# EFFECTIVENESS OF NASA RISK COMMUNICATION STRATEGIES USED FOR THE *NEW HORIZONS* MISSION

by

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ABSTRACT

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In its experience with nuclear powered missions in the last two decades, NASA has learned that the general public is concerned about the use of nuclear power for space exploration. Several risk controversies, first initiated by anti-nuclear activists before the launch of the *Galileo* probe (1989) and culminating with the launch of the *Cassini-Huygens* spacecraft (1997), eventually forced NASA to reexamine how it communicates risk information to the public. New procedures designed for this purpose were used during the launch of the *New Horizons* probe in 2006. The purpose of this study is to examine whether NASA's new strategies actually influenced public risk perceptions of the safety of nuclear power systems used in spacecraft.

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# CHAPTER I

# INTRODUCTION

## Background of the Problem

The activities of the US Space Program have been scrutinized in visual and print media since they began. As a result, there has always been a great potential for highly publicized success - and failure. Unlike the administrators of the more secretive Soviet Space Program, the management of NASA has been required to justify all details of each mission, including budgetary and safety decisions. Failures of planning and execution can ultimately lead to curtailment of public support (i.e., government funding). Consequently, one of the greatest priorities of NASA during the past two decades has been to build a positive image of the Space Program while simultaneously building support for further exploration and research (Friedensen, 2006).

While government and public support for the US space program has waxed and waned, the goal of fiscal efficiency has remained constant (National Aeronautics and Space Administration [NASA], 2004). A consequence of this limitation on funding has been a corresponding reduction in the margin for error. Even though the Apollo Program of the 1960s produced a publicly lauded outcome, public and government support of other space exploration ventures have not always been constant. High visibility failures, most notably the *Challenger* (1986) and *Columbia* accidents (2003), created a public backlash against the "wasteful" expense of debatably justified space exploration (Rodrigue, 2001).

With the failure of spacecraft, the public then became concerned about what might fall from the sky. Perhaps most worrisome was the potential for a release of nuclear material from one of the radioisotope power systems (RPS) used for deep space exploration. Opponents of the use of nuclear power in spacecraft began to see themselves as defenders of humanity against the apparently accident-prone NASA engineers. Despite the fact that the radioisotope thermoelectric generator (RTG) and radioisotope thermoelectric heater unit (RHU) both have a more than a 40 year history of success and safety, the precedent of the *Challenger* explosion was enough to generate opposition against launches of unmanned probes with onboard nuclear power systems (Applied Physics Laboratory [APL], 2005).

Protests first surrounded the launch of *Galileo* in 1989. This spacecraft was intended to be the first probe to enter Jupiter's orbit. The mission profile called for planetary assists from Venus and Earth to reach Jupiter in the most efficient manner. This caused even some supporters of such missions, such as Carl Sagan, to question the safety of the plutonium used in the radioisotope power system (RPS) onboard *Galileo*. However, even he did his best to assure the public that there was only a small chance for explosion in the atmosphere or collision with Earth (Sagan, 1989).

When unsuccessful in preventing its launch, the anti-nuclear activists turned to the scheduled launch of *Ulysses* (1990). This mission was intended to explore the sun. Again, the major issue was the use of plutonium and a fear that the radioactive materials would be released into the atmosphere by an explosion or collision during planetary assist. As with *Galileo*, some of the nuclear activists complained that solar power would be much safer and work equally well (Grossman, 1990). Though protests again failed to lead to the cancellation of the mission, public resistance to launches using RTGs or RHUs continued to grow (Dawson, 2006).

*Cassini-Huygens,* scheduled for launch in 1997, was designed to explore Saturn and was also powered by RTGs. Like *Galileo*, the mission profile required several passes of Earth in a velocity-building gravity assist. As before, anti-nuclear activists wanted to prevent the launch due to the plutonium dioxide onboard the probe. Despite significant internet and media attention, the protest effort was again unsuccessful in its attempt to cancel the launch. However, the debate continued through 1999 when anti-nuclear activists tried to secure cancellation of the Earth fly-bys (Rodrigue, 2001). During the entire episode, NASA and other government agencies received hundreds of letters, several congressional inquiries, intense media scrutiny, and lawsuits. The controversy ultimately created a culture of fear in the area near the Kennedy Space Center, leading a number of school children to write concerned letters to the President of the US (Dawson, 2006).

Believing that continued pressure might eventually succeed in canceling a nuclear powered mission, protestors publicized their opposition to the Pluto-bound *New Horizons* mission eight years before the launch (Stop Cassini Newsletter, 1998). Some of the same protest groups involved in attempting to cancel *Cassini-Huygens*, including the Florida Coalition for Peace & Justice, the Global Network Against Weapons & Nuclear Power in Space, and NoFlyBy, simply changed their focus to the new mission (Rodrigue, 2001; Flybynews, 2006). Expecting this type of aggressive activism, NASA actually began to prepare to counteract the protestors very early for the *New Horizons* mission. Project administrators were determined to control the tempo of the controversy during the launch. Following an extensive review of the failures in risk communication provided on previous flights, the entire process was restructured for the *New Horizons* mission. After the launch was successfully completed in January 2006, NASA was convinced that the new procedures were successful, mainly because of a significant reduction in the level of protests by anti-nuclear activists (Dawson, 2006).

## Researcher's Work Setting and Role

The author is an Aviation Safety Officer in an operational military unit, experienced in risk evaluation, surveys of risk perceptions, and hazard abatement practices.

## Statement of the Problem

In its experience with nuclear powered missions in the last two decades, NASA has learned that the general public is concerned about the use of nuclear power for space exploration (Friedensen, 2006). Several risk controversies, first initiated by anti-nuclear activists before the launch of the *Galileo* probe (1989) and culminating with the launch of the *Cassini-Huygens* spacecraft (1997), eventually forced NASA to reexamine how it communicates risk information to the public (Dawson, 2006; Rodrigue, 2001). New procedures designed for this purpose were used during the launch of the *New Horizons* probe in 2006 (Friedensen, 2006). The purpose of this study is to examine whether NASA's new strategies actually influenced public risk perceptions of the safety of nuclear power systems used in spacecraft.

## Significance of the Problem

It is important for NASA mission planners to know the actual effects of their risk communication strategies. Great expense is devoted to ensuring risks are reduced before the launch of a spacecraft. These efforts must naturally be communicated to the fearful public to ensure that all of the expense required for planning and execution is not wasted.

Continued research on the effectiveness of risk communication plans will improve the processes for future launches.

## Limitations

Because of the scope of this research and the size of the population (i.e., entire US population), it was difficult to gain a true understanding of the general public's risk perceptions relating to the use of nuclear power in Space. Some of the limitations were sample size and location of the study.

The selected sample size was small, allowing the researcher to complete this research project within the allotted time. In addition, it was impractical to survey thousands of individuals or complete detailed studies of the composition of the general population. While this research project was designed to show general trends in risk perception, a smaller sample ultimately limits the overall significance of the results. It does, however, provide guidance for future research.

The optimum location for this study would be one with regular launches of spacecraft using nuclear power sources, such as Kennedy Space Center (KSC). Since the researcher could not travel to Florida during this project, he originally investigated conducting the study near the NASA Wallops Flight Facility, which routinely launches satellites. At the time this project was completed, the facility was located approximately two hours north of the researcher's home. Due to the researcher's professional duties, however, the site could not be used. Instead, the researcher collected the data (via email) from individuals living near several of the approved US commercial spaceports. This decision may also limit the overall significance of the results, but it can also provide guidance for future research.

## Assumptions

RTGs and RHUs have a proven record of safety and duration, providing power for more than 25 successful missions (Department of Energy [DOE], 2002). However, there are individuals who, by principle, believe that no nuclear devices should ever be allowed into space. These individuals have influenced the conversation about the use of RTGs and RHUs towards building fear in the public (Dawson, 2006; Friedensen, 2006, Rodrigue, 2001). NASA has a duty to properly assess risks to the public and environment caused by radioisotopes used in spacecraft and to ensure that such assessments are properly communicated (Dawson, 2006; Friedensen, 2006).

## Definitions of Terms

Radioisotope – "any of several species of the same chemical element with different masses whose nuclei are unstable and dissipate excess energy by spontaneously emitting radiation in the form of alpha, beta, and/or gamma rays" (Radioactive Isotope, 2006)

Radioisotope Heater Unit (RHU) – "Generate heat from the natural radioactive decay of a small pellet of plutonium dioxide (mostly plutonium-238). This heat is transferred to spacecraft structures, systems, and instruments directly without moving parts or intervening electronic components" (DOE, 1998)

Radioisotope Thermoelectric Generator (RTG) – Used by spacecraft operating at significant distances from the sun, where solar or battery power may not be practical. Primary fuel is Plutonium-238. "The natural radioactive decay of the plutonium produces heat (RTGs do not use fission or fusion), some of which is converted into electricity" (Jet Propulsion Laboratory [JPL], n.d.; APL, 2006)

# Acronyms

NASA – National Aeronautical and Space Administration

RHU – Radioisotope Heater Unit

RTG – Radioisotope Thermoelectric Generator

RPS – Radioisotope Power Systems

STS – Space Transportation System

US – United States

# CHAPTER II

# REVIEW OF RELEVANT LITERATURE AND RESEARCH

The exploration of space is fraught with many dangers, affecting both the spacecraft and the human occupants. Each mission must be carefully planned to avoid loss of life or valuable equipment. Managers of space agencies must develop risk probabilities, effectively communicate the risks and then often deal with protests against the mission. Perhaps the most difficult situations involve use of nuclear power, since the public has already developed negative perceptions about the safety of this type of energy (Dawson, 2006). NASA has often been forced to waste valuable time and money to reassure a fearful public of the safety of RTGs and RHUs (Rodrigue, 2001). While providing sound risk assessment information, the processes used for several missions appeared to be unsuccessful due to poor public risk perception and amplification of risk caused by activists and media personnel (Dawson, 2006). Risk communication strategies, designed to manage and minimize the effects of threats to cost, design, and the mission schedule, are essential to NASA administrators to combat these effects (Friedensen, 2006).

## Risk Assessment

One of the more interesting developments in the so-called post-modern society is an obsession with the reduction or complete elimination of risk. In earlier periods, there was a certain degree of acceptance by the public about inherent risks associated with certain tasks. Today, however, the public will not simply accept this risk or the reassurances of scientists or government officials that something is safe. One of the most important aspects of mission planning has become the risk assessment process (Chriss, 2004).

Experts in the field of risk assessment believe that effective characterization of hazards must be determined using both qualitative and quantitative means. The reason for utilizing both methods is to overcome the inherent bias of the qualitative alone. Quantitative assessment involves deliberate definitions of risk (including catastrophic potential, dimensions of risk, and risk comparisons). Qualitative assessment involves mental models of risk decisions and risk processes. Each has value in management decisions relating to risk (Fischhoff, Bostrom & Quadrel, 2002).

There are several means to ensure that assessments of the risk of an activity, such as a launch of a nuclear powered spacecraft, are effective. Fragola proposes that quantitative risk assessments should be completed very early in the planning process. As previously noted, qualitative analyses alone are not adequate. Additionally, the analysis should be independently verified (or even completely conducted) to ensure its veracity and trustworthiness. Finally, uncertainties about the results of risk assessments should be admitted and effectively communicated by management (Fragola, 1992).

The subjective nature of risk assessments can lead them to be interpreted by the public with suspicion. Slovic maintains that risk definitions are exercises in power and therefore can be affected by political, social, and psychological factors of the people responsible for them. Without adequate public education and public involvement in the risk assessment process, the possibility of emotional contamination of the results is entirely possible. In such a scenario, project managers of a hazardous enterprise would actually be allowed to control the funding which determines the eventual safety margins for the mission. Since companies or government agencies would likely tout their own products as being “safe,” Slovic believes this amounts to a conflict of interest. Without fully independent risk assessments, the public will be suspicious of company claims that all hazards have been properly considered (Slovic, 1999).

## Risk Perception

Regardless of the statistical probabilities of a risk leading to a disaster (i.e., risk assessments), the public is influenced by other intangibles. The means by which hazards are communicated to the public can be very important. Some perception is related to interpretations of risk assessments across the spectrum of gender, race, religion or other cultural differences (Fischhoff, Bostrom & Quadrel, 2002). Other risk perceptions are related to the level of exposure of the public to popular culture media. An example of this is the release of movies seeking to evoke a public awareness on a topic (e.g. alien attack, the end of the world, “China Syndrome,” etc.) that may, in fact, be obscured by the entertainment value of the movie. Chapman’s case study on the effect of the 1998 release of the movies “Deep Impact” and “Armageddon” and public awareness of comet or asteroid collision with Earth demonstrates this phenomenon. His research suggests that many people in society are heavily influenced by media attention on an issue that might otherwise be overlooked, especially in the area of risk perception (Chapman, 1998).

It is very possible that fear can exist in a population despite the lack of any scientific reason or probabilistic measurement to substantiate it. One example of this is the Three Mile Island accident of March 1979. While damage to that nuclear plant was nearly as bad as could ever occur (i.e., 90% of the core damaged), minimal amounts of radioactive material were released. The event showed the effectiveness of radioactive containment systems and could even be used to validate the safety practices of the nuclear industry. Despite having a safety record similar to that of the major airlines (i.e., "flying is safer than driving"), the nuclear industry has been unable to successfully convince the public that nuclear power systems are safe and reliable. Fragola believes that this is the result of a feeling of powerlessness by members of the public. No matter how many times the facts are presented to people, they will continue to maintain a fear of something that is completely out of their control. Simply the fact that an accident could occur is enough to perpetuate the negative perception of the public (Fragola, 1992).

Another issue of risk perception is the distrust of the government by members of society. Expert opinion, often presented by government officials, may be completely discounted by individuals solely on the basis of a negative perception of the entities that the officials work for. Douglas proposes a framework of human nature to describe a person's acceptance of risk, dividing people into four groups. One personality type is the Individualist, who believes that risk is essential for personal achievement (e.g. capitalistic success). The Egalitarian type, while comfortable within a group, does not like risk at all and attempts to force the people who have created risk to expose themselves (and not others) to it. Hierarchists also work within groups but are willing to accept risk if expert opinion deems the outcome worthwhile. Lastly, the Fatalists operate outside of the safety of the group and never feel comfortable with risks, since they believe they will not ever benefit. With such personality types involved, the culture affected begins acceptance or rejection of risk analyses based on preconceived ideas. Supposing that there were no external influence on those perceptions, the only issue left for the managers of a risky enterprise would be to transmit the findings of the risk analysis and attempt to convince the doubters (Douglas, 1992).

## Risk Amplification

Unfortunately, the effect of external influence on personal understanding of certain risks should not be underestimated. The primary forces of such risk amplification are normally media outlets and activists. Each has a reason for spreading information about risk and each can also overcome the efforts of management or government recognized experts. Sandman proposes that there are actually two sides to the risk amplification story: the response of management and the efforts of "outrage industries" (i.e. journalists and activists). Primarily, he believes that the outrage industries do not actually manufacture outrage. Instead, they amplify it (Sandman 2006). Slovic confirms this view by pointing out that the media is very adept at reporting bad news, providing more attention to negative events. This, he believes, destroys trust in governmental and corporate institutions. Powerful special interest groups, supported by a fearful public, use every available form of media to communicate their concerns and distrust of government and corporations to the public (Slovic, 1999).

In a 1992 aircraft accident in Bijlmermeer (Amsterdam, Netherlands), research indicated that "media hypes" occurred each time news outlets released a new piece of information about the crash. While only 45 people were killed in the mishap and very few were hurt in the residential area where it occurred, the media coverage continued to discuss hazardous materials that may have been onboard the aircraft when it went down. The resulting medical complaints increased in relation to the media reports until there were more than 6,000 people complaining that they had been affected by the accident (even though some had moved to the area years later). While no common connection could be made with the materials on the aircraft and the types of symptoms experienced, the public remained convinced that there was something to fear. This incident was the genesis of “Bijlmermeer syndrome,” a series of unexplained physical ailments that are later grouped together as being caused by one event (Vasterman, Yzermans & Dirkzwager, 2004).

Another issue directly related to risk amplification is the replacement of reliable (i.e. scientifically based) journalism with untrained experts and 60 second “news-bits.” A study conducted in 2000 on the use of risk terminology in British newspapers indicated that the intense distrust of expert opinion within that media led many reporters to attempt to find “lay experts” as sources for risk information. This was most pronounced in “tabloid” newspapers, which pay little attention to expert opinions and champion individual experiences above scientific knowledge (Petts et al., 2000).

Combining the “lay expert” phenomena with the internet, individuals with the intent to confuse or frighten the public can further amplify any real or imagined risk. The Pew Internet & American Life Project has determined that more than 40 million Americans rely on the internet as the primary source science information. In addition, nearly 128 million adults report that they access the internet for some kind of scientific guidance. This reliance on the internet is amplified in the age groups of 18-29 and 30-49. The convenience of accessing data at any hour or from any location allows all web-connected individuals to believe they are scientifically educated (Pew Internet and American Life Project, 2006). Another reason for the popularity of the internet is that it facilitates the existence of a user-edited web site like Wikipedia.com and is not controlled by a public institution (e.g. government agency). Mistrust of government assessments of risk and other issues relating to misunderstood scientific concepts can lead to the social amplification of risk at the expense of knowledge or economic benefits (Rodrigue, 2001).

In the case of the *Cassini-Huygens* mission, a small group of anti-nuclear activists probably drove the entire debate (i.e., about the safety of the nuclear power subsystems in use aboard the spacecraft). Rodrigue's 2001 study on the associated internet debate showed that the online discussion "had all the appearance of dueling risk assessment experts. Thus, expertise was delegitimated" (Rodrigue, 2001, p.251). The internet provided anti-nuclear activists with the opportunity to spread their own fear among those in that population who originally had no opinion. By creating their own version of "media hype," such activists effectively created controversy where there might otherwise have been none. The medium of the internet allows people who feel like they have no voice (e.g. in government, print or television media) to express their risk opinions in such a way that they actually can nearly silence NASA risk communicators (Rodrigue, 2001).

Sandman believes that while risk amplification may be considered an honorable profession, so may risk reduction. Management should not attempt to belittle the outrage industries or dismiss their claims. Instead, the goal of all managers should be to show that the amplification of the risks involved highlight valid concerns that require action. The onus is actually on the side of the company or agency whose actions have generated the outrage to demonstrate their serious consideration (Sandman, 2006).

## Risk Communication

In order to combat the effects of risk amplification, management must develop effective risk communication strategies. Fischhoff suggests that there are several stages in the development of a productive risk communication strategy. In his framework, management initially believes that all that is required for a good strategy is to be able to effectively tell the public about the scientific and engineering data (e.g. probabilistic measurements). This usually is not adequate, so risk communicators then usually attempt to reason with the public or provide them with some form of incentive to accept the risk. Finally, the process leads to a requirement for management to involve the public in the planning process (i.e. make them partners in the risk decisions). A combination of all seven levels of Fischhoff's framework most likely can minimize controversy surrounding risk decisions, but there may always be some level of dissatisfaction in the public if risk communication is only handled as an afterthought (Fischhoff, 1995).

A 2003 study conducted by Fischhoff, Gonzalez, Small & Lerner on the risk communication related to the potential for terror attacks in the United States showed that the public perceived that there would be widespread panic should a terror attack occur, but that the same individuals did not believe that they would be the ones to panic. In addition, there were several indications that the public had not received the risk messages communicated by the government, most notably in the area of the effects of certain types of attacks (e.g. smallpox, anthrax, dirty bomb, etc.). This is not to say that the government did not attempt to get them the information, just that it was not interpreted correctly (Fischhoff, Gonzalez, Small & Lerner, 2003).

Friedensen characterizes the entire process of risk communication as a combination of the study of psychological responses to risk and the implementation of countermeasures by management to ensure concerns are adequately allayed. She also emphasizes that risk communication requires that the risk information communicated is actually understood by the receivers (Friedensen, 2006). Following Fischhoff's framework, the public must be brought into the process and management must ensure that everyone shares in the risk decision process (Fischhoff, 1995). Effective risk communication strategies should be designed to earn the confidence of the public and provide management with effective tools to keep this confidence (Friedensen, 2006).

It is entirely possible that the absence of good risk communication may eliminate the effectiveness of any risk analysis performed. To this end, Friedensen believes that management must ensure that it continually asks questions about the use of risk information. Types of communication media, personnel chosen to speak to the public, the technical description of certain processes, and the consistency of the message are all facets of the risk communication process. The process is also two-way, requiring that management also listen effectively. Risk communication strategies, therefore, cannot always remain the same through each mission and must constantly be reevaluated (Friedensen, 2006).

One effective means for evaluating the success or failure of a risk communication strategy is to conduct either concurrent (i.e., while it is occurring) or retrospective (i.e., after the fact) data collection. Bostrom, Atman, Fischhoff and Morgan suggest the use of the following concurrent and retrospective methods for this purpose: (1) think-aloud protocol and open-ended; (2) interview; (3) short questions and recall; (4) problem solving scenarios; (5) closed-ended; (6) conducting knowledge tests. Used properly, each of these processes will allow program managers tasked with using risk communication strategies to determine their effectiveness (Bostrom, Atman, Fischhoff & Morgan, 1994).

## Evolution of NASA Risk Communication Strategies

NASA has a proud history as a leading innovator in safety processes. In response to the pressures to ensure total quality in the Space Program, NASA developed a strategy called Continuous Risk Management. It involves a self-sustaining process of risk identification, analysis, planning, tracking, and control. Central to these steps is communication and documentation (Friedensen, 2006).

Prior to the loss of *Challenger* in 1986, NASA's safety record did not provide much cause for alarm among the general public. Upon release of the findings of the investigation into NASA's safety climate during that period, however, the public confidence was severely shaken. The use of nuclear devices aboard manned and unmanned spacecraft then became a matter of concern. The public became afraid that nuclear material might be released with a catastrophic explosion in the atmosphere. Seizing upon these feelings of dread, anti-nuclear activists petitioned the government for the cancellation of several nuclear powered space missions. Though these efforts were ultimately unsuccessful, the opposition was more than NASA desired (Dawson, 2006).

Due to the controversies relating to the use of RTGs and RHUs during the *Galileo* (1989), *Ulysses* (1990) and *Cassini-Huygens* (1997) missions, NASA administrators became concerned that the public was losing confidence in the safety of spacecraft and launch systems. It appeared that the risk communication procedures in use at the time of the *Cassini* mission were ineffective for dealing with a fearful public. An example of this failure was a lack of coordinated effort between all agencies (e.g. NASA, Jet Propulsion Laboratory, etc.). It was clear that better inter-agency cooperation was required to ensure proper planning and implementation of the risk communication strategy. For this reason, the entire risk communication plan was redeveloped in preparation for the *New Horizons* mission (Dawson, 2006).

Project managers for *New Horizons* initially summarized lessons learned from the previous (controversial) missions. Personnel were then designated from each agency to act as "risk communicators." A plan was also developed which outlined the risk communication issues relevant to the entire mission development process (Dawson, 2006). Risk communicators from NASA, the Department of Energy (DOE), the principal investigator and the mission center signed the plan. Risk communication training was provided for agency employees throughout the entire project (Friedensen, 2006).

To ensure that all agencies and personnel involved with the project understood the risk communication plan, several goals were developed: (1) earn and maintain the public confidence; (2) identify and respond to specific public interest groups; (3) ensure "clear, accurate, timely and consistent information is readily available" (Dawson, 2006, p.2). In addition, guiding principles were created to ensure everyone involved could provide appropriate communication when needed: (1) be transparent; (2) be inclusive; (3) be interactive. Each of the goals and principles were employed throughout the *New Horizons* project in an attempt to ensure effective risk communication (Friedensen, 2006).

Use of a Joint Information Center (JIC), which is standard procedure for nuclear system launches, was also part of the risk communication plan. In addition, personnel within each agency were given four to six hours of training on the importance of good communication, as well as the resources available to them if needed (Friedensen, 2006). Because web site visitors reported that nuclear safety information was difficult to locate, the *New Horizon* project managers decided to move this information to the project home page. Another lesson from the *Cassini-Huygens* mission was that concerned public citizens used NASA web sites to download nuclear safety information (Dawson, 2006).

Dawson suggests that risk communication strategies used during the *New Horizons* project were successful due to constant interaction with local officials and media outlets and effective communications training of employees. The concerns of public interest groups were effectively allayed through the use of fact sheets, talking points and (when necessary) response to queries (RTQs). Due to the emphasis placed on the development of an effective web site, there were over 8000 visitors to the site in 2005 and an additional 8000 in the first three months of 2006. Nuclear safety information was provided in Spanish and English (Dawson, 2006). The Final Environmental Impact Statement (EIS) and Record of Decision (ROD) for the *New Horizons* mission were both completed by NASA and DOE in July 2005, allowing time for public discussion and debate before the launch occurred (National Aeronautics and Space Administration [NASA], 2005).

According to Dawson, there was at least one area of NASA's new strategies that needs further improvement: the final goal of providing clear, concise, timely and consistent information. There were also still problems with public affairs interviews and differences between the full technical explanation and the short (i.e. news release) explanation (Dawson, 2006).

## Summary

NASA's risk communication program developed as a result of several controversial nuclear powered space missions. While technically and scientifically successful, *Galileo*, *Ulysses,* and *Cassini-Huygens* each revealed worrisome trends about the nature of public perceptions and the susceptibility of such perceptions to amplification by activists and media personnel. From each failure in risk communication, NASA was able to restructure its strategy, ensuring that all agencies and employees were better prepared for the *New Horizons* launch in 2006. From the lack of noticeable public outcry, NASA administrators believe that the new risk communication processes were successful.

## Statement of the Hypothesis

It is hypothesized that the NASA risk communication strategies used in preparation for the launch of the *New Horizons* mission did not significantly affect public risk perceptions of the safety of nuclear power systems used in spacecraft.

# CHAPTER III

# RESEARCH METHODOLOGY

## Research Model

This Graduate Capstone Project (GCP) is considered a pilot study. The project was conducted using a causal-comparative (quantitative) model. Five basic research statements formed the foundation for analysis of the null hypothesis:

1. "NASA believes that the safety of the public is more important than the success of the mission."
2. "Radioisotope thermoelectric generators (RTGs) are dangerous devices."
3. "My health will be negatively affected if there is an accidental release of any nuclear material in the atmosphere."
4. "NASA accurately assesses the risks of using nuclear power in space."
5. "Instead of using nuclear power in space, NASA should only design spacecraft that are powered with other energy sources."

## Survey Population

Since this is a pilot study, only a small part of the general public was sampled. Data were collected using non-random purposive (judgment) sampling. Participants were selected from the researcher's educational, professional and personal environment, utilizing a pre-determined set of criterion. Individuals were purposely chosen for their gender, age group and residence location, ensuring that each group would be represented as best as feasible.

Original data collection goals included: (1) N of 400; (2) gender targets of 50% male and 50% female; (3) age group targets of 20.7% 18-29, 41.8% 30-49, 20.4% 50-64 and 17.1% 65 and above. The gender target was set using Pew Internet usage data that indicated gender parity on the internet (Pew Internet and American Life Project, 2005) The age group targets were set using US Census Bureau population statistics from the 2000 Census and assuming that the population aged 18 and over was approximately 205 million in 2000 (United States Census Bureau, n.d.). Using email and face-to-face contact, the researcher solicited data from 400 different people for this Capstone Project. All participants were aged 18 years or older.

Possibility for sampling bias exists. Perhaps the most obvious impact is the small size of the sample population in relation to the entire US population. The use of an internet survey and email distribution limited the personal contact between the researcher and the participants and curtailed the ability of the researcher to follow up with non-participants. The fact that this was an internet survey also limited the full participation of non-internet capable individuals. The researcher believes, however, that the sampling bias does not seriously threaten the legitimacy of the results.

## Data Collection Devices

Data were collected using an electronic data collection device (i.e. internet/online survey). This survey, included in Appendix B, was used to determine the general knowledge of the survey population on the existence of the *New Horizons* mission and their risk perceptions relating to the use of nuclear power in Space. The survey was first created during the Embry-Riddle GCPP-605 course and originally only asked five questions about the use of nuclear power in the US Space Program.

An instrument pre-test of the data collection device was conducted between October 26, 2006, and November 3, 2006. While it only used eight participants, the original survey, shown in Appendix C, was found to be useful in determining risk perceptions and general knowledge of the researcher's classmates. Following the pretest, it was clear that the survey should be changed to allow for four choices: agree, neutral, disagree and "don't know." The five core research statements (also referred to as "questions" in this project) were deemed adequate for this research project. Appendix C contains the chi-square results (and discussion) found from the instrument pre-test. The recommendations for survey improvement were incorporated into the final data collection device.

The survey was later revised to allow participants to answer the same five questions both before and after reading a Fact Sheet distributed by NASA during the lead-up to the *New Horizons* launch. The choice of this Fact Sheet was made after evaluating several such resources available on NASA websites. Some of these are included in Appendix C.

Because of the non-random sampling process, the researcher also added demographic questions, including gender, age group and location of participants relative to six spaceports in the US. Finally, a few other questions (e.g. about relationship to government or anti-nuclear protest groups, knowledge of the existence of the *New Horizons* mission) were included to allow the researcher to further understand the results of the survey.

As it became obvious that administering the survey in person was impractical, the researcher determined that developing an internet alternative was required. The researcher utilized his personal web server space and downloaded a copy of internet freeware designed to create internet surveys. The researcher created a questionnaire on the web site that looked similar to the original (paper) survey. Construction required experience with html programming language. Each of the original questions was given coded answers (e.g. Agree=1, Neutral=2, Disagree=3, Don't Know=4) to allow for use with SPSS 14.0 for Windows (Student Version). All questions required an answer before the participant could continue or submit the finished survey. The last page of the online data collection device automatically forwarded the browser to NASA *New Horizons* web site. Appendix B contains the entire data collection device as it appeared on the internet during the survey process.

## Distribution Method

The distribution method included the use of email and face-to-face contact. The data collection device was constructed using PHP Surveyer, downloaded from http://www.phpsurveyor.org, and was placed on the researcher's personal web server to ensure that all participants could easily complete it at their convenience. The address of the survey is http://goneonwalkabout.com/erau/index.php?sid=1. Individuals were asked to complete the electronic survey instrument without the use of assigned tokens (i.e. participation codes). Several of the emails sent by the researcher were forwarded by some of the participants to a limited number of further participants. The researcher kept records of each email sent and tallied the total number throughout the project. After 350 people were contacted via emails, the researcher decided to contact 50 additional people in person. He set up a computer workstation and set up the web browser on the first page of the survey. Each of these 50 participants then completed the survey in the presence of the researcher.

## Instrument Reliability

The Split-half reliability was used to determine the reliability of the survey. Each question on the survey was numbered, allowing the researcher to divide the questionnaire results into two sub-tests: a set of five questions (before the participants read the fact sheet) and a second set of five questions (taken after reading the fact sheet). Questions were correlated using SPSS 14.0 for Windows (Student Version) and results of the reliability tests are included in Appendix D. Calculations using the Spearman-Brown correction formula yielded a value of 0.832.

## Instrument Validity

Following the completion of the survey process, the answers given for each of the five base questions were evaluated for concurrent validity. The question pairs were correlated using SPSS 14.0 for Windows (Student Version) and results of the reliability tests are included in Appendix D. Resulting validity coefficients (i.e. the degree of concurrent validity of the survey taken before being exposed to the NASA risk communication fact sheet with the survey taken afterwards) were all found to be statistically significant at the 0.01 level.

## Procedures

The survey was conducted between January 26, 2007, and March 5, 2007. During this period, the researcher sent six emails to a total of 292 individuals. Another eight (8) people requested personalized emails to be forwarded to them after the original emails were sent. The researcher's wife contacted 20 more individuals using one email and three individuals reported forwarding emails to an additional total of 30 people. As previously stated, the researcher solicited the remaining 50 participants to complete the surveys in person.

The web server was open for survey completion during the dates mentioned above and there were no known instances where the survey was not available 24 hours a day. The researcher was not able to continue to collect data after March 5 due to professional duties.

## Treatment of Data

All information collected was automatically placed in a database that required password access. The PHP Surveyor software produced a results table that showed the number of participants and statistical depictions of the results to that point. The researcher used this information to further increase the number of participants in a particular area (e.g. gender, location of residence).

From the PHP Surveyor, the researcher was able to download results using a comma delimiting extraction from the database. These results were imported into a Microsoft Excel spreadsheet to ensure that they would be suitable for analysis.

The results of the survey process were analyzed using SPSS 14.0 for Windows (Student Version). Changes in participant response (both before and after the NASA risk communication Fact Sheet) were evaluated using the Dependant Samples (Matched Pairs, Paired Samples) t-Test for each question.

Some additional data was collected from (unsolicited) emails sent by participants. The researcher also collected notes on progress, observation and other feedback.

# CHAPTER IV

## RESULTS

Of the 350 individuals solicited by email, only 157 (44.9%) completed the survey. However, all 50 (100%) of the people contacted in person completed the survey on a computer provided by the researcher. Thus, a total of 207 out of 400 (51.8%) possible participants completed the survey. Expected N values discussed below are based on these 207 participants.

Since the return rate for the survey was not optimal, the researcher asked several of the email non-participants to state their reasons for not taking the survey. Most admitted that they simply did not have enough time to complete it. One reason given was lack of access to the internet for a sufficient amount of time. Another was that they forgot, even though they had received the email and wanted to help the researcher. There was never any indication that the survey itself (i.e. length, topic) was the reason for lack of participation. In fact, all persons contacted in person seemed happy to participate when presented with a computer and a web browser already showing the survey web site.

One final problem observed during the use of the internet survey was that some participants were unable to access the NASA Fact Sheet. In some cases, this was due to a lack of web browser capability (e.g. no Adobe Acrobat for PDF viewing) or lack of computer memory for file download (e.g. file too large). Of the 207 participants in the survey, 16 (7.7%) indicated that they could not read the Fact Sheet. Their responses were not removed from the results.

## Demographics

*Gender*

Target results (i.e. 200 male and 200 female) were not achieved. The total number of male participants was 113 (54.59%) and the total number of female participants was 94 (45.41%). Despite not achieving the expected N (103.5) for each gender, the difference was not statistically significant when evaluated using the Chi-Square test of independence ($p = 0.187$).

*Age*

Target results (i.e. 83 18-29 year olds, 167 30-49 year olds, 82 50-65 year olds, 68 over 65 years old) were not achieved. The total number of 18-29 year old participants was 28 (13.53%), the total number of 30-49 year olds was 100 (48.31%), the total number of 50-65 year olds was 45 (21.74%), and the total number aged above 65 was 34 (16.43%). Despite not achieving the expected N values (42.8, 86.5, 42.2 and 35.4 respectively) for each category, the difference was not statistically significant when evaluated using the Chi-Square test of independence ($p = 0.058$).

*Location & Employment*

The researcher only used residence location and employment data as a gauge of how the email solicitation was working. There were no target results for these demographics but all five major launch site areas were represented and there was even some participation from residents of New Mexico living near the proposed location of Spaceport America (also known as Southwestern Regional Spaceport). Only 23 participants (11.1%) identified themselves as NASA employees or government contractors while none reported ties with groups opposing the use of nuclear power.

*Participant Familiarity with Topic*

One question was used in the survey to gauge the actual familiarity of the participants with the *New Horizons* mission. This question revealed that of the 207 participants, only 12 (5.8%) were able to correctly state that the mission was not planned for exploration of Saturn. Informal polling of participants and non-participants indicated they were unaware of the mission or of the use of radioisotopes for deep space exploration.

Summary of Data

While many of the survey questions were designed to collect demographic data, the researcher's main goal was to collect information on public perception of the *New Horizons* mission using five basic questions. Numbering of questions in the internet survey did not actually indicate the specific importance of each question. For the following evaluation of project results, survey questions 1 through 5 have been renumbered as 1A, 2A, 3A, 4A and 5A. Survey questions 8 through 12 have been renumbered as 1B, 2B, 3B, 4B and 5B. All statistics, correlations and test results can be found in Appendix D.

*Survey Question 1: NASA's Positions on Public Safety*

The first question, "NASA believes that the safety of the public is more important than the success of the space mission," provided evidence that participants generally agreed that NASA was conscientious in its execution of the US Space Program with public safety as a priority. There was also evidence that the NASA Fact Sheet actually may have changed opinions of participants, leading several to change their minds about NASA's position on public safety. Results for this question are included in Table 1.

Table 1

*Results from Survey Question 1*

| | Frequency (Percentage) of Responses Before Fact Sheet | | Frequency (Percentage) of Responses After Fact Sheet | |
|---|---|---|---|---|
| Agree (1) | 110 | (53.14%) | 132 | (63.77%) |
| Neutral (2) | 38 | (18.36%) | 43 | (20.77%) |
| Disagree (3) | 29 | (14.01%) | 18 | (8.70%) |
| Don't Know (4) | 30 | (14.49%) | 14 | (6.76%) |
| Total | 207 | (100%) | 207 | (100%) |

A Paired Sample Test of question pair 1A-1B revealed a correlation of 0.575 and a change in participant perception that was statistically significant ($p < 0.05$).

*Survey Question 2: Perceptions of RTGs*

The second question, "Radioisotope thermoelectric generators (RTGs) are dangerous devices," provided perhaps the most dramatic evidence of the effects of the NASA Fact Sheet on public perception. While the other questions showed some migration in degree of response, the 115 responses for "don't know" for this question changed to only 31 after participants read the Fact Sheet. While some participants were not convinced of the safety of RTGs after reading the NASA risk communication literature, they were certainly able to take a position on either side of the issue. When respondents were informally polled after taking the survey, most indicated that they had never heard of RTGs but felt that they had been given helpful information about them in the Fact Sheet. Many also stated that they didn't understand technical things like RTGs but felt that the Fact Sheet was actually very easy to read. Results for this question are included in Table 2.

Table 2

*Results from Survey Question 2*

| | Frequency (Percentage) of Responses Before Fact Sheet | | Frequency (Percentage) of Responses After Fact Sheet | |
|---|---|---|---|---|
| Agree (1) | 21 | (10.14%) | 29 | (14.01%) |
| Neutral (2) | 27 | (13.04%) | 51 | (24.64%) |
| Disagree (3) | 44 | (21.26%) | 96 | (46.38%) |
| Don’t Know (4) | 115 | (55.56%) | 31 | (14.98%) |
| Total | 207 | (100%) | 207 | (100%) |

A Paired Sample Test of question pair 2A-2B revealed that there was a correlation of 0.358 and that the change in participant perception was statistically significant ($p < 0.05$).

*Survey Question 3: Fear of Exposure to Nuclear Material*

The third question, “My health will be negatively affected if there is an accidental release of any nuclear material in the atmosphere,” did not provide conclusive results for this project. While some change in perception was noted, the distribution of responses was not pronounced. There is evidence that many of the participants who were originally worried became less so, or at least less convinced of the danger of a release of any nuclear material. Results for this question are included in Table 3.

Table 3

*Results from Survey Question 3*

| | Frequency (Percentage) of Responses Before Fact Sheet | | Frequency (Percentage) of Responses After Fact Sheet | |
|---|---|---|---|---|
| Agree (1) | 69 | (33.33%) | 50 | (24.15%) |
| Neutral (2) | 19 | (9.18%) | 30 | (14.49%) |
| Disagree (3) | 76 | (36.71%) | 97 | (46.86%) |
| Don’t Know (4) | 43 | (20.77%) | 30 | (14.49%) |
| Total | 207 | (100%) | 207 | (100%) |

A Paired Sample Test of question pair 3A-3B revealed that there was a correlation of 0.468 and that the change in participant perception was not statistically significant ($p > 0.05$).

*Survey Question 4: NASA Risk Assessment*

The fourth question, "NASA accurately assesses the risks of using nuclear power in space," provided more evidence of how the NASA Fact Sheet was an effective educational tool, providing valuable information on the use of RTGs and describing their positive effect on the success of the *New Horizons* mission. While it was evident that the "don't know" responses were greatly reduced, the use of the word "accurately" may have improperly skewed the results. Several participants provided unsolicited complaints that the word "adequately" should probably have been used instead. One person noted that the word "accurately" implied there was proof of the safety of RTGs. Despite this concern, it appears that most participants were able to understand the meaning of the question. Results for this question are included in Table 4.

Table 4

*Results from Survey Question 4*

| | Frequency (Percentage) of Responses Before Fact Sheet | | Frequency (Percentage) of Responses After Fact Sheet | |
|---|---|---|---|---|
| Agree (1) | 84 | (40.58%) | 111 | (53.62%) |
| Neutral (2) | 31 | (14.98%) | 51 | (24.64%) |
| Disagree (3) | 19 | (9.18%) | 18 | (8.70%) |
| Don't Know (4) | 73 | (35.27%) | 27 | (13.04%) |
| Total | 207 | (100%) | 207 | (100%) |

A Paired Sample Test of question pair 4A-4B revealed that there was a correlation of 0.562 and that the change in participant perception was statistically significant ($p < 0.05$).

*Survey Question 5: Spacecraft Power Sources*

The fifth question, “Instead of using nuclear power in space, NASA should only design spacecraft that are powered with other energy sources,” did not provide clear evidence of NASA Fact Sheet impact on public perception. Perceptions appeared to be already mostly entrenched in the belief that the use of nuclear power should be considered in deep space exploration. There was, in fact, a marked lack of significant change in the responses. Results for this question are included in Table 5.

Table 5

*Results from Survey Question 5*

| | Frequency (Percentage) of Responses Before Fact Sheet | | Frequency (Percentage) of Responses After Fact Sheet | |
|---|---|---|---|---|
| Agree (1) | 26 | (12.56%) | 19 | (9.18%) |
| Neutral (2) | 36 | (17.39%) | 42 | (20.29%) |
| Disagree (3) | 113 | (54.59%) | 128 | (61.84%) |
| Don’t Know (4) | 32 | (15.46%) | 18 | (8.70%) |
| Total | 207 | (100%) | 207 | (100%) |

A Paired Sample Test of question pair 5A-5B revealed that there was a correlation of 0.540 and that the change in participant perception was not statistically significant ($p > 0.05$).

# CHAPTER V

# DISCUSSION

## Relevance of Questions

Of all the questions, question 5 appears to not have had as much relevance with the NASA Fact Sheet as the others did. Participants already seemed to agree that NASA should be allowed to consider the use of nuclear power systems on spacecraft. Reading the Fact Sheet only served to reinforce this belief. The researcher still believes that this question was useful, since it indicated that respondents generally see nuclear power as a viable option for further space exploration, even with minimal knowledge of how RPS are deployed.

## Bias Concerns

As the results indicate, both the sample size and response rate are causes for concern in researcher interpretation of the effect of the NASA Fact Sheet on the public during the *New Horizons* mission. Time constraints, professional responsibilities and inexperience on the part of the researcher created sample bias. Further, while the researcher originally intended to use non-random purposive (judgment) sampling, the actual outcome should be more properly characterized as non-random convenience (accidental) sampling. While important, the researcher believes that the effect of the sampling bias does not override the significance of the research project results and conclusions.

## Gender Effect on Response

Table 6 provides a comparison of the mean responses given by men and women (and the overall group of participants) for each question. Lower numbers indicate greater agreement and higher numbers indicate disagreement or lack of subject knowledge.

Table 6

*Mean Response to Questions by Gender*

| | Mean of Responses Before Fact Sheet | Mean of Responses After Fact Sheet |
|---|---|---|
| Question 1 (NASA & Public Safety) | | |
| Male (113) | 1.6726 | 1.4071 |
| Female (94) | 2.1702 | 1.7979 |
| Overall (207) | 1.8986 | 1.5845 |
| Question 2 (RTGs) | | |
| Male (113) | 3.1327 | 2.5487 |
| Female (94) | 3.3298 | 2.7128 |
| Overall (207) | 3.2222 | 2.6232 |
| Question 3 (Health & Nuclear Accident) | | |
| Male (113) | 2.4867 | 2.4425 |
| Female (94) | 2.4043 | 2.6064 |
| Overall (207) | 2.4493 | 2.5169 |
| Question 4 (NASA's Risk Assessment) | | |
| Male (113) | 2.2301 | 1.6814 |
| Female (94) | 2.5851 | 1.9681 |
| Overall (207) | 2.3913 | 1.8116 |
| Question 5 (Use of Nuclear Power for Space) | | |
| Male (113) | 2.7876 | 2.7788 |
| Female (94) | 2.6596 | 2.6064 |
| Overall (207) | 2.7295 | 2.7005 |

Note: High means for question 2 were due to the large number of "don't know" answers.

Previous research conducted by Rodrigue on the *Cassini-Huygens* mission showed that women have been less likely to accept or support space missions with some degree of danger. Conversely, men have shown a greater acceptance of risk in the pursuit of some gain, such as scientific knowledge (Rodrigue, 2001). There is evidence that this effect is present in this research project, since two questions show slightly different gender views of NASA's risk assessment processes. In the area of NASA's concern for public safety (question 1) and NASA's accuracy in risk assessment (question 4), female respondents began from a position of less agreement than male respondents. However, reading the Fact Sheet influenced female participants nearly the same degree as male participants. Results from the other three questions indicate that female responses were similar to male responses.

## Age Effect on Response

Table 7 provides a comparison of the mean responses given by each age group surveyed (and the overall group of participants) for each question. Lower numbers indicate greater agreement and higher numbers indicate disagreement or lack of subject knowledge.

Table 7

*Mean Response to Questions by Age*

| | Mean of Responses Before Fact Sheet | Mean of Responses After Fact Sheet |
|---|---|---|
| <u>Question 1 (NASA & Public Safety)</u> | | |
| 18-29 (28) | 1.7143 | 1.4286 |
| 30-49 (100) | 1.8800 | 1.5800 |
| 50-65 (45) | 2.2444 | 1.7556 |
| Over 65 (34) | 1.6471 | 1.5000 |
| Overall (207) | 1.8986 | 1.5845 |
| <u>Question 2 (RTGs)</u> | | |
| 18-29 (28) | 3.1786 | 2.6786 |
| 30-49 (100) | 3.1900 | 2.6300 |
| 50-65 (45) | 3.2889 | 2.6889 |
| Over 65 (34) | 3.2647 | 2.4706 |
| Overall (207) | 3.2222 | 2.6232 |
| <u>Question 3 (Health & Nuclear Accident)</u> | | |
| 18-29 (28) | 2.2143 | 2.5357 |
| 30-49 (100) | 2.4200 | 2.5100 |
| 50-65 (45) | 2.8222 | 2.8000 |
| Over 65 (34) | 2.2353 | 2.1471 |
| Overall (207) | 2.4493 | 2.5169 |
| <u>Question 4 (NASA's Risk Assessment)</u> | | |
| 18-29 (28) | 2.0000 | 1.3214 |
| 30-49 (100) | 2.4700 | 1.8100 |
| 50-65 (45) | 2.5333 | 2.0444 |
| Over 65 (34) | 2.2941 | 1.9118 |
| Overall (207) | 2.3913 | 1.8116 |
| <u>Question 5 (Use of Nuclear Power for Space)</u> | | |
| 18-29 (28) | 2.7143 | 2.5714 |
| 30-49 (100) | 2.7700 | 2.7400 |
| 50-65 (45) | 2.6889 | 2.6667 |
| Over 65 (34) | 2.6765 | 2.7353 |
| Overall (207) | 2.7295 | 2.7005 |

Note: High means for question 2 were due to the large number of "don't know" answers.

While most of the results are similar between each age group and the overall responses, the 50-65 year old age group responses for questions 3 and 5 were each nearly identical before and after reading the NASA Fact Sheet. Similarity of answers from all age groups for question 5 may indicate that this question had less relevance than the other four questions. The 50-65 year olds' responses to question 3, however, seem to indicate that the NASA Fact Sheet did not have any impact on their opinions. It also appears that this age group's responses prevented the overall results for question 3 from showing a statistically significant change in response.

The 18-29 year old age group seemed to have been reassured by the NASA Fact Sheet more than the other age groups, especially in question 3 answers. This response, coupled with the increase in support for NASA's risk assessment practices, may be the result of the younger generations comfort with internet and other web based risk communication methods.

# CHAPTER VI

# CONCLUSIONS

This research project shows that much of the public was unaware of the activities of NASA during the time leading up to the launch of *New Horizons*. In addition, there was an overwhelming lack of understanding of the types of nuclear power systems aboard spacecraft.

As discussed in the review of relevant literature, it is clear that the public can be greatly influenced by positive or negative publicity of hazards. Since this survey was conducted in the form of email communication between individuals (i.e. “word of mouth”), it provided insight into the possibility that rational discourse on the use of nuclear power in space can lead to public acceptance of such programs. As documented by other researchers, alarmist or non-scientific publicity (in the form of web-logs or email) can, conversely, help to perpetuate negative images of the RPS option. During this research project, the researcher consistently encountered a type of “surprised interest” in both participants and non-participants. Most said they had no idea that a spacecraft was traveling to Pluto but stated that they wanted to follow the progress of the *New Horizons* mission because the research project had introduced it to them.

Of the five basic survey questions used for this project, three (1, 2, and 4) provided statistically significant evidence that the NASA Fact Sheet used by the researcher changed the minds of participants or educated them on the use of nuclear power systems for space exploration. While the other two questions (3 and 5) did not show statistically significant influence on participants, there was still evidence that the NASA Fact Sheet contained useful safety information and other thought provoking material for a generally interested public. Question 3 may have been unduly influenced by one age group's responses. Question 5 seems to have only shown that support for using nuclear power in space can be reinforced by risk communication resources. Questions 1 and 4 may have been affected by gender.

## Re-Statement of the Hypothesis

It is hypothesized that the NASA risk communication strategies used in preparation for the launch of the *New Horizons* mission did not significantly affect public risk perceptions of the safety of nuclear power systems used in spacecraft.

## Survey Outcome

Because of the strong evidence that the NASA Fact Sheet changed the minds of survey participants in at least three of the questions, coupled with evidence of pre-survey support for the use of nuclear power in space, the null-hypothesis can be rejected.

# CHAPTER VII

## RECOMMENDATIONS

The researcher recommends that this survey be conducted a second time. A group of individuals, perhaps graduate students, could easily manage the selection and surveying of a larger group. In addition, the response rate could be greatly improved. Parameters for another research project should include a better definition of the sample population, perhaps choosing individuals from the telephone book from a city near one of the federally approved launch sites using a simple random selection method. Using more than one launch site (i.e. two sample groups) and a location not near a launch site (i.e. control group) could provide further confirmation of the results of this survey.

Use of additional risk communication tools (i.e. fact sheets) could also be used in one city to compare responses of different groups. Examining two groups near one launch site could be performed using a NASA Fact Sheet for one part of the group and using a Fact Sheet generated by an anti-nuclear activist group for another part of the group.

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# APPENDIX A

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Kirkpatrick, L. A., Feeney, B. C. (2006). *A simple guide to SPSS for Windows for version 12.0 & 13.0*. Belmont, CA: Thomson Wadsworth.

# APPENDIX B

## DATA COLLECTION DEVICE

## Nuclear Power In Space

The purpose of this survey is to examine the public's opinions relating to nuclear power used for space exploration.

Thank you for agreeing to participate in this survey! Please answer each of the following questions without referencing any other sources.

*Click on the "next >> " button to begin.*

*Click here if you don't want to participate:*
[Exit and Clear Survey]

next >>

## Nuclear Power In Space

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

Step 1

Please select an answer which best describes your feelings about each statement.

1 *NASA believes that the safety of the public is more important that the success of the space mission.

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

2 *Radioisotope thermoelectric generators (RTGs) are dangerous devices.

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

3 *My health will be negatively affected if there is an accidental release of any nuclear material in the atmosphere.

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

4 *NASA accurately assesses the risks of using nuclear power in space.

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

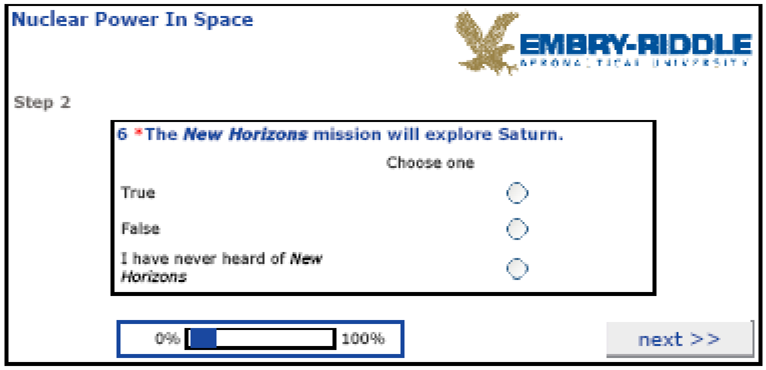
5 *Instead of using nuclear power in space, NASA should only design spacecraft that are powered with other energy sources.

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

0% 100%

next >>



Nuclear Power In Space

Step 2

6 *The *New Horizons* mission will explore Saturn.

| | Choose one |
|---|---|
| True | ◯ |
| False | ◯ |
| I have never heard of *New Horizons* | ◯ |

0% 100%

next >>

## Nuclear Power In Space

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

**Step 3**

Please click on the link below to read a NASA Fact Sheet (2005) about the *New Horizons* mission.

Click HERE.

Note: a new browser window will be opened.

**7 *Were you able to read the fact sheet when you clicked on the link above?**

Choose one

Yes ○

No ○

0% 100% next >>

NASA Fact Sheet
February 2005

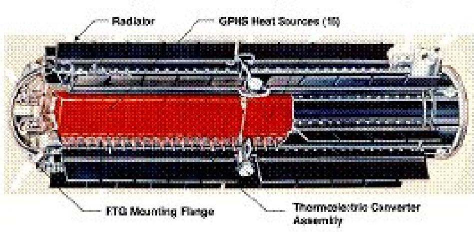
# *Spacecraft Power for New Horizons*

NASA's planned New Horizons mission would be the first-ever spacecraft exploration of Pluto and the Kuiper Belt. If approved, a radioisotope thermoelectric generator (RTG) will provide the electrical power to operate the New Horizons spacecraft's mechanical and electronic systems in the cold darkness of deep space. The Johns Hopkins University Applied Physics Laboratory (APL) will build the spacecraft.

New Horizons' journey is planned to take it more than 4 billion miles from Earth, where the Sun is just a bright star in the dark sky. Besides taking longer than 4 hours to reach Pluto and nearby Kuiper Belt objects, light from the Sun is 1,000 times fainter there than at Earth.

## What Are RTGs?

RTGs are compact and extraordinarily reliable spacecraft power systems.




RTGs convert the heat generated from the natural decay of the radioactive fuel into electricity. RTGs consist of two major elements: a heat source that contains plutonium dioxide in the form of ceramic pellets and a set of solid-state thermocouples that convert the plutonium's heat energy to electricity.

In 1821, Thomas Johann Seebeck discovered how to convert heat directly into electricity using a simple and robust device. He found that an electrical current is generated when two dissimilar electrically conductive materials are connected in a closed circuit and their junctions are kept at different temperatures. Thermoelectric couples (or thermocouples) in various forms are in common use today, with proven long-term reliability and no moving parts they are well suited to the space environment.

The RTG thermocouples use heat generated by the radioactive decay of plutonium to heat the hot junction of the thermocouple, and exposure to the cold of outer space to maintain the temperature of the cold junction. The electrical output is a function of the temperature difference between the hot and cold sides of the thermocouple. A number of these thermocouples are arranged in a converter assembly and the electricity generated by the converter is then available to power the spacecraft instruments.

RTGs can provide continuous power in regions of space where the use of solar power is not feasible. Over the past 40 years, RTGs have been used safely and reliably on 25 missions, including six Apollo flights to the moon, two Pioneer spacecraft to Jupiter and Saturn, two Mars Viking landers, two Voyager missions to the outer planets, the Galileo mission to Jupiter, the Ulysses mission to the Sun's poles, and the Cassini-Huygens mission to Saturn.

## Designed for Safety

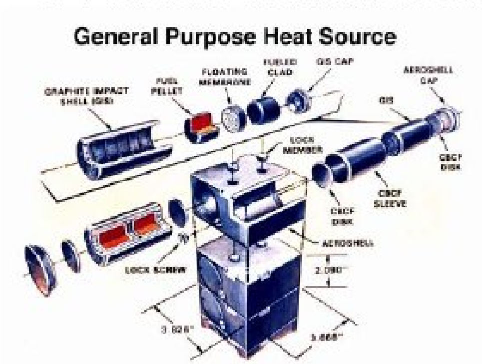
More than 40 years have been invested in the engineering, analysis and testing of RTGs. As described below, safety features of an RTG include the use of a specific type of fuel material, a modular design and construction and the use of multiple physical barriers.

Source: http://pluto.jhuapl.edu/common/content/pdfs/NHRTG_FS_100804.pdf

The plutonium dioxide fuel contained in RTGs is a specially formulated fire-resistant ceramic that is manufactured as pellets to reduce the possibility of fuel dispersion in a launch or reentry accident. This ceramic form resists dissolution in water and reacts little with other chemicals. If fractured, the ceramic tends to break into relatively large particles and chunks that pose fewer hazards than small, microscopic particles.

Multiple layers of protective materials, including iridium capsules and high-strength graphite blocks, protect and contain the fuel and reduce the chance of release of the plutonium dioxide. Iridium, a strong, ductile, corrosion-resistant metal with a very high melting temperature, encases each fuel pellet. Impact shells made of lightweight and highly heat-resistant graphite provide additional protection.

Each RTG contains 18 heat source modules with four plutonium dioxide pellets in each module. There are two plutonium dioxide pellets in each graphite impact shell, and two graphite impact shells go into each heat source module. The figure below shows part of a heat source stack within the RTG.




<u>Risk Assessment and Launch Approval</u>

Any mission that plans to use an RTG as a power source undergoes a safety analysis carried out by the Department of Energy (DoE). The safety analysis report provides a comprehensive assessment of the potential consequences of a broad range of possible launch accidents. In addition to the DOE review, an ad hoc Interagency Nuclear Safety Review Panel (INSRP), which is supported by experts from government, industry and academia, is established as part of a Presidential nuclear safety launch approval process to evaluate the safety analysis report prepared by DOE. Based upon the INSRP evaluation and recommendations by DOE and other Federal agencies, NASA may then submit a request for nuclear safety launch approval to the White House Office of Science and Technology Policy (OSTP). The OSTP Director (i.e., the President's science adviser) may make the nuclear safety launch decision or refer the matter to the President. In either case, the launch cannot proceed until nuclear safety launch approval has been granted.

<u>SUMMARY</u>

RTGs enable spacecraft to operate on missions where solar power systems would not be feasible. The Department of Energy is responsible for all aspects of RTG production and delivery to NASA, including safety analysis of the mission. RTGs can be used on NASA spacecraft only after this detailed safety analysis has been completed, reviewed by safety experts, and launch approval obtained from OSTP. RTGs have a proven record of safety and remain unmatched for reliability and durability over any other power technology for outer solar system missions.

For New Horizons, an RTG is uniquely capable of powering this reconnaissance mission to distant Pluto and the Kuiper Belt, where the Sun is no more than a bright point of light in the sky.

For more information, please contact:

Michael Braukus, NASA Headquarters
(202) 358-1979,

Alice Caponiti, Department of Energy
(301) 903-6062, or

Mike Buckley, Applied Physics Laboratory
(240) 228-7536

<u>Source</u>: http://pluto.jhuapl.edu/common/content/pdfs/NHRTG_FS_100804.pdf

## Nuclear Power In Space

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

Step 4

Please select an answer which best describes your feelings about each statement.

**8 *NASA believes that the safety of the public is more important than the success of a space mission.**

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

**9 *Radioisotope thermoelectric generators (RTGs) are dangerous devices.**

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

**10 *My health will be negatively affected if there is an accidental release of any nuclear material in the atmosphere.**

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

**11 *NASA accurately assesses the risks of using nuclear power in space.**

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

**12 *Instead of using nuclear power in space, NASA should only design spacecraft that are powered with other energy sources.**

Choose one

- Agree ◯
- Neutral ◯
- Disagree ◯
- Don't Know ◯

0% 100%

next >>

## Nuclear Power In Space

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

Step 5

13 *Have you ever lived near of one of the following Federal Aviation Administration (FAA) approved spaceports?

Note - "near" indicates that you routinely hear about activities at the site from local news media.

| | Choose one |
|---|---|
| Near California Spaceport (Vandenberg AFB) | ○ |
| Near Spaceport Florida (Cape Canaveral) | ○ |
| Near Virginia Space Flight Center (Wallops Island) | ○ |
| Near Kodiak Launch Complex (Alaska) | ○ |
| Near Mojave Airport (California) | ○ |
| Near (proposed) Southwestern Regional Spaceport (New Mexico) | ○ |
| No | ○ |

14 *Do you currently live near of one of the following Federal Aviation Administration (FAA) approved spaceports?

Note - "near" indicates that you routinely hear about activities at the site from local news media.

| | Choose one |
|---|---|
| Near California Spaceport (Vandenberg AFB) | ○ |
| Near Spaceport Florida (Cape Canaveral) | ○ |
| Near Virginia Space Flight Center (Wallops Island) | ○ |
| Near Kodiak Launch Complex (Alaska) | ○ |
| Near Mojave Airport (California) | ○ |
| Near (proposed) Southwestern Regional Spaceport (New Mexico) | ○ |
| No | ○ |

0% 100%

next >>

**Nuclear Power In Space**

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

Step 6

**15 *What is your gender?**

Choose one

- Male ◯
- Female ◯

**16 *What is your age?**

Choose one

- under 18 ◯
- 18-29 ◯
- 30-49 ◯
- 50-65 ◯
- over 65 ◯

**17 *Would you characterize yourself as an employee/member of the following?**

Choose one

- NASA or government contractor ◯
- Group which opposes use of nuclear power ◯
- No ◯

0% 100%

last

**Nuclear Power In Space**

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

**Thank You**

**You have completed answering the questions in this survey.**

Click on [submit] now to complete the process and save your answers.

submit

***A note on privacy***

The record kept of your survey responses does not contain any identifying information about you unless a specific question in the survey has asked for this. If you have responded to a survey that used an identifying token to allow you to access the survey, you can rest assured that the identifying token is not kept with your responses. It is managed in a seperate database, and will only be updated to indicate that you have (or haven't) completed this survey. There is no way of matching identification tokens with survey responses in this survey.

# APPENDIX C
# PRE-PROJECT ANALYSIS

**Instrument Pre-Test**
(GCPP-605 Questionnaire Exercise)

Thanks for agreeing to participate in this survey! Please answer each of the following questions without referencing any other sources. Indicate your choice by circling the number which best approximates your feelings about each statement.

The purpose of this survey is to examine whether NASA's risk communication strategy actually reduced opposition to power devices used for the New Horizons mission.

1. NASA believes that the safety of the public is more important than the success of a Space mission.

1 - Agree Strongly 2 - Agree 3 - Disagree 4 - Disagree Strongly
5 - Don't Know

2. Radioisotope thermoelectric generators (RTGs) and radioisotope heater units (RHUs) are dangerous devices.

1 - Agree Strongly 2 - Agree 3 - Disagree 4 - Disagree Strongly
5 - Don't Know

3. My health will be negatively affected if there is an accidental release of any nuclear material in the atmosphere.

1 - Agree Strongly 2 - Agree 3 - Disagree 4 - Disagree Strongly
5 - Don't Know

4. NASA accurately assesses the risks of using nuclear power in Space.

1 - Agree Strongly 2 - Agree 3 - Disagree 4 - Disagree Strongly
5 - Don't Know

5. Instead of using nuclear power in Space, NASA should only design spacecraft that are powered with other energy sources.

1 - Agree Strongly 2 - Agree 3 - Disagree 4 - Disagree Strongly
5 - Don't Know

---

PLEASE ALSO ANSWER THESE QUESTIONS:

The New Horizons mission will explore Saturn.

1 - Agree 2 – Disagree 3 - I have never heard of New Horizons

What is your Gender? 1 - Female 2 – Male

**<u>Instrument Pre-Test (Continued)</u>**
(GCPP-605 Questionnaire Chi-Square Test)

My questionnaire had the following questions:
1. NASA believes that the safety of the public is more important than the success of a Space mission.
2. Radioisotope thermoelectric generators (RTGs) and radioisotope heater units (RHUs) are dangerous devices.
3. My health will be negatively affected if there is an accidental release of any nuclear material in the atmosphere.
4. NASA accurately assesses the risks of using nuclear power in Space.
5. Instead of using nuclear power in Space, NASA should only design spacecraft that are powered with other energy sources.

**There were 8 respondents to the survey (this led to the 1.6 expected N for 5 questions).**

Categories in the charts below correspond to:
1 – Strongly Agree 2 – Agree 3 – Disagree
4 – Strongly Disagree 5 – Don't Know

**Frequencies**

| | question1 | | | | question2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Category | Observed N | Expected N | Residual | Category | Observed N | Expected N | Residual |
| 1 | 1.00 | 1 | 1.6 | -.6 | | 0 | 1.6 | -1.6 |
| 2 | 2.00 | 4 | 1.6 | 2.4 | 2.00 | 2 | 1.6 | .4 |
| 3 | 3.00 | 1 | 1.6 | -.6 | 3.00 | 1 | 1.6 | -.6 |
| 4 | | 0 | 1.6 | -1.6 | | 0 | 1.6 | -1.6 |
| 5 | 5.00 | 2 | 1.6 | .4 | 5.00 | 5 | 1.6 | 3.4 |
| Total | | 8 | | | | 8 | | |

| | question3 | | | | question4 | | | |
|---|---|---|---|---|---|---|---|---|
| | Category | Observed N | Expected N | Residual | Category | Observed N | Expected N | Residual |
| 1 | 1.00 | 2 | 1.6 | .4 | 1.00 | 1 | 1.6 | -.6 |
| 2 | 2.00 | 2 | 1.6 | .4 | 2.00 | 5 | 1.6 | 3.4 |
| 3 | 3.00 | 3 | 1.6 | 1.4 | | 0 | 1.6 | -1.6 |
| 4 | | 0 | 1.6 | -1.6 | | 0 | 1.6 | -1.6 |
| 5 | 5.00 | 1 | 1.6 | -.6 | 5.00 | 2 | 1.6 | .4 |
| Total | | 8 | | | | 8 | | |

| | question5 | | | |
|---|---|---|---|---|
| | Category | Observed N | Expected N | Residual |
| 1 | | 0 | 1.6 | -1.6 |
| 2 | 2.00 | 3 | 1.6 | 1.4 |
| 3 | 3.00 | 5 | 1.6 | 3.4 |
| 4 | | 0 | 1.6 | -1.6 |
| 5 | | 0 | 1.6 | -1.6 |
| Total | | 8 | | |

**Test Statistics**

| | question1 | question2 | question3 | question4 | question5 |
|---|---|---|---|---|---|
| Chi-Square(a) | 5.750 | 10.750 | 3.250 | 10.750 | 13.250 |
| df | 4 | 4 | 4 | 4 | 4 |
| Asymp. Sig. | .219 | .030 | .517 | .030 | .010 |

a 5 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.6.

**Instrument Pre-Test (Continued)**
(GCPP-605 Questionnaire Discussion)

I made an assumption – that all choices had an equal chance of being picked (expected N=1.6). It appears that the results varied significantly from the expected N in Question 2 (RTG & RHU are dangerous…), Question 4 (NASA accurately assesses risks…) and Question 5 (Instead of using nuclear power…). This may be an indication of specific opinion in these areas (or lack of knowledge of the subject for Question 2) in the survey population. For the other two questions, there is no evidence of consensus among the participants.

Ideas for survey improvement:
It appears that I did not need to use the category "Strongly Disagree", since it was never chosen. I might be able to combine the Agree and Strongly Agree (and Disagree and Strongly Disagree) categories into just "Agree" and "Disagree". I could also add a choice of "Undecided" to see if that changed the results.

I may be able to use a variant of this survey in my GCP as follows:

Step 1. Have participants take the survey.
Step 2. Show participants NASA risk assessment data on RTGs/RHUs (i.e. use their risk communication strategy).
Step 3. Have participants take the survey again.
Step 4. Compare the results.

## Fact Sheet Analysis

There are at least two NASA sponsored *New Horizons* websites:
http://www.nasa.gov/mission_pages/newhorizons/main/
http://pluto.jhuapl.edu/

Several choices for the NASA (or DOE) risk communication resources were evaluated before the final choice was made. Three of the Fact Sheets that were considered as candidates for this project are included in the following pages.

The researcher used Choice 1 because it could be located from NASA websites and was therefore easily accessible from more than one location if someone was to look for information about the *New Horizons* mission or RTGs.

There are (at least) two locations with access to the fact sheet:
http://pluto.jhuapl.edu/spacecraft/power.php
(This one has a link to the fact sheet and discusses nuclear safety issues -you have to open another window)
http://pluto.jhuapl.edu/overview/deis/intro.html
(This one has the link to the fact sheet and discusses nuclear safety issues)

# Choice 1:

NASA Fact Sheet
February 2005

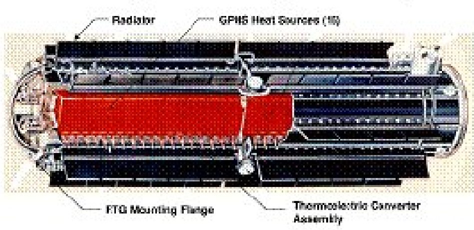
## *Spacecraft Power for New Horizons*

NASA's planned New Horizons mission would be the first-ever spacecraft exploration of Pluto and the Kuiper Belt. If approved, a radioisotope thermoelectric generator (RTG) will provide the electrical power to operate the New Horizons spacecraft's mechanical and electronic systems in the cold darkness of deep space. The Johns Hopkins University Applied Physics Laboratory (APL) will build the spacecraft.

New Horizons' journey is planned to take it more than 4 billion miles from Earth, where the Sun is just a bright star in the dark sky. Besides taking longer than 4 hours to reach Pluto and nearby Kuiper Belt objects, light from the Sun is 1,000 times fainter there than at Earth.

What Are RTGs?

RTGs are compact and extraordinarily reliable spacecraft power systems.




RTGs convert the heat generated from the natural decay of the radioactive fuel into electricity. RTGs consist of two major elements: a heat source that contains plutonium dioxide in the form of ceramic pellets and a set of solid-state thermocouples that convert the plutonium's heat energy to electricity.

In 1821, Thomas Johann Seebeck discovered how to convert heat directly into electricity using a simple and robust device. He found that an electrical current is generated when two dissimilar electrically conductive materials are connected in a closed circuit and their junctions are kept at different temperatures. Thermoelectric couples (or thermocouples) in various forms are in common use today, with proven long-term reliability and no moving parts they are well suited to the space environment.

The RTG thermocouples use heat generated by the radioactive decay of plutonium to heat the hot junction of the thermocouple, and exposure to the cold of outer space to maintain the temperature of the cold junction. The electrical output is a function of the temperature difference between the hot and cold sides of the thermocouple. A number of these thermocouples are arranged in a converter assembly and the electricity generated by the converter is then available to power the spacecraft instruments.

RTGs can provide continuous power in regions of space where the use of solar power is not feasible. Over the past 40 years, RTGs have been used safely and reliably on 25 missions, including six Apollo flights to the moon, two Pioneer spacecraft to Jupiter and Saturn, two Mars Viking landers, two Voyager missions to the outer planets, the Galileo mission to Jupiter, the Ulysses mission to the Sun's poles, and the Cassini-Huygens mission to Saturn.

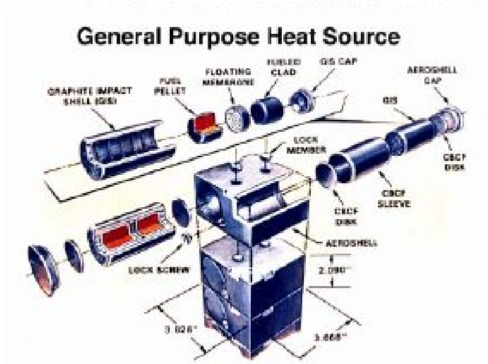
Designed for Safety

More than 40 years have been invested in the engineering, analysis and testing of RTGs. As described below, safety features of an RTG include the use of a specific type of fuel material, a modular design and construction and the use of multiple physical barriers.

The plutonium dioxide fuel contained in RTGs is a specially formulated fire-resistant ceramic that is manufactured as pellets to reduce the possibility of fuel dispersion in a launch or reentry accident. This ceramic form resists dissolution in water and reacts little with other chemicals. If fractured, the ceramic tends to break into relatively large particles and chunks that pose fewer hazards than small, microscopic particles.

Multiple layers of protective materials, including iridium capsules and high-strength graphite blocks, protect and contain the fuel and reduce the chance of release of the plutonium dioxide. Iridium, a strong, ductile, corrosion-resistant metal with a very high melting temperature, encases each fuel pellet. Impact shells made of lightweight and highly heat-resistant graphite provide additional protection.

Each RTG contains 18 heat source modules with four plutonium dioxide pellets in each module. There are two plutonium dioxide pellets in each graphite impact shell, and two graphite impact shells go into each heat source module. The figure below shows part of a heat source stack within the RTG.




Risk Assessment and Launch Approval

Any mission that plans to use an RTG as a power source undergoes a safety analysis carried out by the Department of Energy (DoE). The safety analysis report provides a comprehensive assessment of the potential consequences of a broad range of possible launch accidents. In addition to the DOE review, an ad hoc Interagency Nuclear Safety Review Panel (INSRP), which is supported by experts from government, industry and academia, is established as part of a Presidential nuclear safety launch approval process to evaluate the safety analysis report prepared by DOE. Based upon the INSRP evaluation and recommendations by DOE and other Federal agencies, NASA may then submit a request for nuclear safety launch approval to the White House Office of Science and Technology Policy (OSTP). The OSTP Director (i.e., the President's science adviser) may make the nuclear safety launch decision or refer the matter to the President. In either case, the launch cannot proceed until nuclear safety launch approval has been granted.

SUMMARY

RTGs enable spacecraft to operate on missions where solar power systems would not be feasible. The Department of Energy is responsible for all aspects of RTG production and delivery to NASA, including safety analysis of the mission. RTGs can be used on NASA spacecraft only after this detailed safety analysis has been completed, reviewed by safety experts, and launch approval obtained from OSTP. RTGs have a proven record of safety and remain unmatched for reliability and durability over any other power technology for outer solar system missions.

For New Horizons, an RTG is uniquely capable of powering this reconnaissance mission to distant Pluto and the Kuiper Belt, where the Sun is no more than a bright point of light in the sky.

For more information, please contact:

Michael Braukus, NASA Headquarters
(202) 358-1979,

Alice Caponiti, Department of Energy
(301) 903-6062, or

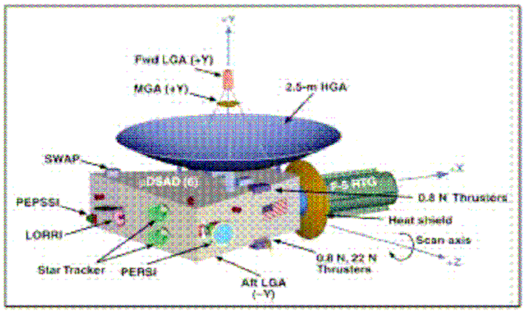
Mike Buckley, Applied Physics Laboratory
(240) 228-7536

Source: http://pluto.jhuapl.edu/common/content/pdfs/NHRTG_FS_100804.pdf

# Choice 2:

## Space Radioisotope Power Systems
## *New Horizons Mission (Pluto)*
October 2002

In January 2006, the New Horizons Project plans to send a spacecraft on a mission to fly by the Pluto-Charon system and encounter up to three Kuiper Belt Objects (KBOs). The mission trajectory would swing by Jupiter. While the mission's main objective is to gather and return data on Pluto-Charon, science data would also be obtained on Jupiter and some of its moons and on the as-yet undetermined KBOs. This data would be used by the international science community to better understand the formation and history of the outer solar system.




*New Horizon RTG*

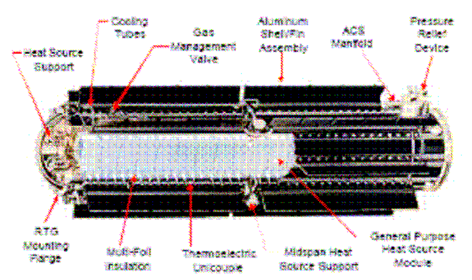
The launch window is from January 13 to January 31, 2006. The New Horizons spacecraft would utilize a Radioisotope Thermoelectric Generator (RTG) to provide electricity and heat to the science instruments and other spacecraft components.

### Why are Radioisotope Thermoelectric Generators Needed in Space?

Most Earth orbital spacecraft use solar panels to convert solar energy into electricl power. Because Pluto is nearly four billion miles from the sun, more than 30 times farther away than earth, solar radiation intensity is extremely low. As a result, solar panels would have to be excessive in size -- too massive for existing launch vehicles. Similarly, existing batteries and chemical power sources cannot provide power for the length of time required by the Pluto mission.

### What is the History of RTGs in Space?

RTGs are not a new part of the U.S. space program. In fact, they have enabled the National Aeronautics and Space Administration (NASA) to explore the Solar System for many years. The Apollo missions (to the Moon), the Viking missions (to Mars), and the Pioneer, Voyager, Ulysses, Galileo, and Cassini (outer Solar System) missions all used RTGs. The RTGs for the Pioneer 10 spacecraft have operated flawlessly for three decades and continue to power the spacecraft as it continues into enterstellar space. Over the last three decades, the United States has launched 25 missions involving 44 RTGs. While RTGs have never been the cause of a spacecraft accident, they have been on board three space missions that did fail for other reasons. In all three cases, the RTGs performed as designed. Early RTGs carried smaller amounts of radioisotope material and in keeping with the safety philosophy at the time, were built to burn up at high altitude during an accidental reentry. One such reentry occurred in 1964 during the malfunction of a navigational satellite for the Navy. Later RTGs were designed to contain their plutonium in case of reentry and performed this function successfully in mission failures in 1968 (a weather satellite launch failure) and 1970 (Apollo 13).




Radioisotope Thermoelectric Generator

### How Do RTGs Work?

The New Horizon RTG consists of two major elements: a heat source that contains the plutonium-238 dioxide fuel and a set of solid-state thermocouples that convert the plutonium's heat energy into electricity.

Conversion of heat directly into electricity is not a new principle. It was discovered 150 years ago by a German scientist named Thomas Johann Seebeck. He observed that an electric voltage is produced when two dissimilar, electrically conductive materials are joined in a closed circuit and the two junctions are kept at different temperatures.

Such pairs of junctions are called thermoelectric couples, or thermocouples. The power output is a function of the temperature of each junction and thermoelectric materials properties. The thermocouples in RTGs use heat from the radioactive decay of plutonium to heat the hot junction of the thermocouple, and the cold of outer space to produce a low temperature at the cold junction of the thermocouple.

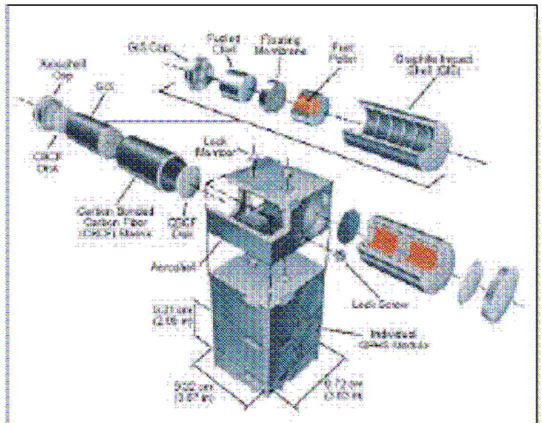
The heat source for an RTG is composed of 72 specially contained ceramic pellets of plutonium-238 dioxide. The pellets weigh a total of about 24 pounds (11 kilograms). The RTG will produce about 213 watts of electricity, at the beginning of the mission in January 2006.

### Safety Design

RTGs are designed and tested to contain their radioactive fuel during all normal and accident conditions.

The RTG is composed of 18 modules. Each module contains 4 plutonium dioxide fuel elements enclosed within several layers of protective materials. The purpose of these multiple protective layers is to minimize the effect of the physical conditions that might result from an accident and to reduce or prevent the release of plutonium fuel into the environment.

The plutonium fuel used in the RTG is a ceramic, oxide form, similar in nature to ceramics used in kitchenware. It is insoluble in water and chemically nonreactive. This means that if released into the environment, the plutonium migrates very slowly into the food chain. Then it hits hard surfaces, it breaks into relatively large pieces rather than crumbling into dust; consequently, potential inhalation of very small particles is minimized. The plutonium pellets are surrounded by a metal alloy of iridium capable of withstanding very high temperatures. This cladding protects against reentry heating and other accident scenarios.



*GPHS Module*

The other protective layers are made of a special graphite composite material with an extremely high temperature resistance. This material is used by the Air Force to protect missile nose cones and is on of the best available for reentry applications. A three-quarter inch thick layer of metal and fiberglass insulation surrounds the modules and provides an additional protective barrier. The entire assembly is then enclosed in an aluminum outer shell.

### Summary

Extensive safety tests conducted by the Department of Energy demonstrated that the RTGs are rugged and can withstand all but the most extreme and unlikely accident conditions. Because they are also light weight and highly reliable power sources, the RTG is uniquely suited to meet the needs of the New Horizons mission.

Visit our web site: nuclear.gov

Source: http:// www.ne.doe.gov/pdfFiles/MMRTG_Oct2002.pdf

Choice 3:

# New Horizons Mission

## Emergency Response Preparations

The New Horizons mission, scheduled for launch in January 2006, is an exciting undertaking for NASA and the nation. New Horizons is designed to help us understand worlds at the edge of our solar system by making the first reconnaissance of Pluto and Charon – a "double planet." The mission would then visit one or more objects in the Kuiper Belt region beyond Neptune.

Electrical power for the New Horizons spacecraft will come from a radioisotope thermoelectric generator (RTG), which produces electricity from the heat emitted by plutonium-238. These generators have been used on many previous NASA missions. NASA and the Department of Energy (DOE) are committed to protecting the public and the environment under both normal operations and from any accident that might potentially release the radioactive materials in the RTG.

NASA and DOE do not expect the safety of the public to be threatened by the launch of the New Horizons mission even if an accident should occur. We are taking proactive steps to provide technical resources, trained personnel, and timely communication of information. NASA and the agencies of the local, State, and Federal government responsible for emergency response have collectively developed a strategy and plan for responding to an accident involving the New Horizons spacecraft.

In the unlikely event of an accident, the emergency response activities will always be directed toward protecting the health and safety of the public and on-site personnel from potential hazards. Once protective measures have been taken, NASA, DOE, and other Federal agencies would execute recovery plans to locate and recover radioactive materials if necessary.

A launch accident would not necessarily produce a radiation hazard, so the critical first action in responding to any situation will be collecting accurate information about whether any radiation hazard actually exists. Prior to launch, 16 mobile field teams comprising radiation safety and detection specialists from the Federal agencies and the State of Florida will be in the area surrounding the launch site, both inside and outside the Kennedy Space Center/Cape Canaveral Air Force Station boundary. Each of these teams will carry state-of-the-art, specialized instrumentation for air sampling and contamination detection. Additionally, automated air monitoring stations will be in place before launch to continuously monitor the air to detect any release of radioactive material following a launch accident.

A Radiological Control Center (RADCC) onsite and an offsite control center will be staffed with radiation detection and assessment experts from Federal, State and local agencies to evaluate the measurements being made by the mobile field teams, and the automated air monitoring stations. The purpose of the two control centers is to evaluate the field measurement information to assess whether a release of radioactive material has occurred, to characterize quickly the extent of any radiological release, and make recommendations to the State and County and launch site managers, regarding any protective actions that might be required.

Key in preparing to respond to a launch accident is to have trained professionals ready to provide appropriate assistance. Although it is unlikely there will be a launch accident with a release of radioactive material and exposure of the public, specific training is being provided to medical personnel at local hospitals on how to treat individuals possibly exposed to radioactive materials. This training for health professionals in the area is being provided as a prudent and proactive measure.

Finally, it is essential to clearly communicate the information to the public. NASA and DOE will be meeting with local officials and the media to provide background information and answer questions regarding the New Horizons mission. If a launch accident were to occur, NASA would work with County and State Emergency Management Centers and the media to ensure that the public is immediately informed of the situation and any recommended protective actions.

NASA and DOE will have in place the technical resources, trained personnel, and timely communication procedures so that the public and local officials have access to the most current and highest quality information available.

### For More Information

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Source: originally published at http://www.nasa.gov (since removed)

# APPENDIX D
# TABLES

**Reliability Case Processing Summary**

| | | N | % |
|---|---|---|---|
| Cases | Valid | 207 | 99.5 |
| | Excluded(a) | 1 | .5 |
| | Total | 208 | 100.0 |

a Listwise deletion based on all variables in the procedure.

**Reliability Statistics**

| | | | |
|---|---|---|---|
| Cronbach's Alpha | Part 1 | Value | .412 |
| | | N of Items | 5(a) |
| | Part 2 | Value | .380 |
| | | N of Items | 5(b) |
| | Total N of Items | | 10 |
| Correlation Between Forms | | | .555 |
| Spearman-Brown Coefficient | Equal Length | | .713 |
| | Unequal Length | | .713 |
| Guttman Split-Half Coefficient | | | .705 |

a The items are: Ques1A, Ques2A, Ques3A, Ques4A, Ques5A.
b The items are: Ques1B, Ques2B, Ques3B, Ques4B, Ques5B.

**Validity Correlations**

| | | | Ques1A | Ques1B |
|---|---|---|---|---|
| Spearman's rho | Ques1 A | Correlation Coefficient | 1.000 | .562(**) |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 207 | 207 |
| | Ques1 B | Correlation Coefficient | .562(**) | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 207 | 207 |

** Correlation is significant at the 0.01 level (2-tailed).

| | | | Ques2A | Ques2B |
|---|---|---|---|---|
| Spearman's rho | Ques2 A | Correlation Coefficient | 1.000 | .307(**) |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 207 | 207 |
| | Ques2 B | Correlation Coefficient | .307(**) | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 207 | 207 |

** Correlation is significant at the 0.01 level (2-tailed).

| | | | Ques3A | Ques3B |
|---|---|---|---|---|
| Spearman's rho | Ques3 A | Correlation Coefficient | 1.000 | .436(**) |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 207 | 207 |
| | Ques3 B | Correlation Coefficient | .436(**) | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 207 | 207 |

** Correlation is significant at the 0.01 level (2-tailed).

| | | | Ques4A | Ques4B |
|---|---|---|---|---|
| Spearman's rho | Ques4 A | Correlation Coefficient | 1.000 | .560(**) |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 207 | 207 |
| | Ques4 B | Correlation Coefficient | .560(**) | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 207 | 207 |

** Correlation is significant at the 0.01 level (2-tailed).

**Validity Correlations (Continued)**

| | | | Ques5A | Ques5B |
|---|---|---|---|---|
| Spearman's rho | Ques5 A | Correlation Coefficient | 1.000 | .501(**) |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 207 | 207 |
| | Ques5 B | Correlation Coefficient | .501(**) | 1.000 |
| | | Sig. (2-tailed) | .000 | . |
| | | N | 207 | 207 |

** Correlation is significant at the 0.01 level (2-tailed).

## Paired Samples Statistics and Correlations

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | Ques1A | 1.8986 | 207 | 1.11666 | .07761 |
| | Ques1B | 1.5845 | 207 | .90915 | .06319 |
| Pair 2 | Ques2A | 3.2222 | 207 | 1.02346 | .07114 |
| | Ques2B | 2.6232 | 207 | .90470 | .06288 |
| Pair 3 | Ques3A | 2.4493 | 207 | 1.15586 | .08034 |
| | Ques3B | 2.5169 | 207 | 1.01372 | .07046 |
| Pair 4 | Ques4A | 2.3913 | 207 | 1.32801 | .09230 |
| | Ques4B | 1.8116 | 207 | 1.05585 | .07339 |
| Pair 5 | Ques5A | 2.7295 | 207 | .87259 | .06065 |
| | Ques5B | 2.7005 | 207 | .75502 | .05248 |

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | Ques1A & Ques1B | 207 | .575 | .000 |
| Pair 2 | Ques2A & Ques2B | 207 | .358 | .000 |
| Pair 3 | Ques3A & Ques3B | 207 | .468 | .000 |
| Pair 4 | Ques4A & Ques4B | 207 | .562 | .000 |
| Pair 5 | Ques5A & Ques5B | 207 | .540 | .000 |

## Paired Samples Test

| | | Paired Differences | | | | |
|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper |
| Pair 1 | Ques1A - Ques1B | .31401 | .95172 | .06615 | .18359 | .44443 |
| Pair 2 | Ques2A - Ques2B | .59903 | 1.09660 | .07622 | .44877 | .74930 |
| Pair 3 | Ques3A - Ques3B | -.06763 | 1.12572 | .07824 | -.22189 | .08663 |
| Pair 4 | Ques4A - Ques4B | .57971 | 1.14153 | .07934 | .42328 | .73614 |
| Pair 5 | Ques5A - Ques5B | .02899 | .78773 | .05475 | -.07896 | .13693 |

| | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|
| Pair 1 | Ques1A - Ques1B | 4.747 | 206 | .000 |
| Pair 2 | Ques2A - Ques2B | 7.859 | 206 | .000 |
| Pair 3 | Ques3A - Ques3B | -.864 | 206 | .388 |
| Pair 4 | Ques4A - Ques4B | 7.307 | 206 | .000 |
| Pair 5 | Ques5A - Ques5B | .529 | 206 | .597 |