New Horizons - Immersion in Robotic Exploration of the Solar System Culture

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I. Introduction

The following report analyzes the mission **New Horizons** mission to Pluto and its insights. This report summarizes the key ideas of the book *Chasing New Horizons* based on the first-hand experience from Dr. Alan Stern, principal investigator of the New Horizons mission and the Chief Scientist at Moon Express [1].

NASA's New Horizons spacecraft is the first spacecraft to explore Pluto up close, flying by the dwarf planet and its moons on July 14, 2015. In early 2019, New Horizons flew past its second major science target—2014 MU69, the most distant object ever explored up close [2] (check Table I for a summary of the mission).

New Horizons was the first of it's kind in many events and accomplished milestones no other spacecraft has ever achieved.

- First spacecraft to explore Pluto and its Moons up close.
- First spacecraft to explore a second Kuiper Belt Object up close (2014 MU69)

II. Preliminary stage

The *why* question started in a dinner which happened one night in May of 1989 in an unremarkable Italian restaurant in Baltimore's Little Italy, this dinner gathered hundreds of scientists and engineers. Among the exchange of ideas, the idea of how it would take to plan a mission to Pluto emerged. Afterwards, this first group of plutophiles was known as Pluto Underground.

It was daunting, since there was no Pluto mission planned anywhere at NASA's plans. Besides, there were other candidates such as Mars, Venus and Cassini. Each of them had a lot of potential of being NASA's next big project. But NASA's budget was so limited that only two new planetary missions had been started in all of the 1980s (Chapter 2).

Budget was limited and turned out to be one the main reasons why Pluto mission was not being considered seriously, since both Galileo and Cassini, NASA's next two big approved missions, each multibillion-dollar giant-planet orbiters, were both experiencing major problems at the time. In order to husband economic resources, the team developed an concept spacecraft and set their target mass at thirty-five kilograms. However this concept was teared down immediately since even a stripped-down, bare-bones spacecraft with only two instruments—a camera and a radio-science experiment to probe Pluto's atmosphere—came out at more than 100 kilograms. And this was without any backup systems to make the spacecraft reliable enough to undertake the nearly decade-long mission (Chapter 2) (Chapter 3).

Dan Goldin began to work as NASA administrator a on April 1, 1992. He set a budget of 400 million dollars including launching costs. But this seemed and was indeed, an impossible assignment. The real magnitude of the mission elevated to around 1 billion dollars. During Dr. Goldin's mandate, the project did not advance very well since the requirements by Goldings were extremely difficult to achieve. Besides, Golding decided that the Pluto community had been disingenuous in their promises when the team said a 35 kg spacecraft was not possible to achieve. So Goldin priorized other missions on top of Pluto. In order to solve this problem, Dr. Stern thought

TABLE I. New Horizons mission characteristics. Source:[2].

Nation	United States of America (USA)
Objective(s)	Pluto Flyby, Kuiper Belt Object Flyby
Spacecraft	New Horizons
Spacecraft Mass	1,054 pounds (478 kilograms)
Mission Design and Management	NASA / Johns Hopkins University Applied Physics Laboratory (APL)
Launch Vehicle	Atlas V 551 (AV-010)
Launch Date and Time	Jan. 19, 2006 / 19:00:00 UT
Launch Site	Cape Canaveral, Fla. / Launch Complex 41
Scientific Instruments	Ralph-Visible and Infrared Imager/Spectrometer
	Alice-Ultraviolet Imaging Spectrometer
	Radio-Science Experiment (REX)
	Long-Range Reconnaissance Imager (LORRI)
	Solar Wind and Plasma Spectrometer (SWAP)
	Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)
	Student Dust Counter (SDC)

of a joint project with Russia in which the soviets will provide the Rocket and the US provides the spacecraft. Nevertheless, it turned out that the Russian's offer was not free, the price they instead demanded was substantially cheaper than using an American rocket, but not zero.

Afterwards, Pluto mission was selected top priority by the Decadal Survey, a new, once-in-a-decade review of all of NASA's planetary mission priorities, undertaken by the National Academy of Sciences. And in 1989, the mission began its construction (Chapter 5).

The biggest concern just before the launch was the use of RTG (Radioisotope thermoelectric generator) since a failure in the launch will be hazardous, however, risks related to the proof tank failure were demonstrably minimal (Chapter 8).

Finally, a major setback came around before launching the spacecraft. The weather was not clear and Alan decided to cancel the launch until it was clear. Then, after 2 failed launch attempts, on January 2006, it finally launched.

III. Cruise to Pluto

During the first weeks of flight, each on-board system—communications, guidance, thermal control, propulsion, and all the others—was tested thoroughly. So were all of the backup systems. Their major concern, of course, was that New Horizons would point away from Earth or otherwise lose its ability to communicate with them, causing them to lose the spacecraft entirely.

But not everything went perfectly. One engineer found that a pair thruster was behaving abnormally in the sense that it was firing many times more than it frequently should. One engineer had miscalculated the spacecraft's mass and balance parameters, and unlike hundreds of other computations, this one had slipped all independent engineering reviews. As a result, the thrusters had to work extra in flight to compensate for the underspecced thrusters, and the thrusters were firing too often. Their design life was rated for around 500,000 uses before failure, and computer simulations estimated that by the time they investigated Pluto, they would have been used just about half that. Now, due to hyperactive firing, these thrusters were expected to be utilized over a million times before the Pluto flyby was finished which was way out of the thruster's safe margin.

To address this issue, the team implemented some additional restrictions on how often the spaceship would turn in the future, hoarding the usage of the two underspecced thrusters while simultaneously starting to "load-share" these thrusters by using backup thrusters. The backups had the same problem, but the flight control crew was able to keep both the prime and backup sets well under their 500,000-cycle limit all the way to Pluto by rotating which sets were utilized and limiting their use for certain maneuvers. In the end, this problem was solved, but the problem will remain for the rest of the duration of the journey (Chapter 10).

Over a period of many weeks, all seven scientific instruments checked out perfectly, but a near miss with disaster occurred during the LORRI instrument checkouts. LORRI is a high-powered telescopic camera. The main

problem here was that the instrument pointed directly to the Sun at one time, which could lead to a malfunction of the sensor. The team solved the problem by upgrading the control code software (Chapter 10).

Jupiter's flyby was a success, however, the team realized how radiation can negatively affect the electronics onboard. The main computer rebooted itself various times when approaching Jupiter which was caused by the radiation (Chapter 10).

Dr. Stern mapped out a multistage effort to assess and mitigate the risk when approaching Pluto. The first step was to carefully reanalyze all existing data sets that could shed light on potential hazards, such as space debris. Further studies showed that the concern was real. The team now shall dodge potential debris. It was a huge new workload and cost to the project, but given the lethality of debris strikes high speed velocity, and the reality of having only one spacecraft and no second chances, there didn't seem to be any other option (Chapter 12).

IV. Scientific observations

Just some weeks before Pluto encounter, communication with the spacecraft was lost, nothing came back. All the team were shocked, it was uncertain what caused the lost of communication. Perhaps, the spacecraft hit some debris but nothing was clear. This was the biggest strike to the team since everything could be gone, and the mission did not even achieved its main goal and destination. The sudden loss of signal fed the worst fears that something catastrophic might have happened to the spacecraft. New Horizons was still millions of miles from Pluto, and any hazards it posed. The chances of striking anything there in interplanetary space were absurdly low, but it was not null. After a thorough research, and assaying all the data recovered prior to the loss of communication. The team pointed out that the main computer could be overloaded with tasks since the main computer had been doing two things at once, both of which were computationally demanding. One of these tasks was compressing sixty-three Pluto images taken previously, in order to free up memory space for the close flyby imaging soon to begin, and at the same time, the computer was also receiving the Core load from Earth and storing it in its memory. If this was the case, the computer would automatically restart using the backup computer, and 60 to 90 minutes, the ground station would receive the signal. After the endless wait, finally, communication had been restored and so the fear of a catastrophic loss of the spacecraft evaporated. With that in mind, the team learned from the lesson and lessened the amount of tasks of the main computer ensuring it to utilize its full potential but without overloading it (Chapter 14). Despite all setbacks, the encounter with Pluto went flawlessly and the collected data went beyond expectations (Chapter 16).

Hal Weaver, mission scientist, presented photographs of Pluto's tiny, outermost moon, Hydra, revealing its size and form for the first time. Hydra was elongated and potato-shaped, with axes measuring twenty-eight by nineteen miles across, according to the photos. Dr. Weaver then recounted how they discovered Hydra's reflectivity was extremely high, similar to newly fallen snow, implying that its surface is most likely made out of water ice (Chapter 16).

Will Grundy, the leader of the New Horizons Composition scientific topic team, then presented the first tentative composition maps of Pluto, which revealed significant differences in methane ice concentration across various geological zones. Dr. Grundy also stated that his team was already witnessing even more remarkable composition variety, with distinct molecular ices—nitrogen, methane, and others—varying in abundance across various areas of Pluto (Chapter 16).

Another finding of Pluto encompassed that Pluto was profoundly affected by such high, sharp, and fresh-looking mountains. Scientist believed that Pluto's surface contains a lot of nitrogen and methane but that mountains could not be built out of those elements because solid nitrogen and methane are just not strong enough minerals to support such high relief, even in Pluto's low gravity. As a result, mountains of nitrogen or methane would collapse under their own weight. The final verdict was that those mountains needed to be composed of something more durable, most likely water ice, which is the most frequent surface material on satellites and other worlds in the outer solar system.

V. Conclusions

I've always believed that the technical aspect of a space mission is the most challenging. Creating a machine that could traverse millions of kilometers without exploding over the course of a decade or more. After reviewing Dr. Stern's book, now realize I was clearly mistaken. There are other aspects, such as political or economical that comes into account when designing a mission which entails all of the work necessary to get the mission approved and funded. The number of setbacks that the mission team had to go through was endless, and even that, Dr. Stern's team persisted, and achieved a milestone that will be remembered forever.

References

[1] Alan Stern and David Grinspoon. *Chasing New Horizons: Inside the Epic First Mission to Pluto*. Picador, 2018.

[2] NASA. *New Horizons*. 2018. URL: https://solarsystem.nasa.gov/missions/new-horizons/in-depth/#:~:text=New%5C%20Horizons%5C%20is%5C%20a%5C%20NASA,50%5C%20AU%5C%20from%5C%20the%5C%20Sun.