellant kick stages and a Russian Proton with similar add-on stages.

All signs were that PFF had become a real project, not a paper one, and a favorite of Goldin's. Yet in the end it would be Goldin, not the external critics, who would derail PFF. In

FIGURE 2. STAMATIOS "TOM" KRIMIGIS (LEFT) AND ROBERT FARQUHAR at the Johns Hopkins University Applied Physics Laboratory (APL) in 2001. Farquhar worked with Stern on the Pluto-350 proposal early on, and later headed trajectory design for *New Horizons*. As the lab's space department head, Krimigis was critical to the emergence of the *New Horizons* proposal in 2000–01 and its political survival in Congress. (Courtesy of APL.)

August 1993 he told the team that he could not afford two Titan IVs. Support for Pluto was further undermined by other factors. Later that month, the Mars *Observer* disappeared shortly before it was to orbit the red planet. The loss provoked much criticism of NASA; Goldin had to ask Congress and the Clinton administration for a replacement. In fall 1993 Mikulski succeeded in getting Congress to fund both JPL's Mars *Pathfinder* and the Near-Earth Asteroid Rendezvous (NEAR) mission by the Johns Hopkins University Applied Physics Laboratory (APL). Goldin, under pressure from Congress and the Clinton administration to cut budgets and personnel, was furious at being dictated to. Huntress, now associate administrator for space science, was pleased, but in his first full budget he felt he could not pick Pluto as another "new start." He did not want to appear biased toward planetary exploration over his other major units, astrophysics and heliophysics. Stern says Huntress essentially told him that PFF was being sent to the back of the line for new missions.

The Russian interlude

Frustrated by the lack of progress, Stern went to Moscow in January 1994. He traveled at a politically opportune time when Russian–American space collaboration was reaching a peak: In September 1993 the two nations agreed to conduct joint human missions and merge their space station programs. In addition, NASA's space science directorate had a cooperative arrangement with Russia in Mars exploration, including its next launch.

Stern convinced the Russians to launch both Pluto spacecraft if the two carried Russian impact probes to measure the planet's atmosphere on the way down. The agreement led to a series of joint meetings in Moscow, in Hamburg, Germany, and in Pasadena, California, in 1994 and to exchange visits and

FIGURE 3. *NEW HORIZONS*, ASSEMBLED. The spacecraft is blanketed to retain heat, and it powers its science payload with a radioisotope thermoelectric generator (black, in foreground). The payload consists of seven instruments, which collectively draw a mere 28 watts. They include Ralph and Alice (named after characters in the 1960s television show *The Honeymooners*); Ralph has both a visible-light color camera and an IR imaging spectrograph, and Alice is a UV imaging spectrograph. Together they reveal color, composition, and temperature maps of the surface and atmosphere of Pluto, Charon, and Kuiper belt objects. The five other instruments are a telescopic CCD camera for high-magnification imaging, two plasma instruments for measuring the solar wind and other energetic particles, a dust counter for monitoring the interplanetary environment along the spacecraft's trajectory, and a radio experiment integrated into *New Horizons* telecommunications circuitry for measuring the atmosphere's mean molecular weight and temperature near the surface. (Courtesy of NASA.)

conferences until 1996. But by the end of 1994, warning signs appeared. The Russians first backed away from offering the Proton booster rocket, then from any free launch at all. Attempts to get German financing never gained traction. In late 1996 the deterioration in Russian space-science capability was confirmed by a disastrous Mars launch.

Back in the US, things had not gone well either. Goldin nitpicked the proposals and pushed for radical ideas. The net result was that by 1995, Staehle's JPL team was projecting two spacecraft, renamed Pluto Express, of 75 kg dry weight each. Later estimates put them at 90–100 kg, an indication of the challenges of building such light spacecraft for a mission so deep in the outer solar system. But at 75 kg it was possible to imagine two craft on one large booster or two medium-class launchers using Earth, Venus, and Jupiter as gravitational slingshots.

What emerges from the details of the mid 1990s is a pattern driven almost entirely by Goldin's space-technology policy and personality, magnified by budget problems. Goldin's drive for "faster, better, cheaper" missions was in full flower, and as a result, the JPL team emphasized its innovative technology concepts, not so much the science. But the net result of the administrator's multiple interventions was to string the Pluto project along for years.

From Pluto Kuiper Express to cancellation

On 7 August 1996, NASA officials held a historic press conference and announced that extremely tiny bacteria fossils may have been discovered in a Martian meteorite found in Antarctica. In hindsight, the whole affair appears overblown—the claim ultimately lost favor in the scientific community—but the immense publicity had an immediate impact on NASA space science. The Clinton administration found money for an origins program to look into the origins of life, the solar system, and the universe—a clever repackaging of existing projects. The science budget stopped declining, and even rose a bit, which made possible yet another version of the mission to Pluto.

Huntress was able to get the budget authority to fund a new outer-planets program. It would include Pluto Kuiper Express (PKE), renamed to emphasize the emerging science, and a mission to Jupiter's moon Europa, thought to have a subsurface ocean that might harbor life. In 1998 Huntress created a JPL project office called Outer Planets/Solar Probe, with the rationale that the Europa Orbiter, PKE, and Solar Probe, a mission designed to get very close to the Sun, would all have to encounter Jupiter. All three were also tied to NASA's X2000 program, intended to create a new generation of integrated, radiation-hardened avionics. Wrapping the four projects together made for an appealing political package in Washington and at JPL, but it was to prove the program's downfall.

Staehle was made deputy to a more senior JPL project manager, John McNamee, and the ultralight proposals were cast aside. The spacecraft grew to several hundred kilograms in weight, exacerbated by a heavy, radiation-hardened electronics package not needed for PKE's more distant flyby of Jupiter. The X2000 program fell behind and ran over budget quickly, as did the three spacecraft.

Burned out by dealing with Goldin and Congress, Huntress left NASA in fall 1998, so the decision fell on the next associate administrator. Edward Weiler already had reason to distrust JPL, as both Mars missions launched in 1998 ignominiously ended in failure the next year. When he got the reports from a June 2000 meeting in which McNamee painted a bleak picture of cost overruns and delays, he was angry that the combined multiyear cost of missions to Europa and Pluto had gone from $654 million to nearly $1.5 billion. On 12 September he issued a stop-work order for PKE (see PHYSICS TODAY, November 2000, page 45).

Already in July, the Planetary Society had attempted to mobilize its members over a projected cancellation, and now it did so again. By October it delivered 10 000 letters to Congress. A student save-the-Pluto-mission website also drew attention. Weiler, however, asserts that the public campaign had no effect on his decision making—only science mattered. So it was critical that a rebellion broke out in the planetary-science community. The division for planetary sciences (DPS) of the American Astronomical Society issued a press release noting the time-critical character of a Pluto launch: More delays would lose the Jupiter gravity-assist possibility. Missing that, the DPS argued, made it very unlikely that a spacecraft could reach Pluto before its atmosphere collapsed. The press release did not mention the other timeliness argument—that the planet was turning its north pole toward the Sun, so every delay meant more of the southern hemispheres of Pluto and Charon would disappear into darkness. But the decreasing-visibility and atmospheric-collapse arguments certainly figured in the next meeting of NASA's advisory committee on 30–31 October, which immediately followed the DPS annual conference on JPL's home turf in Pasadena.

Weiler, speaking by phone, said that he had "clear direction and authority from the Clinton administration" that Europa was the priority. Therefore, he issued the stop-work order on Pluto. Goldin had given him "until the end of the year to 'fix' the Outer Planets Program." JPL was ordered to show how to lower costs for the Europa and Pluto missions by the end of November, otherwise Goldin would start "making decisions on competition." Later that day McNamee briefed the committee. His admission that PKE had been, in Stern's words, "saddled with all of the costs for radiation hardening on Europa" caused an uproar. By the end of the meeting, the scientific consensus was clear. No one was against a Europa program, but a Pluto mission needed to be done first and through competition, or a historic opportunity might be lost.

A new era

The scientific and popular reaction to the cancellation initiated a new era in which NASA no longer dominated planetary-science policy formation. The "faster, better, cheaper" era had come to an end in 2000 after the embarrassing failures of two Mars missions. But the Discovery Program had survived the transition and demonstrated the virtues of competitive mission proposals. It also fostered the rise of non-NASA organizations—primarily APL—that might challenge JPL in planetary exploration. Moreover, the planetary-science community had begun to organize itself more effectively at the turn of the 21st century. As a result, in the subsequent battles over Pluto, it would be non-NASA organizations, Congress, the scientific community, and perhaps the public that determined what would be done.

Credit for initiating the competitive approach for Pluto belongs to Weiler, although Stern sees him mostly as the project's nemesis. Weiler had not only canceled PKE and defended the decision to the media and Congress, he also was the public face of two subsequent cancellations by the incoming George W. Bush administration in 2001 and 2002. Yet at least as early as 13 October 2000, a month after the first cancellation, Weiler raised the possibility of a competitive Pluto procurement with APL's Krimigis. Then, in his talk to the Pasadena meeting, he threatened JPL with competition. According to Krimigis, on 20 November "he called me and he said, 'I don't have any money, but would you guys be able to do a very quick study to tell me how you would do a Pluto mission à la NEAR?'" At the time, APL's spacecraft was orbiting the near-Earth asteroid 433 Eros, which gave the laboratory a lot of credibility with NASA, notably for its low-cost approach. After a frantic Thanksgiving week drafting a proposal, Krimigis and a few key staff presented it to Weiler and his planetary division director, Colleen Hartman; they asserted that it could be done for less than the half-billion-dollar upper limit specified by Weiler.

Weiler has only the vaguest recollection of such a meeting but says that he made similar inquiries with other organizations. Certainly he would have asked JPL. The objective was to find out whether any credible competitors at that dollar amount could be found before Hartman and her staff wasted weeks during the winter holidays turning out an announcement of opportunity (AO), a legally precise document tens of pages in length requiring an extensive internal NASA review.

With that in mind, on 11 December Weiler wrote a memo to Goldin proposing Pluto first, and postponing Europa, which still had technology challenges. Goldin told him to go ahead. On 20 December, NASA gave notice that the AO would be released in a month. Normally it could take up to a year to clear such a document through channels. But the very hard deadline set by the Jupiter gravity-assist opportunity in late 2004 meant that a highly accelerated process was critical; no one had yet shown that there was a last chance in early 2006.

The 20 December announcement set in motion a flurry of team building. Krimigis called Stern, head of the Southwest Research Institute's space-science unit in Boulder, Colorado, about becoming the principal investigator for an APL spacecraft. Charles Elachi, the incoming JPL director, had already contacted Stern. Stern asked Elachi to guarantee that his proposal would be the only one from JPL, and "if we win it, that you will never let it be cancelled." He asked the same questions of Krimigis, who said "absolutely." When Elachi called back to say he could not promise either, Stern's mind was made up.

The answers to his questions illustrate the differences between the two institutions. APL's space department was one-tenth the size of JPL and could only mount one proposal at a time. JPL was large enough that Elachi apparently felt that he would create problems if he stopped the formation of more than one team—he would support two. As for the political promise, JPL may have been part of Caltech but was, *de facto*, another NASA field center and did not have much political independence from headquarters. Nor did it attract that much attention from California's congressional delegation in a big state with more powerful aerospace institutions. By contrast, APL was effectively a free agent in a smaller state with a powerful senator on its side.

Weiler and Hartman released the AO on 19 January 2001. Within weeks, the Bush administration released its first budget, canceling the Pluto mission and asserting that the program had greatly overrun its budget—an excuse not even applicable to the new competition. NASA then halted the AO. Stern was naturally upset that his dream could once again be derailed. He called Krimigis about the disingenuous rationale, and Krimigis immediately called Mikulski's office. APL's political connections saved the day. Shortly afterward, as chair of the Senate Appropriations subcommittee responsible for

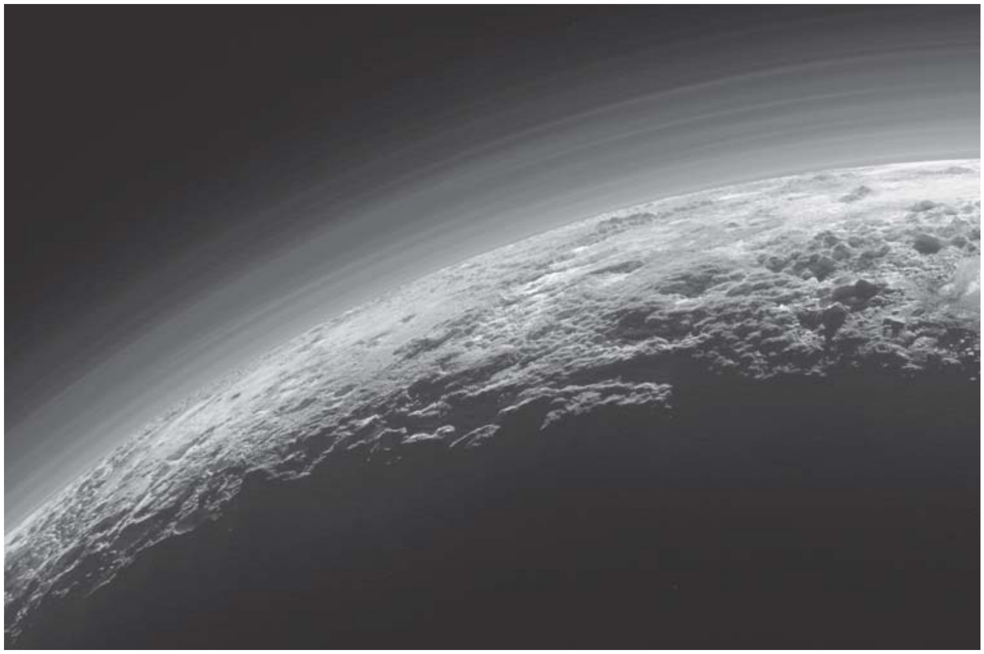

FIGURE 4. PLUTO'S ICY MOUNTAINS, FLAT PLAINS, AND ATMOSPHERIC HAZE are visible in this near-sunset scene nearly 1300 km wide. *New Horizons* captured the image by turning its camera back toward the Sun just 15 minutes after the spacecraft's closest approach on 14 July 2015. (Courtesy of NASA, the Johns Hopkins University Applied Physics Laboratory, and Southwest Research Institute.)

space, Mikulski instructed NASA to continue the review process so as not to exclude any options from congressional consideration. If JPL had still been in charge of the Pluto project, the mission would have died right then.

The interruption caused NASA to delay the submission deadline to early April. Five teams survived the grueling pace to put together proposals the size of phone books. On 6 June Weiler's office announced that two were selected to receive $450 000 each for phase A studies: *New Horizons* and the JPL proposal with the most engineering continuity from PKE.

For *New Horizons*, shown in figure 3, the continuity was almost entirely in the science payload. Stern brought his integrated UV-, visible-, and IR-wavelength imager, which had been developed for Pluto Express and PKE, and persuaded Leonard Tyler of Stanford University to provide his radio experiment as well. Stern at first thought of adding a "daughter probe," a small deployable spacecraft to image the side of the planet not seen during the single flyby, but decided on a long-range telescopic camera instead. (See figure 4 for an example of the images the camera captured.) The team added particle and field detectors not on PKE and a solid-state memory 24 times as large as PKE's. To design the 400 kg spacecraft, APL drew on experience with NEAR and two other missions recently won but not yet launched.

Battles over *New Horizons*

After another delay caused by the terrorist attacks on 11 September 2001, the two teams submitted their proposals. On 29 November NASA announced the selection of *New Horizons*. Weiler's award letter was, however, one of the most challenging that any principal investigator has ever received. Budget was absolutely critical. Although Mikulski had put $30 million in the NASA appropriation for fiscal year 2002 to cover one phase of spacecraft development, it was against the will of the Bush administration and only a small down payment on the half-billion dollars needed. Another challenge was meeting the launch-vehicle requirements at a time when new boosters were only just coming into operation. In particular, obtaining the federal environmental clearance to launch nuclear material—the plutonium in the radioisotope thermoelectric generator—was far from easy. And the spacecraft and mission had to pass a "confirmation review" after one year to receive any more support. Stern saw the message as "'You won, but you didn't win.' . . . I literally sat in my chair and said, 'I have to make all these tumblers work.'"

The award happened days after Goldin exited as administrator. President Bush appointed Sean O'Keefe, the deputy director of the Office of Management and Budget (OMB), as his replacement. That only worsened the *New Horizons* budget prospects, as officials in the OMB were angry that Congress had rammed Pluto down their throat. Predictably, when the FY 2003 presidential budget came out in early 2002, Pluto was canceled again, with O'Keefe's full support. But the budget did contain a proposal that became essential to *New Horizons*: a New Frontiers program line for competitive outer-solar-system missions.

Krimigis, Stern, and the Planetary Society girded for yet another Pluto fight. Mikulski announced that she would again try to insert the money into the budget, but earmarking a whole program on a year-to-year basis meant getting the Senate and House to agree each time, which made rational planning nearly impossible. *New Horizons* would need $122 million in 2003 to build and buy hardware. One way would be to call the Pluto mission the first in the New Frontiers program and increase the budget from the planned $15 million. The best and really only hope was that the National Academies' decadal survey for planetary science would put a Pluto–Kuiper belt mission at the top of the list.

In mid-July 2002, the committee announced that such a mission was number one on the medium-sized missions list. The Kuiper belt argument was primary, not only for Pluto–Charon but also for the possibility that the spacecraft might make another encounter afterward, if a body in an appropriate orbit could be found (as one now has). The argument for Pluto as the last unexplored planet was, for the scientific community, pretty much dead. Rather, that body was the key to understanding a whole new region of planets, or at least dwarf planets, as the International Astronomical Union would label Pluto in 2006.

With the *New Horizons* budget prospects looking much brighter in summer 2002, Stern and APL had one last problem: Weiler and Hartman's skepticism about the program actually launching to Jupiter in 3.5 years. But at the program's confirmation review in October, the board was convinced that the laboratory knew what it was doing. At the same time, Congress, thanks to Mikulski, placed it in the FY 2003 budget as

the first New Frontiers mission, so even O'Keefe and the OMB begrudgingly had to accept it.

In March 2003 NASA headquarters issued its mission confirmation. Although several crises with the plutonium supply and the booster rocket would threaten the project before its launch in January 2006, a fully funded Pluto expedition was at last on NASA's program.

Power shift

No one factor can be singled out as decisive in that result. So fragile and contingent was the *New Horizons* victory that everything had to line up to make it possible. A tortured birth lasting more than a decade is, however, not that unusual a story in the NASA robotic space program. Congressional interventions are not new in NASA's science program either, although major path-changing ones tend to occur only at intervals of a decade or more, when the agency's political position is weak.

What the Pluto mission story does provide is a window on US space science and technology policy during the 1990s and 2000s. It reveals a shift in the balance of power around 2000 among the important players: NASA senior management, the planetary-science community, the space technology community and industry, Congress, the sitting presidential administration, and public advocates and lobbies. The post-1990 environment of smaller missions, competitively chosen from a larger number of space-science institutions, many of them outside NASA, has created a culture in which political lobbying and intervention are more likely.

Meanwhile, *New Horizons* continues to fly outward to its next target, a 60-km-diameter icy Kuiper belt asteroid that it will encounter in 2019. We can all expect fascinating revelations about it and, from the data still streaming down to Earth, the Pluto–Charon system.

ADDITIONAL RESOURCE

▶For a more complete account of the Pluto mission's history, see M. J. Neufeld, *Hist. Stud. Nat. Sci.* **44**, 234 (2014) and references therein. PT